Symposium on Aseptic Surgical Technic and its Application to Thoracic Surgery

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SYMPOSIUM ON ASEPTIC SURGICAL TECHNIC AND ITS APPLICATION TO THORACIC SURGERY

HISTORICAL ASPECTS OF ASEPTIC SURGICAL TECHNIC

JOSIAH C. TRENT, M.D., F.A.C.S.*

IN this section, devoted to aseptic surgical technic and its application to thoracic surgery, it is quite appropriate to include an account of the development of the modern aseptic ritual; for, in an attempt made at Duke Hospital to control "unexplained" infections in operative wounds of the thorax, an important contribution to our present technic, an effective and practicable method of sterilizing the air in the operating room, was devised.[15]

THE PREANTISEPTIC ERA

Occasionally in the history of a science we come upon a discovery so revolutionary that it serves as a point of division in that science between the ancient and the modern. In surgery, the discovery of the antiseptic principle was of such significance that the centuries of tradition and experience which preceded it appear as nothing when compared with the rapid advances made in the decades which followed. It is difficult for us, in possession of the benefits of asepsis, to visualize the terrible and tragic conditions prevailing only eighty years ago, in the preantiseptic era. Erysipelas, pyemia, septicemia, hospital gangrene and tetanus were never absent from the wards, and every operative wound was infected. It is small wonder that "pure" creamy

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Some of the material in this essay has appeared in Thumbnail Sketches of Eminent Physicians: The Evolution of the Aseptic Principle in Surgery, North Carolina Med. J., 6, 1936.

pus, without the tell-tale odor of incipient gangrene, was referred to as laudable. Because of sepsis, little progress had been made in extending the scope of, and indications for, surgery. Abdominal surgery was hardly thought of; the only operation performed on the thorax was empyema drainage; the cranial cavity and spinal cord were virtually unexplored. Amputation, lithotomy, vascular surgery and the drainage of abscesses made up the bulk of a surgeon's practice. Sur-

Fig. 434.—The Preantiseptic Era. Amputation of an arm under strict "septic" conditions. (From Laurenz Heister's *Chirurgie,* Dritte Auflage, Nürnberg, 1731.)

gical results were judged by the mortality statistics of amputation: 25 per cent was considered a "very low" rate; 50 per cent was a more normal figure. The very multitude of the wound dressings that were advocated through the centuries, from the simple wine dressings of the ancient Greeks to the pus-promoting dressings of the middle ages —a pernicious practice which continued well into the nineteenth century—is evidence enough that none was entirely satisfactory, though

some were mildly antiseptic in character; nor could a satisfactory method be devised until the cause of wound suppuration was understood.

Some progress toward the acquiring of such an understanding was made in the study of puerperal fever, a disease peculiarly adapted to observations on its transmissibility. John Burton[8] first suggested, in 1751, that puerperal fever might be conveyed to a patient by an outside agency. Charles White of Manchester,[44] in 1773, stressed the similarity between puerperal fever and surgical fever; he advocated, in dealing with the former, such precautionary measures as complete isolation of infected patients, rigid cleanliness (asepsis) and thorough ventilation of the delivery room, and the use of antiseptic douches. The first positive statement as to the contagious nature of the disease was made by Alexander Hamilton[14] in 1781, when he described puerperal fever as "remarkably contagious" and capable of being conveyed from one patient to another. The ensuing decades saw repetitions of this assertion by various physicians, with increasing emphasis on the function of attendants and doctors as carriers of the fever; prophylactic measures similar to those of White were recommended by many. The doctrine was an unattractive one, however, since physicians in general did not care to think of themselves as bearers of disease, and it received no wide acceptance. Not until 1843 was the issue brought squarely before the medical profession in America. In that year Oliver Wendell Holmes published his famous essay on "The Contagiousness of Puerperal Fever,"[16] maintaining that the *"disease known as Puerperal Fever is so far contagious as to be frequently carried from patient to patient by physicians and nurses."* This doctrine and the preventative measures which Holmes advocated were not original with him, but his article had the merit of stirring up a controversy which aroused wide attention. Beginning in 1847, a similar debate was excited in Europe by the work of Ignaz Philipp Semmelweis.[40] In the face of acrimonious opposition, this great Hungarian demonstrated the contagiousness of puerperal fever and showed that its transmission could be prevented by such simple measures as washing the hands in an antiseptic solution before examining, assisting or in any way touching a patient.

ADVANCE IN BACTERIOLOGY

Despite such anticipatory stirrings, the complete realization of the aseptic principle could come only with an understanding of the etiology of wound infections, and this knowledge waited upon the development of the science of bacteriology. The long foreground of that science, from Leeuwenhoek's great discoveries until the mid-nineteenth century, need not concern us here. Throughout this period, as during preceding ages, men postulated as the causative agents of

disease various miasmas, vapors, gases and animalcules. The germ theory of disease developed but slowly, although a great number of observations on the origin and cause of infectious diseases, wound suppuration and putrefaction appeared during the late eighteenth and early nineteenth centuries.

In 1822, Ollivier[28] produced experimental hospital gangrene by autoinfection, and in 1822–1823 Gaspard,[11] at the suggestion of François Magendie, made experimental studies in pyemia, injecting putrid fluids and other substances into various animals. In 1835, with his demonstration of the parasitic nature of the muscardine disease of silkworms, Bassi[2] laid the foundation of the doctrine of pathogenic microorganisms. A year later Franz Schulze[37] demonstrated that no putrefaction occurred in boiled infusions if the air was drawn through acid or alkali, and Theodor Schwann[38] carried out similar experiments using heat rather than chemicals to sterilize the air. Schwann[39] and Cagniard-Latour[9] presented evidence, in 1837, to prove that the fermentation of sugar was due not to oxygen, as was commonly believed, but to the growth in the solution of a yeast, Torula cerevisiae. These discoveries, and others of like import, received scant attention from a bigoted scientific world, dominated by armchair logic, but the time was ripe for genius to integrate these isolated facts and demonstrate their significance.

At this most opportune time, Louis Pasteur, an obscure French chemist whose work had dealt chiefly with crystalloids and their polarizing properties, began to encounter in certain industrial fermentations exceptions to the laws of correlation between crystals and rotary power, laws which he had previously found invariable. He gradually shifted his field of interest from pure chemistry to biology. Since he knew from previous observations that life alone is capable of creating full-fledged new dissymmetries, he began careful researches into the vital principle of fermentation, presenting the results of his study to the Société des Sciences de Lille in August of 1857.[29] He concluded:

> It is now my opinion as the result of the knowledge I have gained on this subject that whoever will judge impartially of the results of this work and those which I shall publish in the future[30] will recognize with me that fermentation is correlative with life, with the organization of globules (yeast) not the death or putrefaction of these globules.°

From these studies it was but a step to questioning the origin of these "globules," and Pasteur soon became absorbed in an effort to solve once and for all the celebrated question of spontaneous generation, an effort intimately connected with his desire to arrive at a

° The doctrine which Pasteur here rejected was a widely accepted one, forcefully advocated by the great German chemist, Justus Liebig.

knowledge of the causes of putrid and contagious diseases. By 1862, with a series of simple but masterful experiments, he had demolished the theory of spontaneous generation.[31]

THE ANTISEPTIC PRINCIPLE

In 1865 Dr. Thomas Anderson, Professor of Chemistry at the University of Glasgow, who was familiar with Pasteur's work, called it to the attention of the Professor of Surgery at the same institution, Joseph Lister. Lister had already given much thought to inflammation and suppuration and had patiently sought for a means of assuring the healing of wounds by primary intention. The missing link in his search was supplied by the knowledge he derived from Pasteur's writings: there he learned that putrefaction was in fact fermentation, that it was caused by the growth of microorganisms carried to the wound on particles of dust floating in the air, and that it was possible to free the air of these germs by heat, filtration or chemical action. Of these three germ-destroying methods, Lister chose the chemical as the most practicable. Fortunately, the first antiseptic which he tried was carbolic acid (German creosote); he had heard of its recent successful use in the disinfection of sewage at Carlisle, and Dr. Anderson supplied him with a sample of the chemical. In March, 1865, at the Glasgow Royal Infirmary, Lister for the first time employed the undiluted chemical in a case of compound fracture; the case was improperly managed, and the attempt unsuccessful. The next experiment, on August 12, 1865, was undertaken in a case of compound fracture of the tibia. The wound was treated first with lint soaked in carbolic acid, later with dressings of carbolic acid diluted in water and in olive oil. This simple technic, based on Pasteur's teaching that putrefaction is caused by bacteria coming from the air, met with complete success. Bacteria which had gained access to the wound were first destroyed, then by the application of antiseptic dressings the entry of new bacteria was prevented until healing had occurred.

The use of antiseptics in putrefactive diseases was certainly not original with Lister. Many early surgeons employed dressings containing alcohol and various balsams. Sir John Pringle,[34] in 1752, reported a series of experiments in which he had tested the effects of a variety of substances in delaying putrefaction. Pringle's work was continued by Madame d'Arconville[1] who, in 1766, reported the effectiveness of mercurial salts, among other substances, in the prevention of putrefactive changes. In 1764 the German surgeon Bilguer[4] described his method of treating wounds, which consisted essentially in filling the recesses of the wound with antiseptics and placing on the surface a piece of lint dipped in an antiseptic solution. Alcohol, glycerin, chlorine and its various compounds, iodine and other chemicals were variously recommended in the early nineteenth century.

French surgeons and chemists became much interested in the disinfectant properties of coal tar and conducted an extensive inquiry into its usefulness. One result of this inquiry was the work of Jules Lemaire, who studied first the antiseptic properties of coal tar combined with tincture of saponine, and later those of carbolic acid, publishing his report on the latter in 1863.[21] In the same year Enrico Bottini, then at Novara Hospital, later a professor at Pavia, began to investigate the value of carbolic acid as a disinfectant of the operative field; his findings were published in 1866,[7] when Lister's work was still in its experimental stages. Both Lemaire and Bottini knew of, and accepted,

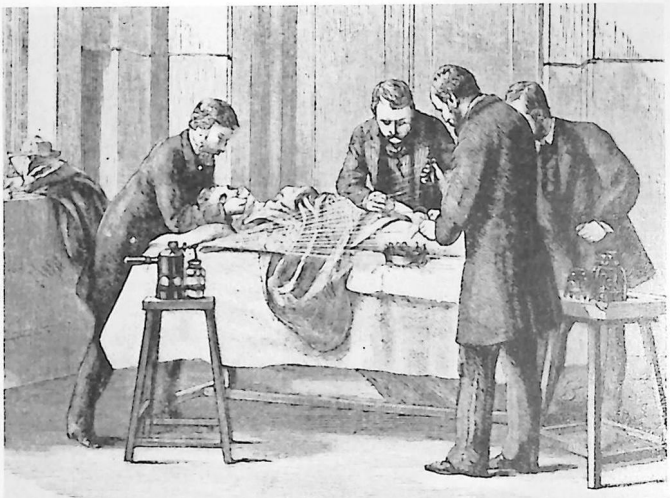


Fig. 435.—The Antiseptic Method. A drawing showing strict observance of the method developed by Lister. (From W. Watson Cheyne, *Antiseptic Surgery, Its Principles, Practice and Results,* London, 1882.)

the germ theory of disease; both preceded Lister in the use of carbolic acid to destroy germs. Nearly a year before Lister came to recognize the significance of Pasteur's work in relation to surgery, Spencer Wells[43] discussed Pasteur's doctrines before the British Medical Association and described the antiseptic experiments of Polli of Milan, who had given sulfites and hyposulfites by mouth to neutralize the effects of purulent infections.

Why then do we credit Lister, and not one of these men or of the other pioneers who might be named, with the establishment of antisepsis? Wells offered only a brilliant hypothesis, Lemaire and Bottini offered only an effective antiseptic. Lister alone brought forward and

maintained a scientific principle, in accordance with which methods of procedure might be devised. For him, carbolic acid was simply a means to an end; for Lemaire, Bottini and the others, the particular antiseptic which each employed was an end in itself, was itself the most important factor in wound dealing. Lister never allowed his real purpose, the destruction of the pathogenic organisms which he knew to be present everywhere, to be obscured by blind devotion to established details of technic, to chemical substances or to pieces of apparatus.

In 1867 Lister reported the then amazing results of his new method of wound therapy in a paper entitled, "On a New Method of Treating Compound Fracture, Abscess, Etc., with Observations on the Conditions of Suppuration."[22] It is significant that in the title he speaks of a "method" of treatment and does not specify carbolic acid. Several months later, on August 9, 1867, in addressing the British Medical Association at Dublin "On the Antiseptic Principle in the Practice of Surgery,"[23] Lister remarked:

> To prevent the occurrence of suppuration with all its attendant risks was an object manifestly desirable, but till lately apparently unattainable, since it seemed hopeless to attempt to exclude the oxygen which was universally regarded as the agent by which putrefaction was effected,° but when it had been shown by the researches of Pasteur that the septic property of the atmosphere depended not on the oxygen or any gaseous constituent but on minute organisms suspended in it which owed their energy to their vitality, it occurred to me that decomposition in the injured part might be avoided without excluding the air by applying as a dressing some material capable of destroying the life of the floating particles.
>
> Upon this principle I have based a practice . . . .

After further careful experiments and reasoning, Lister was able to set down the factors necessary for "per primam" healing of clean wounds: (1) the germs must be destroyed on the patient's skin, on the surgeon's hands, on the instruments used, and on everything sur-

° The belief that the air or one of its components had a harmful effect upon wounds was long in force, and various methods were devised to prevent suppuration by excluding the air. To combat the cooling and drying effects of air, Jules Guyot, in 1835 and later, recommended incubation of the wounded part at a temperature of about 36° C. The subcutaneous method of surgery grew up as a result of the fear of air: Delacroix, Anel and Abernethy were pioneers in the technic; Delpech, in 1816, performed the first subcutaneous tenotomy; Dupuytren, Stromeyer, Dieffenbach and Jules Guérin contributed greatly to the development of the method. Various methods of occlusion were proposed: Guérin (1839) favored covering the wound with goldbeater's skin; William Rhind (1842) and Laugier (1844) recommended gum arabic; Chaissagnac (1844) used layers of diachylon plaster. Guérin (1866) and Maissoneuve (1867) proposed pumping the air away from the wound by the use of complicated apparatuses. Still other approaches to the problem were suggested: the substitution of various gases for air, a technic on which Demarquay and Leconte experimented extensively, reporting in 1866 in favor of carbonic acid gas; the immersion of wounds in a warm water bath, a method principally advocated by Stromeyer and Langenbeck.

rounding the area of operation; (2) germs must be prevented from entering the wound during operation; (3) germs must be prevented from spreading into the wound after operation. This revolutionary concept was difficult for the profession to grasp, and it met with considerable opposition. Many insisted on calling Lister's method the "carbolic acid treatment" and completely lost sight of the underlying principle necessary for its proper application. It had its champions, however, particularly on the continent, where it was apparently first introduced in 1869 by Mathias Saxtorph, Professor of Clinical Surgery in the University of Copenhagen, who visited Glasgow in that year and observed Lister's technic.[24] The practice was adopted by such eminent surgeons as Richard von Volkmann at Halle in 1872, Nussbaum at Munich in 1874, and Esmarch at Kiel in 1875. Volkmann practiced exact Listerism with brilliant results and became one of the strongest and most outspoken advocates of the system. A similar position was taken by Just Lucas-Championnière in France. In America, where the disciples of Lister and Pasteur were few, the introduction of the antiseptic system was only slowly accomplished.

ASEPSIS

As the antiseptic principle spread, surgeons everywhere sought for newer and safer methods of accomplishing the same end. Lister himself constantly emphasized the point that the means employed were of small significance as long as the desired end—the exclusion of germs from the wound—was gained. Even his vehement opponent, Lawson Tait, of the soap-and-boiling-water school, was actually the advocate of a somewhat primitive aseptic technic. The great German surgeon, Billroth, accepted Lister's principle while questioning his means, and stated that he would regard the antiseptic system with suspicion as long as it depended on carbolic acid; he like many other surgeons had had fatal cases of poisoning from carbolic acid.[5]

In spite of the brilliant work of Pasteur in the promulgation of the germ theory of disease and the development of Lister's remarkable antiseptic treatment of wounds, utter confusion existed among medical men as to the causative organism or organisms of surgical sepsis. Bacteriology as a science was still undeveloped, and pure cultures of bacteria were unobtainable. In retrospect, in view of the meager knowledge then available concerning the infective agents, the results achieved by Lister seem all the more remarkable. Before further progress was possible in the development of asepsis, it was necessary for the bacteriologists to overtake the surgeons, who had far outdistanced them.

The modern concept of wound infection began with the publication of Robert Koch's great work on the etiology of traumatic infective diseases,[18] in which he reported six different kinds of surgical

infections artificially produced in animals and clearly demonstrated that each was due to a different microorganism which bred true in pure culture. Probably Koch's greatest contribution, however, was the poured plate method of obtaining bacteria in pure culture.[19] Also, with Gaffky and Loeffler in 1881,[20] he designed the first steam sterilizer, an important advance which was not utilized in the aseptic technic for several years.

While bacteriologists were providing the knowledge necessary for intelligent procedure in wound therapy, surgeons themselves were assiduously seeking for simpler means of accomplishing their goal of primary wound healing. Lister himself made great contributions to the development of asepsis. In 1881, at the Seventh International Medical Congress, held in London, during the symposium on "The Causes of Failure in the Primary Healing of Wounds," he presented the results of further experiments, which showed that blood serum itself possessed bactericidal properties and that actual closure of a wound was not necessary if the wound were filled with blood clot, properly covered, and left alone.[25] In 1883 he recorded an "Antiseptic Operation without Antiseptic Contact"[12] and by 1887 he had abandoned the antiseptic spray.°

As the antiseptic system spread, constant improvements in technic were made. The transition from the "wet" or antiseptic treatment of wounds to the "dry" or aseptic method, however, was largely due to the work of two German surgeons, Gustav Neuber of Kiel and Ernst von Bergmann of Berlin. Neuber, long an assistant to Esmarch and a devoted experimenter in the antiseptic technic, came to the realization that no further progress could be made until caustic antiseptics could be dispensed with. In 1884 he built a private hospital in Kiel for the express purpose of carrying out his new methods of asepsis, and two years later he published the details of his technic,[27] the main

° Early in his experiments, in a rather crude attempt to sterilize the air, Lister had introduced the carbolic acid spray, which, during the operation, filled the air around the operating table with a mist of carbolic acid. Lister first publicly recommended this apparatus on August 10, 1871, at the Plymouth meeting of the British Medical Association (Brit. M. J., 2:225–233 [Aug.] 1871). Besides working a hardship on both surgeon and patient, the spray failed to produce the desired results. Its utility was first assailed by Bruns of Tübingen in 1880 (Fort mit dem Spray, Berl. klin. Wchnschr., *17*:609, 1880), and many surgeons abandoned it. A Canadian surgeon visiting the European clinics in 1887 found Lister using no spray, MacEwen at Glasgow using it in small quantities only "perhaps as a kind of fetish," but reported of Ogston at the Aberdeen Infirmary: "He is a thorough Listerite of the old lines and envelops his operations in a cloud of carbolized incense. His ritual is orthodox and complete. I saw him do an abdominal section and although standing some feet off was drenched from head to foot with the spray and felt the chilling effects of the carbolic acid for some days afterwards" (Shepherd, F. J.: Notes of a Visit to Some of the Anatomical Schools and Surgical Clinics of Europe in 1887, Canad. M. J., *14*:56–65 [Jan.] 1924).

features of which were: (1) separation of "clean" and "dirty" cases; (2) sterilization of the air entering the operating room by heat and filtration; (3) cleansing the entire body of the patient and the operative site with mercuric bichloride; (4) washing of the hands and arms of the operating team with soap and water; (5) sterilization of instruments and drapes by boiling; (6) closure of wounds without drainage. The ritual of asepsis thus begun was improved during the latter part of the eighties in the clinic of Ernst von Bergmann, a native of Riga, Russia, later Professor of Surgery at Berlin. His technic, as recorded by Schimmelbusch,[36] differed essentially from Neuber's in that nascent steam according to the method of Koch[20] or steam under pressure was used to sterilize the dressings and drapes, which had been placed in metal drums of the kind in general use today.

The universal adoption of the aseptic principle in surgery rapidly followed upon the elaboration of the technical details by von Bergmann. In spite of the effectiveness of this technic in preventing most infections, there remained several possible sources of wound contamination; namely, the operator's bare hands, droplets from the nose and throat, and the patient's own skin.*

RUBBER GLOVES

Many surgeons were quick to realize that even with prolonged scrubbing and improved antiseptics it was impossible to sterilize the hands, but many years passed before an effective method for screening bare hands from the operative wound was devised. Through the example and influence of William Stewart Halsted, Professor of Surgery at the Johns Hopkins Hospital, the use of rubber gloves as a means of preventing wound contamination was at length introduced. Rubber gloves were first worn in Halsted's clinic as early as 1889† to protect from antiseptics the hands of certain members of the staff: the nurse who squeezed out sponges kept in bichloride of mercury solution and the assistant who passed instruments, which had been immersed in carbolic acid.[13] As the staff became accustomed to the gloves, their use became more general and the emphasis was gradually shifted from protection of the operating personnel to protection

* This still remains a problem, although not a serious one. See in this volume, Lovell, Durward L.: Preoperative Skin Preparation with Reference to Surface Bacteria Contaminants and Resident Flora.

† There were isolated instances of their use prior to this date in Europe. For example, F. Jayle writes: "When an assistant to Professor Verneuil in 1888, I saw Jalaguier who came there to operate; the skin of his hands being very sensitive to antiseptics, he had formed the habit of operating in rubber gloves equipped with cuffs reaching up the forearm." (Aperçu historique de l'antisepsie et de l'asepsie, Presse méd., 36, 2e sem.: 1195 [Sept.] 1928.)

of the patient. In 1895, Hunter Robb, then resident gynecologist of Johns Hopkins, wrote:

> Rubber gloves are not employed so widely as they should be. It is probable that the chances of infection would be very much diminished if the assistants were required to wear them at operations, since they can be rendered absolutely sterile, which is not necessarily true of the skin of the hands. Their use by the operator himself would also facilitate the performance of a great deal of minor work without any inconvenience therefrom.[35]

Fig. 436.—The Use of Rubber Gloves. A photograph of Halsted's first operation in the new surgical amphitheatre at Johns Hopkins in 1904; Drs. Finney, Cushing, Young, Mitchell and Bloodgood appear in the picture. This is one of the earliest photographs showing an entire operating team wearing rubber gloves. Notice the absence of masks. (Reproduced through the courtesy of the Johns Hopkins Press, from W. G. MacCallum, *William Stewart Halsted, Surgeon*, Baltimore and London, 1930.)

Halsted himself at this time occasionally used gloves in operating on clean joints,[6] but it appears that the first person to wear them invariably while operating was Dr. Joseph Colt Bloodgood, Halsted's house surgeon, who began the practice in December of 1896. In 1913, at the insistence of his staff, Halsted finally published a résumé of the

operative technic which had evolved in his clinic.[13] In speaking of the introduction of rubber gloves he said:

> Operating in gloves was an evolution rather than an inspiration or happy thought, and it is remarkable that during four or five years when as operator I wore them only occasionally we could have been so blind as not to perceive the necessity for wearing them invariably at the operating table.°

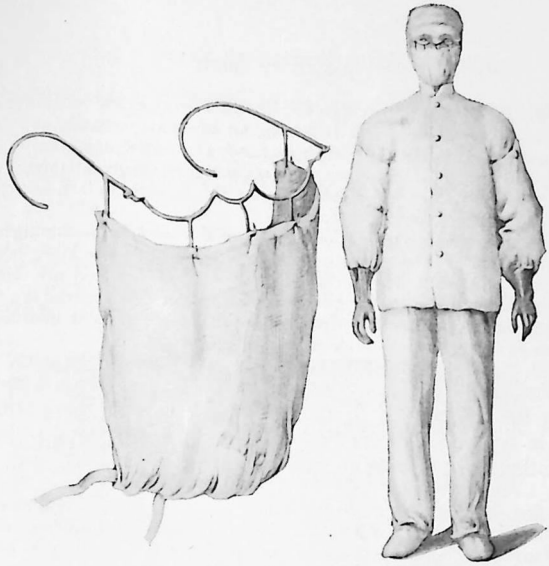
MASKS

Lister based his antiseptic system on the belief that most pathogenic bacteria were airborne; later it was learned that direct contact is a more important factor in their transmission, and after the publication of Tyndall's findings in 1881[42] concerning the relatively harmless character of most airborne germs, surgeons came to regard the danger of airborne infection as negligible. However, occasional cases of sepsis occurred in spite of the most rigid adherence to the ritual of asepsis, and surgeons began to look for other sources of infection. Pasteur[32] and Sternberg[41] demonstrated in 1881 that the pneumococcus could be carried in healthy throats, and it came to be recognized that the human mouth is a perfect breeding place for all types of bacteria. The fact that exhaled air contains far fewer bacteria than inhaled air misled most observers for a time.

In 1897 Carl Flügge, then at Breslau, published an account of his investigations on droplet infection.[10] Flügge not only proved that the human nose, throat and mouth might contain pathogenic bacteria, but he also demonstrated that all persons in speaking, laughing, coughing and sneezing scattered from their mouths a fine spray of germ-laden saliva. He concluded his account by pointing out the importance of his findings to the surgeon. Because of the renewal of interest in airborne infections in recent years, I shall quote at length:

> It is much more natural to think of an airborne infection of an operative wound through droplets from the mouth and nose which are disseminated by those present through speaking, coughing, and sneezing. In the oral secretions of healthy persons one finds numerous pathogenic organisms. The scattering of such droplets can proceed from the operator, from the assisting personnel, and from the spectators. (page 223.)
>
> I do not doubt that by far the greatest part of wound infection is established through contact and that surgeons have with good reason given far more considera-

° The objections customarily advanced against the use of gloves were summarized by Nicholas Senn, writing in 1901: "Perhaps one of the best proofs that all known methods of hand sterilization have their defects is the present quite extensive use of rubber gloves, advocated by Halsted, Mikulicz, Fenger, and other surgeons . . . . It is easy to foresee that this practise will never become general, even in the clinical amphitheaters . . . . The rubber gloves impair the delicate tactile sense of the fingers, are expensive, easily torn, and furnish a soothing poultice for the conscience when the surgeon fails to prepare his hands properly" (Practical Surgery, Philadelphia and London, 1901, p. 172).



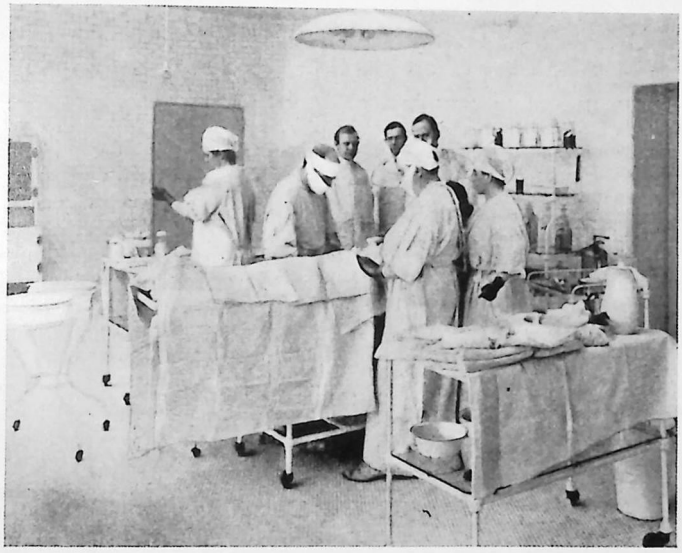


Fig. 437.—The Introduction of Surgical Masks. The second edition of Berkeley Moynihan's *Abdominal Operations* (Philadelphia and London, 1906) contained one of the earliest textbook recommendations for the use of masks during operations, accompanied by the two drawings shown above. The photograph, which, with the legend "The Present-Day Operating Room," appears in Keen and DaCosta, *Surgery, Its Principles and Practice* (Philadelphia and London, 1920), gives evidence of the slowness with which the universal use of masks in the operating room became customary. (All three pictures are reproduced through the courtesy of W. B. Saunders Company.)

tion to this side of the question than to airborne infection. But one dares not ignore the danger, nevertheless, which is set up for operative wounds by the excreted droplets scattered into the air and there floating so easily and transported so far; and the possibility must be taken into account that many abnormalities in the progress of operative wounds which are protected against contact, are to be traced back to this invisible mode of infection.

The extent of this contamination is then of interest in determining the precise dangers which threaten the fresh operative wound; but since knowledge of such questions can be gained only through experience, I have asked my esteemed colleague Professor Mikulicz to be permitted to confirm the practical significance of these proceedings experimentally studied by me, through joint investigation into the sources of the failures of modern asepsis. (page 224.)

Mikulicz, at Flügge's suggestion, began testing various methods of reducing the dangers of droplet infection. In 1897 he published his results, in an article principally devoted to advocating the use of cotton rather than rubber gloves.[26] He wrote:

I was first made aware of the significance of the danger of the dissemination of pathogenic bacteria from the mouth and nose through Herr Flügge who had established experimentally that even by tranquil speech bacteria can be scattered from the mouth in very fine fluid drops into surrounding space. We have, indeed, at Breslau the custom of hardly speaking at all at operations: necessary communications are easily conveyed through signs with the hands. But a word must be said here and there. If the surgeon has a cold which causes him to sneeze at inconvenient moments, then he must, according to Flügge, be entirely excluded from operating. All these dangers will be wholly avoided if one wears during the operation a mouth bandage covering the mouth and also the nostrils. A piece of mull serves the purpose and can be used also to cover the beard. We have operated already quite a long time with mouth bandages at all aseptic operations; we breathe through them as easily as a lady wears a veil on the street. The mask is of course sterilized. (page 716.)

Mikulicz, despite the early satisfaction he expressed regarding his mull mouth bandages, was apparently not entirely satisfied with either the protection they afforded or the comfort. He asked one of his colleagues, W. Hübener, to check on the efficiency of the mask and to improve its design. Hübener published his results in 1898.[17] He demonstrated that the simple cloth mask used by Mikulicz by no means afforded adequate protection at all times, and devised a metal frame—a modified Esmarch chloroform mask with spectacle earpieces—carrying a double layer of close-meshed muslin.

Mikulicz's efforts must have received little attention from surgeons at large, however, for Paul Berger, a French surgeon, writing in 1899[3] of his own experiments with masks modeled on Mikulicz's concluded pessimistically that he expected his communication to receive little more attention from his colleagues than the report of Mikulicz had from German surgeons. In 1901, John Poland spoke of Mikulicz's use of masks as a somewhat ridiculous and extreme measure.[33] From 1900 on, however, numerous articles appeared advocating various modifica-

tions of these masks. A multitude of designs were proposed, all to the same purpose; to keep out of the operative wound bacteria coming from the nose and throat. Today gauze face masks which cover the nose and mouth are worn routinely by all individuals in the operating room.

ULTRAVIOLET IRRADIATION OF AIR

Although today's masks do serve as a filter for the coarser droplets from the upper respiratory tract, it can easily be shown that they are not completely effective in stopping the fine spray generated by talk-

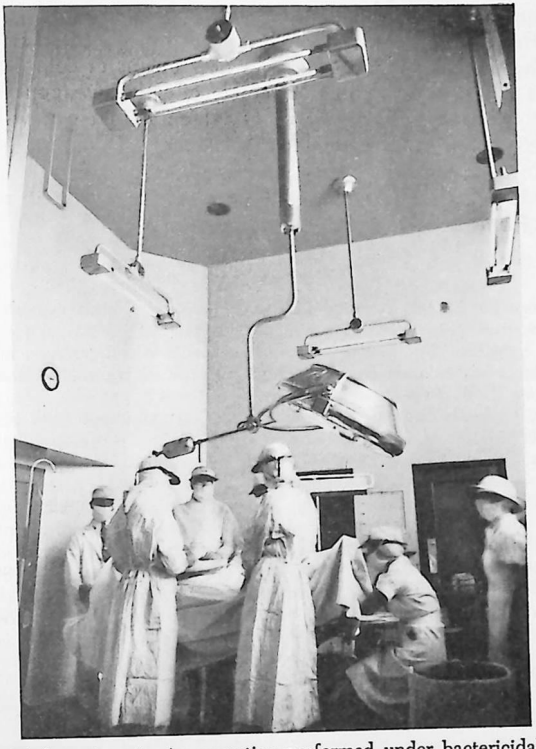


Fig. 438.—Modern Asepsis. An operation performed under bactericidal ultraviolet irradiation at the Duke Hospital, Durham, North Carolina.

ing, coughing or sneezing. It was this fact which led Deryl Hart of Duke University to devise a rapid, practicable method of sterilizing the air in the operating room in an attempt to control those infections which occurred in spite of rigid aseptic precautions.[15] By irradiating

the air with special short-wave ultraviolet light he was able to reduce the number of bacteria in the air to such a point that they no longer constituted a hazard.°

The per primam healing of wounds depends upon many factors other than strict aseptic precautions, and not the least of these are: accurate hemostasis, careful handling of tissues, and the use of fine suture material. However, with the best of technic and the proper observance of all requirements of asepsis, there are still many "unexplained" wound infections. These can be reduced to a minimum by the judicious employment of this last addition to our aseptic armamentarium, sterilization of the air by ultraviolet irradiation.

With the introduction of penicillin and other powerful antibiotic agents, the surgeon has been given a new means of combating infection. It is inevitable that this extremely effective weapon will afford a perfect windfall in many cases of infection in clean wounds, for the surgeon who grows careless in his technic. It should be remembered, however, that the principles of asepsis and good surgery still go hand in hand, and no drug has yet been discovered which can make up for a deficiency in aseptic practice.

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PREOPERATIVE SKIN PREPARATION WITH REFERENCE TO SURFACE BACTERIA CONTAMINANTS AND RESIDENT FLORA

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MODERN aseptic technic theoretically aims at complete eradication of bacteria so that not a single organism can reach the wound at any time during and after the operation. Under such conditions healing would take place aseptically. Such perfection in actual practice is almost impossible to attain but it is our constant goal to minimize contamination of wounds as much as possible. The modern plan of maintaining such a technic is an elaborate one and requires attention to detail and careful observation to see that no loopholes admit any offending organism from many possible sources of contamination. Such a plan is like a chain which is only as strong as the weakest link. Sterilization of the skin of the patient seems to be the weakest link in the chain of sterile technic, because no antiseptic yet devised is able to destroy all of the bacteria in the skin. For this reason the skin is a constant source of contamination of clean operative wounds and precautions must be taken to prevent serious infections from this source. The purpose of this paper is to make clear the value of preoperative preparation of the skin and to point out methods whereby contamination and infection of operative wounds by these bacteria may be minimized.

Classification and Location of Skin Bacteria.—The bacteria of the skin are classified into two main groups: the transient, which may include any organism that comes in contact with the skin; and the resident, which includes bacteria that are normal inhabitants of the skin. The transient bacteria are usually located on the surface embedded in the horny fat, beneath the desquamating superficial cells of the horny layer, and in the crypts and crevices. The number and kind of organisms that make up the transient flora depend on the cleanliness of the individual and his contacts with a variety of sources of contamination including the surrounding air. This transient group contains the more pathogenic types of bacteria including Staphylococcus aureus, streptococcus, Escherichia coli, Bacillus proteus and

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B. pyocyaneus. They frequently cause serious wound infections when they are allowed to enter clean wounds and find conditions favorable for growth.

In contrast to the superficial location of the transient bacteria, some of the resident flora are situated in the deeper parts of the skin. In a previous publication,[1] it was shown that the resident bacteria are lo-

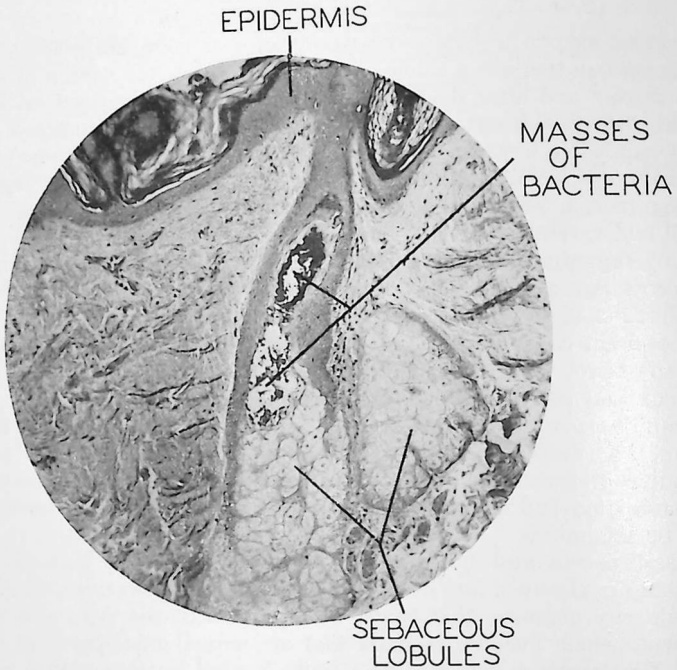

Fig. 439.—Photomicrograph showing a section of skin removed from the female breast and incubated for six hours. The surface of the skin was cleaned with iodine and alcohol before removal, and the section was stained to show the bacteria. Large masses of bacteria are shown extending deep into the sebaceous gland and far below the skin surface. (By permission of Surgery, Gynecology and Obstetrics.)

cated on the surface embedded in the horny fat, in the crypts and crevices, hair follicles and sebaceous glands. A study of sections of skin which had previously been incubated for six hours, in order to locate the bacteria more readily in regard to their position and depth, showed resident bacteria located very deep in the pilonidal follicles embedded in the sebaceous material (Figs. 439 and 440). The number of bacteria in the pilonidal follicles varied greatly. In some in-

stances no organisms were found; in others they had increased sufficiently to fill completely the upper part of the duct (Fig. 440). Careful study of the sweat glands in many sections failed to show any bacteria in the excretory ducts, in the coiled portions as they pass through the epidermis, or in the secreting tubules. All of the bacteria were located outside the body since they were not seen within or between living cells of the epidermis or the cells lining the pilonidal

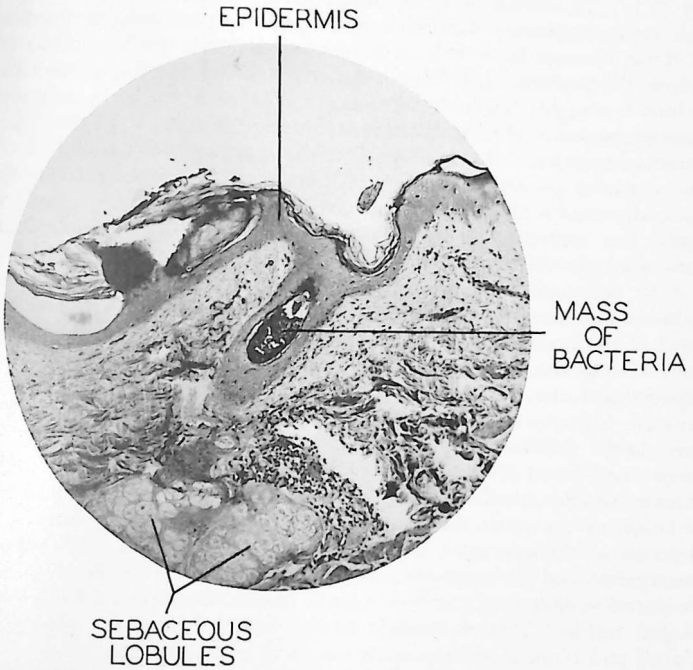

Fig. 440.—Photomicrograph showing a section of skin removed from the female breast and incubated for six hours. The duct of the sebaceous gland is cut in cross section and shows a mass of bacteria which fills the lumen of the ducts. (By permission of Surgery, Gynecology and Obstetrics.)

follicles. The resident flora probably remains fairly constant since over a long period of time the organisms comprising this group have acquired the ability to live and multiply in surroundings that are unfavorable for the growth of other bacteria. The resident bacteria usually include Staphylococcus albus and Staph. citreus, but it is thought that other organisms may become residents in the skin after prolonged contact with them.

Changes in the Bacterial Flora Following Surgical Cleansing Methods.—Price[2] has shown that scrubbing with brush, soap and water removes readily the transient flora of bacteria, but far more slowly the resident flora. Most of the transient organisms of the skin are quite superficial and can be removed by thorough mechanical and chemical cleansing. Mechanical cleansing is more efficient than chemical cleansing for removing surface bacteria, because the dirt, horny fat and other foreign material must be removed before the antiseptic can reach organisms located beneath the desquamating epithelium of the epidermis. Inasmuch as the resident bacteria are located so far below the surface, they cannot be removed by mechanical means. Sebum is a highly insoluble substance and all of it cannot be removed by soap, water or chemicals without injuring the skin (Fig. 439). Any chemical solution that would sterilize the skin would necessarily have an enormous penetrating power. Experiments have shown[1] that the generally used antiseptics do not have sufficient penetrating power to reach the bacteria that are located deep in the hair follicles and sebaceous glands.

After thorough mechanical and chemical cleansing, negative swab cultures can sometimes be obtained from the skin surface because most of the transient bacteria have been removed. The resident bacteria rise to the surface and multiply after a short time, however, especially if the skin becomes moist and the surface tension is increased. Cultures taken from the skin surface at the end of operations are always positive for bacterial growth. These bacteria consist of large numbers of Staphylococcus albus and Staph. citreus, and occasionally smaller numbers of the more pathogenic types. The number of transient organisms that can be recovered from the skin surface at the end of the operation depends on the thoroughness with which mechanical and chemical cleansing was performed. Preoperative skin preparation, therefore, removes most of the surface bacteria but many of the resident bacteria remain in the hair follicles and sebaceous glands and serve as an important source of contamination.

The Role of the Resident Bacteria in Contamination and Infection of Wounds.—In a previous publication,[3] it was shown that bacteria gain entrance to the wound during most clean operations. A few organisms are carried into the incision with the skin knife as a result of cutting into contaminated hair follicles and sebaceous glands. Some of them possibly gain entrance as a result of contaminated perspiration flowing over the skin edges. This may occur regardless of the fact that towels are closely applied. Cultures taken from the wound immediately after the skin incision is made are usually positive for bacterial growth.[3] Similar cultures taken during the latter part of the operation are positive for a greater number of bacteria. This increase in their number during the time of the operation occurs even

though bactericidal radiant energy is used to minimize contamination from the air. This is probably due to the fact that the resident bacteria gaining entrance to the wound by transplantation with the skin knife multiply during the time of the operation. The greater number of these bacteria are of the Staphylococcus albus and Staph. citreus variety. They belong to the resident flora and generally do not cause serious wound infections unless they are present in large numbers or the wound is left in such a condition as to encourage their growth. Very few of the more pathogenic types of bacteria will gain entrance to clean operative wounds if the skin is properly prepared and adequate precautions are taken to prevent this during the time of the operation.

Although the presence of a relatively large number of resident bacteria may not cause gross infection with suppuration in a wound, they should not be disregarded. They may cause prolonged elevation of the postoperative temperature and excessive pain, redness and induration of the wound. In the presence of avitaminosis and other nutritional, systemic or local conditions, these organisms may be factors in delaying healing, thereby predisposing to disruption of the wound and postoperative hernia. Stitch abscesses or excessive scarring may be the result of infection caused by these bacteria. Frequently they cause chronic low grade infection around subcutaneous suture material, leading to draining sinuses; and in many instances, the sutures must be removed before proper healing takes place.

Plan of Minimizing Contamination of the Operative Wound by Skin Bacteria.—The high probability of the entrance of bacteria into every operative wound should be a constant challenge to reduce such contamination. Unless the operation is urgent, the presence of even minor infections in the field of the proposed incision contraindicates operation until the lesion is healed. Incisions that are to be reopened during second stage operations should be carefully examined for stitch abscesses, adhesive dermatitis and low grade infection in the deeper part of the wound.

The transient flora of bacteria can be removed only by careful preoperative preparation of the skin. The day before operation a large area in the region of the proposed incision should be washed thoroughly with soap and water, shaved closely, and then cleansed with soap and water, 70 per cent alcohol and ether in locations where these do not burn. Just before the operation the skin should again be washed thoroughly with soap and water, 70 per cent alcohol and ether, and covered with a sterile towel. After the patient has been anesthetized, chemical cleansing should be performed to further reduce the number of bacteria on the surface. Numerous good antiseptics are available but 3.5 per cent iodine is probably used more frequently than any other chemical on the patient's skin preparatory to operation. Two

layers of iodine should be applied and then removed with 70 per cent alcohol to prevent blistering. Following chemical cleansing all of the skin except a small area where the incision is to be made should be covered by sterile towels which are held in place with clips.

Inasmuch as all of the resident bacteria cannot be removed by modern methods of preoperative preparation, the skin should be considered as contaminated at all times. The skin surface should not be touched with the gloved hand or instruments that are to be used during the remainder of the procedure. The knife employed to make the initial incision should be discarded because it has been contaminated by cutting through pilonidal follicles containing bacteria. All exposed skin should then be covered with sterile towels, and fastened in place with clips, care being taken not to leave the edges of the incision uncovered. These towels should be left in place until the wound is closed to the subcutaneous fascia. At this time the skin surface should be considered as being more contaminated than at the time the original incision was made, because during the operative time the resident bacteria rise to the surface and multiply. This is best combated by changing the towels and cleaning the skin surface with the antiseptic solution before the superficial sutures are inserted. This reduces the bacterial contamination of the subcutaneous tissues and results in fewer bacteria about the subcutaneous and cutaneous sutures.

Factors that Minimize Infection of the Operative Wound by Skin Bacteria.—Since contamination of the wound cannot be entirely prevented, the presence of these bacteria make it imperative that the tissues be left in the best possible condition for combating their growth. When only a few bacteria gain entrance to the wound, they do not interfere with healing because, with good surgical operative technic the tissues can easily cope with them without infection. Emphasis must be placed, therefore, on the fact that these bacteria become important in regard to gross infection only when their multiplication is aided and abetted by faults of operative technic. Such features of technic as gentle handling of tissues, careful hemostasis, avoidance of tension in placing sutures and obliteration of dead space should never be overlooked. Other factors such as the unnecessary use of the cautery, and ligation with strangulation of large amounts of tissue will create conditions favorable for the growth of bacteria in the wound. Stitch abscesses are best avoided by the additional precaution of early removal of the suture and avoidance of tension.

SUMMARY

Sterilization of the skin seems to be the weakest link in the chain of sterile technic. Modern antiseptics fail to remove all the bacteria in the skin because they are located too deep in the hair follicles and sebaceous glands. Contamination of wounds from this source may be

minimized, but with our present knowledge it cannot be entirely prevented. This contamination can be minimized only by thorough mechanical and chemical cleansing of the skin and careful attention to operative technic. Bacteria gain entrance to most clean operative wounds and the presence of these organisms makes it imperative that the tissues be left in the best possible condition for combating their growth.

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THE USE OF METHYL METHACRYLATE PLOMBAGE IN THE SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS

DAVID A. WILSON, M.D.*

SINCE extrapleural pneumolysis was introduced by Tuffier in 1891, phthisiologists and surgeons interested in the treatment of pulmonary tuberculosis have been seeking a nonirritating material which could be used as a plombage to maintain the lung in a collapsed state. Many agents including fat, paraffin, hydrostearolein, gauze, rubber, muscle and air have been utilized in the past with poor results.

In 1938 a new synthetic plastic material was introduced for use in dental prosthesis (Geiler). This plastic material known chemically as methyl methacrylate represented the result of many years of exhaustive chemical research. It had been used for several years prior to this time by commercial plastic manufacturing companies, marketed under the trade names of lucite, plexiglas, vitarilic and others. Methyl methacrylate is an acrylic resin manufactured under exacting chemical and physical conditions from acetone, hydrogen cyanide and methyl alcohol in the presence of sulfuric acid. The polymerized form is a clear, light-weight solid which softens at 105° C., and can easily be molded into any desired shape. Its outstanding physical characteristic is its high tensile strength. Chemically, methyl methacrylate is relatively inert. It is soluble in esters, ketones, chloroform, ethylene dichloride and strong acids, but is not affected by weak acids or alkalies. It absorbs very little water without changing its chemical composition and does not appear to deteriorate like other plastic materials which have been implanted into the human body.

In January 1940 Kleinschmidt studied the effects of methyl methacrylate used to repair cranial defects in experimental animals. He found remarkably little inflammatory reaction and no foreign body response characteristic of other foreign agents used in the human body. This work has been confirmed by others. During the first few days the methyl methacrylate plate is surrounded by a small amount of serum which rapidly becomes organized forming a thin film of hyaline connective tissue. Rarely does sufficient serum accumulate around the implants to require aspiration. This fact has been stressed

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by Gurdjian and his co-workers, by Kahn, and Woolf and Walker who have used methyl methacrylate successfully in human cranioplasties. Woolf and Walker described one patient with an infected wound which cleared up with penicillin and local treatment without removal of the plate. Kahn also believes that this material is so inert that it may be used in the primary repair of perforating wounds of the head.

Spealman, Main, Haag and Larson have studied the effects of methyl methacrylate implanted into the peritoneal cavity. The material was allowed to remain nine months before autopsy of the animals was performed. Encapsulation of the particles by a thin film of hyaline connective tissue without the formation of adhesions was noted.

Methyl methacrylate has been used clinically to repair cranial defects (Zander, Gurdjian, Webster and Brown) and to study the brain and pial circulation (Sheldon, Pudenz, Restarski and Craig). It has been used successfully in reconstructive surgery as a substitute for cartilage for the correction of facial deformities (Penhale, Brown) and in arthroplasties for osteo-arthritis (Harmon). It was first used experimentally to secure a pulmonary collapse by Wilson and Baker in 1944. The effects of this plastic material inserted into the pleural cavity of thirty rats and into the extrapleural space of ten dogs was studied. A collapse of individual lobes was secured in approximately half of the rats by inserting into the pleural cavity a portion of methyl methacrylate premolded into the shape of the lobe to be collapsed. In the other half of the rats the pleural cavity was filled with small ¼ inch methyl methacrylate balls. All of the animals tolerated the methyl methacrylate well and showed no systemic reaction. X-rays taken at frequent intervals following operation showed little evidence of pleural effusion. Autopsies performed at intervals of from ten days to eight months showed only slight inflammatory changes and no foreign body reaction. The balls were surrounded by a thin serum immediately following the operation, and the pleura showed minimal thickening and infiltration with eosinophils. In the majority of the animals the methyl methacrylate became encapsulated by a thin layer of hyaline connective tissue. In ten of the rats the methyl methacrylate implants were still free in the pleural cavity eight months after operation.

The methyl methacrylate implanted into the extrapleural space of the ten dogs became encapsulated by a dense layer of hyaline connective tissue. The adjacent lung showed little evidence of reaction except atelectasis as a result of compression.

ADVANTAGES

Methyl methacrylate, in addition to being nonirritating to the tissues, possesses certain definite advantages over other foreign materials

which have been advocated for use as a plombage. The material is light-weight, and a large quantity can be introduced without danger of penetrating the pleura or thin-walled cavities. It is radiolucid and does not interfere with the interpretation of roentgenograms. Both these factors are of great importance in thoracic surgery.

For use in patients the methyl methacrylate was molded into solid and hollow balls 1 inch in diameter. This makes possible the filling of varying sized pockets at operation. As many as sixty balls have been utilized in a single patient without ill effects. As the air between the balls is absorbed, serum accumulates around the balls. This serum later becomes organized into hyaline connective tissue maintaining the lung permanently in a collapsed state.

A nonirritating plombage material permits the successful utilization of the operation, extrapleural pneumolysis. Introduced by Tuffier in 1891, this procedure consists of stripping the lung along with the parietal pleura away from the chest wall through a small anterior or posterior incision. The advantages of this operation over other major surgical procedures used in the treatment of pulmonary tuberculosis are: (1) Operation can be performed under local anesthesia. (2) There is little or no shock or blood loss, and transfusions are rarely required. (3) The involved area of lung can be selectively collapsed thus preserving the function of normal lung tissue. This makes possible the successful treatment of patients with bilateral apical cavities, low vital capacity, and the like. (4) There is no mediastinal shifting following operation. Expectoration of sputum is easy, and there is little danger of bronchogenic spread. (5) The postoperative management is relatively easy. (6) There is no chest deformity or scoliosis.

INDICATIONS

The indications for extrapleural plombage with methyl methacrylate are limited, since the use of this material in thoracic surgery is still in the experimental stage. The indications, however, are much broader than those established for extrapleural pneumothorax. All patients in which this procedure has been used have been under a strict sanatorium regimen, and pneumothorax has been attempted and found to be unsuccessful. Recent spread does not constitute the same contraindication to operation as it does for thoracoplasty. Many patients not suitable for either thoracoplasty or resection can be successfully treated by this method.

Those patients considered most suitable for operation are: (1) Patients with bilateral apical cavities. (2) Patients with unilateral cavities and infiltration in the opposite lung. (3) Patients in which the pulmonary tuberculosis is complicated by asthma, diabetes, heart disease or low vital capacity. (4) Patients of advanced age who, because of their general physical condition, are not candidates for major

surgical procedures. (5) Patients in whom thoracoplasty has been performed without successful closure of the cavity. Extrapleural stripping of the apex of the collapsed lung and plombage in these patients

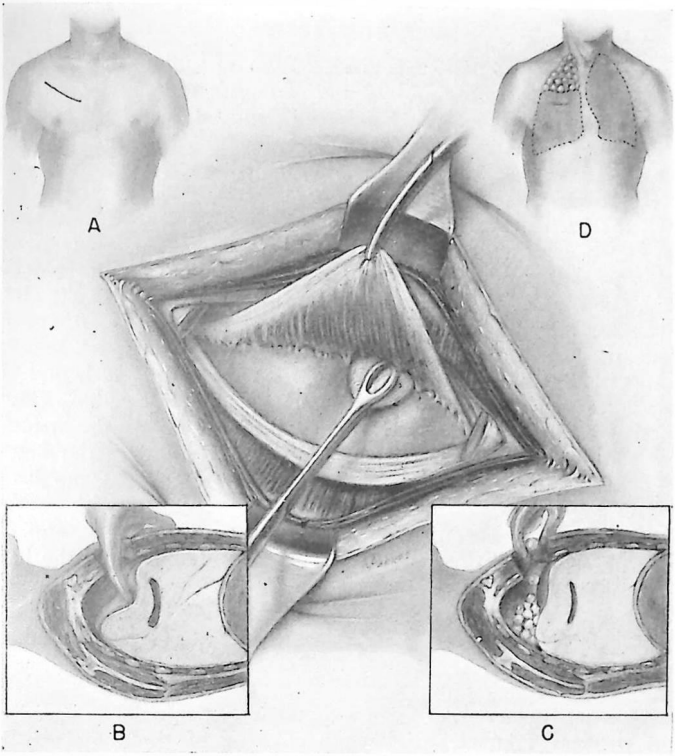

Fig. 441.—Operative technic. The extrapleural space is developed by blunt dissection. A lighted retractor is used for the deeper part of the dissection. *A*, Incision is made over the second rib and cartilage. The pectoralis major muscle is split and retracted. The incision is made through the anterior periosteum. A section of rib and cartilage is resected and the incision carried through the posterior periosteum. *B*, The extrapleural space is enlarged and the apex may be dropped down or compressed against the mediastinum. *C*, The extrapleural space is filled with methyl methacrylate balls, after which the section of rib is replaced and the periosteum is approximated to the rib. *D*, Composite drawing of balls in extrapleural space.

offers a single stage procedure which can be performed under local anaesthesia with little or no shock and with a good chance of cavity closure. (6) Patients with a thoracoplasty on one side who have

developed a cavity in the opposite apex. (7) Patients with cavities in the basal portion of the lung. In these patients extrapleural pneumolysis and plombage of the lower lobe permits a selective collapse and preserves the function of the uninvolved upper lobe.

OPERATIVE TECHNIC

Preoperatively, the patient is given 0.1 gm. of sodium pentobarbital the morning of operation and 16 mg. of morphine one-half hour before operation. An anterior or a posterior approach may be used (Fig. 441). I prefer the anterior approach, because access to the extrapleural space is easier and because the patient is more comfortable in the supine position during operation. After the skin has been prepared, the area overlying the second rib and cartilage is infiltrated with 2 per cent procaine and the incision is made down to and parallel to the rib and cartilage. The intercostal nerves are blocked with 2 per cent procaine. The pectoralis major muscle is split along the course of its fibers and a 4-inch segment of rib and cartilage resected aperiosteally. The rib segment is carefully saved. A longitudinal incision is made through the posterior periosteal bed, and the extrapleural space is carefully developed by blunt dissection. Finger dissection is much safer than instrumental dissection. As the space is developed, a small sponge on a clamp is substituted for the finger. A lighted retractor is indispensable. The entire apex is mobilized down to the hilum of the lung and the space filled with methyl methacrylate balls. The rib segment is resutured into place, and the periosteum is reapproximated around the rib margin to hold the balls in the extrapleural space. The pectoralis major muscle is reapproximated and the skin closed with interrupted silk sutures. Additional anesthesia is rarely needed after the extrapleural space is entered.

COMMENT

Extrapleural pneumolysis from a theoretical standpoint is based on sound surgical principles. Adequate collapse of the lung can be secured by this method as with intrapleural pneumothorax or thoracoplasty. Entrance into the extrapleural space probably occurs during the course of most thoracoplasties and is attended by little, if any, increase in danger to the patient. Many present-day thoracic surgeons routinely combine extrapleural apicolysis with thoracoplasty.

At the present time over twenty-five patients with far advanced pulmonary tuberculosis have been operated upon using methyl methacrylate plombage to maintain a collapse of the lung developed by extrapleural pneumolysis. Two patients have had bilateral apicolysis; two patients with a thoracoplasty on one side have had an apicolysis performed for a cavity in the apex of the other lung; four patients have had an uncollapsed apical cavity beneath an old thoracoplasty;

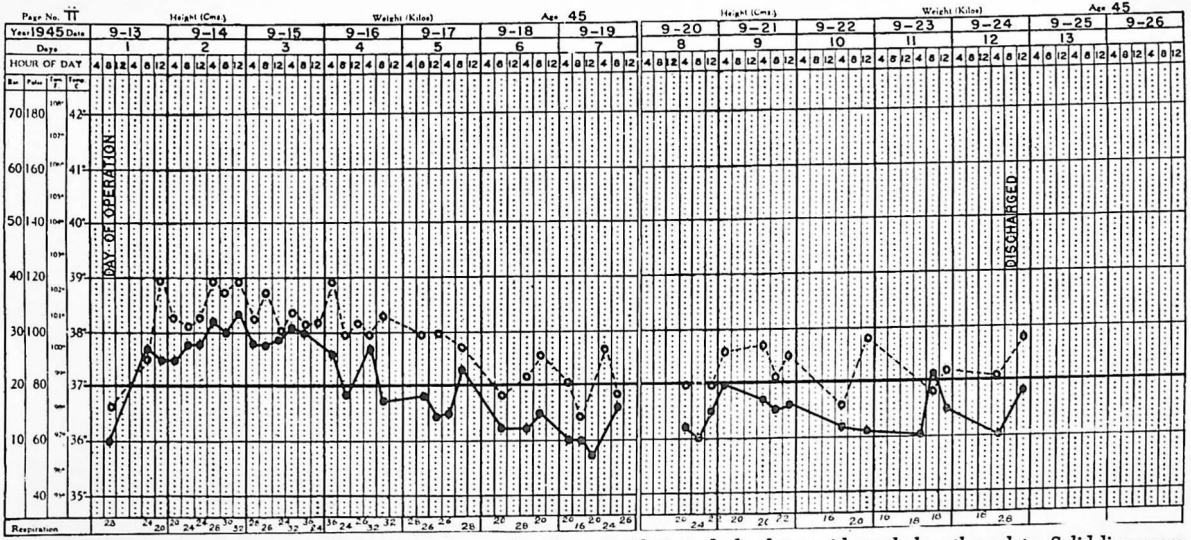

Fig. 442.—Temperature chart of patient following extrapleural pneumolysis and plombage with methyl methacrylate. Solid line represents temperature; dotted line, pulse.

one patient has had a cavity in the left lower lobe in the costovertebral angle. With few exceptions, all of the patients have had complications which contraindicated thoracoplasty or pulmonary resection. The results have been sufficiently gratifying to continue the operation upon an increasing number of patients and to broaden the indications to include many patients who are candidates for thoracoplasty but who refuse thoracoplasty because of the operative risk and deformity.

Contrary to the experience following thoracoplasty and pulmonary resection, the postoperative management of patients with extrapleural pneumolysis and methyl methacrylate plombage has been relatively easy. Since operation is performed under local anesthesia the cough reflex is not abolished, and expectoration is easy. There is no mediastinal shifting, and bronchogenic spread has not been encountered in any of the patients following the use of this procedure.

All of the patients have been operated upon in operating rooms equipped with bactericidal radiation, and all of the patients have been given penicillin postoperatively. Infection in the extrapleural space which previously discouraged the use of plombage has not been encountered with the use of methyl methacrylate and with the above precautions. A small amount of blood-tinged fluid accumulates around the balls as the air is absorbed. Aspiration of this fluid is rarely required and the danger of infection from repeated thoracentesis is nil. The average postoperative temperature has been 38.2° C., on the second or third postoperative days, with a return to normal by the fifth or sixth postoperative days (Fig. 442). Most of the patients complain of a feeling of pressure in the operative site and notice the clicking together of the balls during the first three or four days. These complaints have never been troublesome. The average postoperative hospital stay has been ten to fourteen days.

COMPLICATIONS

Complications of extrapleural pneumolysis and plombage with methyl methacrylate may be divided into two groups: namely, those arising as a result of the operative procedure, and those attributed to the use of methyl methacrylate. This former group includes (1) accidental rupture into the lung or thin-walled cavity, (2) hemorrhage into the extrapleural space, (3) formation of a bronchopleural fistula, (4) tuberculous or secondary infection in the extrapleural space, and (5) cardiac failure due to diminution of the pulmonary circulatory bed.

Accidental rupture into a thin-walled cavity adjacent to the pleura during extrapleural pneumolysis has been recorded many times. It is an error in surgical technic and may occur in the best of hands. Im-

mediate open drainage or cavernostomy is imperative either with or without thoracoplasty. Such an accident frequently results in a fatality. It constitutes a real danger in all extrapleural operations. This complication has not been encountered in my personal experience.

Massive hemorrhage, a troublesome complication in extrapleural pneumothorax, has not been encountered in association with methyl methacrylate plombage. Large vessels running between the chest wall and the lung are carefully coagulated by means of a diathermy during operation. Transfusions have not been required in any of the patients.

Formation of a bronchopleural fistula, a complication which so frequently occurred with extrapleural pneumothorax and with paraffin plombage, has not been encountered in this series. Methyl methacrylate, unlike paraffin, is relatively inert in the extrapleural space. It does not predispose to foreign body reaction and inflammatory changes which is so frequently the basis for formation of bronchopleural fistulas.

Neither tuberculous nor secondary infection of the extrapleural space has occurred in this series of cases. This is attributed to the use of bactericidal radiation and the liberal use of penicillin during and following operation.

Cardiac failure due to reduction in the pulmonary circulatory bed constitutes a real risk with extrapleural pneumolysis and plombage. Many of the patients upon whom this operation is performed already have their circulatory capacity reduced to a dangerously low level. In this series there has been one delayed death as a result of cardiac failure due to diminution of the pulmonary circulatory bed.

The second group of complications is that which might be attributed to the methyl methacrylate. Experimental human toxicity studies of methyl methacrylate were conducted by Spealman, Main, Haag and Larson using the patch test method on fifty medical students. No reactions whatsoever were observed when the polymerized form was used. Similar studies performed on experimental animals also led them to conclude that methyl methacrylate is nontoxic when introduced into the body. In our series only one reaction which could be attributed to the methyl methacrylate has been observed. This reaction occurred in the form of a generalized urticaria in a patient who had no previous history of atopic manifestations. The urticaria appeared on the tenth postoperative day and lasted three days. There has been no recurrence.

SUMMARY

Methyl methacrylate is an acrylic plastic which fulfills all the essential criteria of an ideal plombage material. It is solid at ordinary temperature but softens when heated to 105° C. It is light in weight but has a high tensile strength. It is radiolucid and does not obscure the lung detail. It is nonirritating to the human body.

Extrapleural pneumolysis and plombage with methyl methacrylate is still in the experimental stage. It has been used in the treatment of

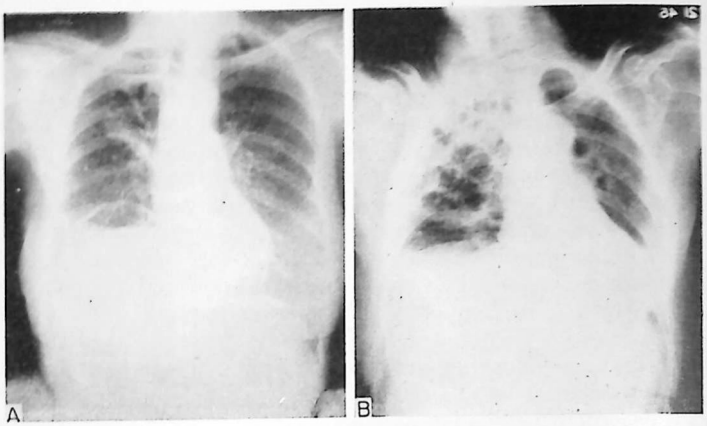

Fig. 443.—*A*, Preoperative and, *B*, postoperative roentgenograms of chest of 59 year old woman with far advanced pulmonary tuberculosis treated by extrapleural pneumolysis and plombage.

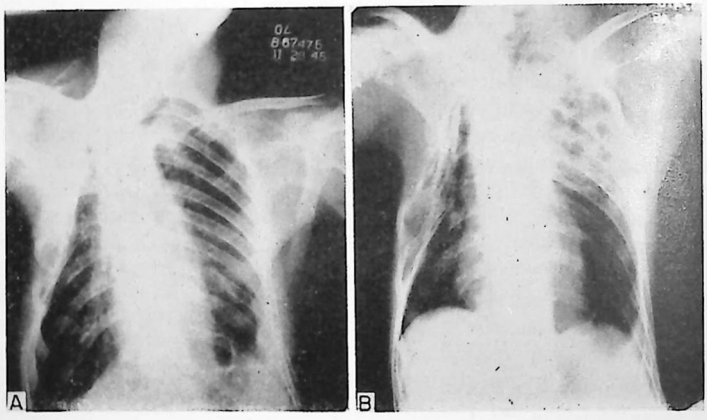

Fig. 444.—Roentgenograms of chest of a 34 year old man with cavity in left apex occurring two years after right two-stage thoracoplasty. Roentgenograms (*A*) before and (*B*) after patient was treated successfully by extrapleural pneumolysis and plombage.

over twenty-five patients with pulmonary tuberculosis. Most of these patients have had complications which contraindicated thoracoplasty

or pulmonary resection. The results in these patients have been sufficiently gratifying to continue its use in many less complicated cases of pulmonary tuberculosis.

The use of this procedure has certain advantages over other present-day surgical methods of collapse therapy. It is a single-stage operation which can be performed under local anesthesia with relatively little operative risk. The collapse is permanent. There is no postoperative mediastinal shifting, expectoration is easy, and the danger of bronchogenic spread is greatly diminished. The postoperative management

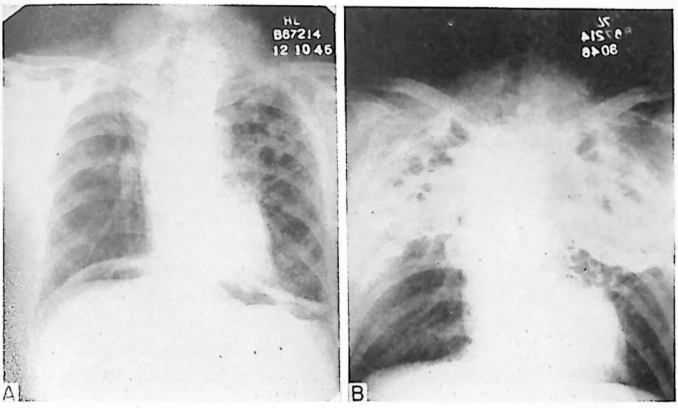

Fig. 445.—Roentgenogram of chest of 54 year old man with bilateral apical cavities (*A*) before and (*B*) after being treated by means of bilateral extrapleural pneumolysis and plombage with methyl methacrylate balls.

is easy. Patients with bilateral apical cavities, patients with basal cavities, patients with low vital capacity, cardiac disease, and advanced age, and patients with residual cavities beneath a thoracoplasty can be successfully treated by this method.

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CONTROL OF SO-CALLED "UNEXPLAINED INFECTIONS" IN SURGICAL WOUNDS, WITH PARTICULAR REFERENCE TO THORACIC SURGERY

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WITH the introduction of antiseptic and then aseptic technic in surgery, rapid strides were made in extending operative treatment to all parts of the body.

In his earlier work on antiseptic methods Lister gave great consideration to the bacteria in the air as a cause of wound infections, but later realized that contact contaminations played by far the major role in wound infections of that day. As a result of this better understanding of the relative dangers of contact versus airborne bacteria as a cause of wound infections, he gave up the carbolic spray, and throughout the surgical world the air came to be ignored as a medium for transporting the bacteria causing wound contamination. Gradually surgeons came to realize the danger of droplet contamination from the noses and throats of the occupants of the operating rooms, and masks of a totally inadequate type came to be worn, first over the mouth and then also over the nose.

As a result of (1) the great reduction in contact contamination, (2) the increased knowledge of the importance of leaving the wound in the best condition to cope with the reduced number of contaminants, (3) the improvements in anesthesia, (4) the increasing knowledge of shock and its prevention, (5) the introduction of parenteral fluids of all types, particularly blood transfusions, and (6) the increasing knowledge of function and physiology of various parts of the body, the extent and magnitude of surgical procedures were greatly extended.

INCIDENCE OF "UNEXPLAINED INFECTIONS"

Early Experience.—With this increasing scope of surgical procedures, and thus with one or more of the following conditions prevailing: (1) exposure of larger denuded areas, (2) for longer periods of time, (3) in operative procedures with greater trauma, (4) with poorer hemostasis, (5) where the wound could not be immobilized, (6) in tissues with poor local resistance, and (7) frequently in de-

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bilitated patients, so-called "unexplained infections" became more and more common with all too frequent fatalities. Such infections were likely to be grouped at irregular intervals, and many surgeons can recall times when such infections reached serious proportions. Walker in 1930 reported from a teaching hospital in Boston an infection rate of approximately 20 per cent for December, January and February and 42 per cent for March, dropping off to an average of 8 per cent for the months of April through September. In March the percentage of streptococcal wound infections rose to 10.5 per cent at which time 50 per cent of the operating room personnel were carriers of the hemolytic streptococcus. During the influenza epidemic of 1918 many operating rooms were closed except for emergency cases "because of the widespread dissemination of streptococci." So far as we know, at this time the air was not considered as a medium for transporting these organisms. Masks were widely used, at least over the mouth, and emphasis was at times placed on the danger of droplets from talking, coughing and sneezing. It was urged that the masks (fairly adequate to stop large droplets but totally inadequate to prevent air contamination with finer particles) be worn over the nose and mouth.

One of the authors (D.H.), while serving as resident on a busy neurosurgical service in 1924–25, witnessed a series of fatalities from unexplained infections. A widely known bacteriologist was called in to pass on every step of the aseptic technic and after careful observation for several weeks he pronounced that the "technic was airtight," but he entirely ignored the air. With certain changes in the sterilizing technic (a longer period of time at a higher steam pressure) there were no serious infections for a period of a year, and it was thought that inadequate sterilization of supplies had been the cause of the infections. Later the infections again occurred despite the changed autoclaving technic. In retrospect it would appear that these cycles of high and low infection rates were associated with changes in the bacterial flora of the noses and throats of the operating room occupants.

Individual reports occasionally appeared correlating the organisms in an infected wound with those found in the nose and throat of one of the operating room personnel. In such cases it was generally thought that the wound infection was caused by contact or droplet inoculation. General dissemination of bacteria that floated in the air for relatively long periods of time, and for considerable distances, was not considered as a source.

Experience at Duke Hospital.—Following the opening of the Duke Hospital in 1930, occasional "unexplained infections" occurred. In attempting to prevent these, every phase of our aseptic technic was subjected to critical analysis with a general increase in all precautions to guard against the generally accepted sources of contamination.

There was no appreciable reduction in the "unexplained infections," and there was an occasional fatality. These occurred almost entirely in such large operative procedures as thoracoplasties, craniotomies and arthroplasties. Finally with a widespread increase in the nose and throat contamination with Staphylococcus aureus (70 to 80 per cent of the general population) and with several heavy carriers among the operating room personnel, six deaths occurred from such infections within a period of three months, forcing us to cease performing operations of election until general conditions improved.

During the years 1930 through 1935 there were seventeen deaths from unexplained infections. Thus within these three months occurred 35 per cent of such deaths for the five-and-one-half-year period. The epidemic nature of these infections is even further emphasized by the fact that during these three months there were performed only 1.5 per cent of the approximately 15,000 operations for the entire period.

Before this epidemic occurred, we had concluded that pathogenic bacteria floating in the air and sedimenting on the wound and sterile supplies caused most of these "unexplained infections." Repeated cultures of every phase of technic including the incoming air convinced us that the pathogenic bacteria in the air of the operating room originated in the noses and throats of the occupants. We reduced the degree of air contamination by ventilating the room with large quantities of air rendered relatively free of bacteria by washing and filtering. Even though the reduction was appreciable, we continued to have occasional infections. Attempts were then made to control this air contamination by limiting the number of occupants of the operating room, elimination of persistent carriers, improvement in and more constant wearing of masks, performing large clean operations only as the first procedure in the morning after the room had been free of occupants overnight, and finally by postponing until the summer months, when the carriers are few, those procedures which were not urgent. The latter of these was the most effective as exemplified by the fact that of these 17 deaths from "unexplained infections" in clean operative wounds, not one occurred in May, June, July or August, while 41 per cent occurred in December and January, 18 per cent in November and February, 29 per cent in October and March, and 12 per cent in September and April. The facts that no deaths occurred during the summer months when the air contamination was repeatedly demonstrated to be low and that the greatest mortality occurred during the winter months when it was known to be high were more than suggestive that the organisms entered the wound by way of the air.

Ultraviolet Radiation of Air.—By 1934 we had demonstrated that these airborne bacteria could be killed even at considerable distances (6 to 10 feet) by means of ultraviolet radiation. It was early in 1936, however, after many animal experiments, before we had convinced

ourselves that we could operate in such a field without danger to the wound, and before we had equipped an operating room for use with patients. This addition to the generally accepted aseptic technic has all but eliminated our infections in clean operative wounds and not one of these has been severe.

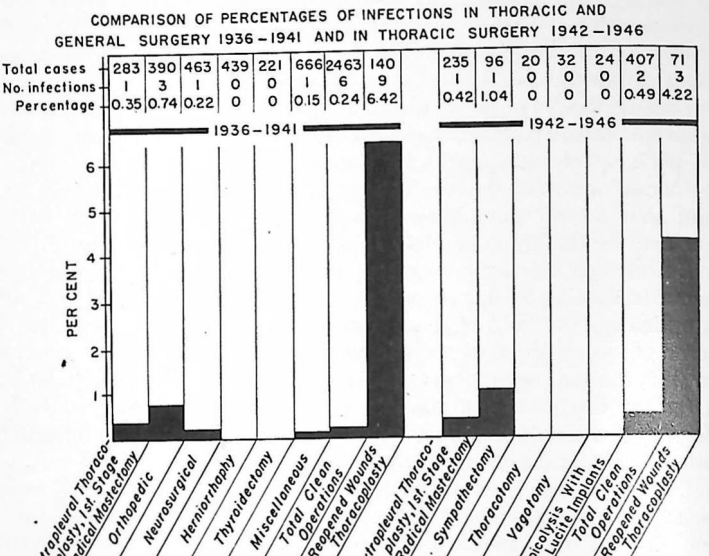

Fig. 446.—The slightly higher infection rate (less than 0.5 per cent) for the total clean operations for 1942–1946 as compared with 1936–1941 is explained by the fact that the smaller operations which never become infected have not been included.

The higher infection rate in the reopened wounds for both periods can be explained. The air contaminants have been largely eliminated, but the resident skin flora even though of low pathogenicity are still present. They rarely cause an infection in a primary incision, but may produce stitch abscesses with a greatly increased number of bacteria about the skin sutures but not showing signs of suppuration. When any wound is reopened at an early date after removal of the skin sutures, these bacteria are disseminated through the superficial part of the new incisions, and may from their numbers produce a mild or moderate suppuration usually in the subcutaneous fat.

A reported analysis of all operations performed with ultraviolet radiation for the years 1936–41 (Fig. 446) shows an infection rate of only a fraction of 1 per cent, ranging from no infections in 439 herniorrhaphies and 221 thyroidectomies, to one infection in 463 neurosurgical operations, one infection in 283 first-stage thoracoplasties and radical mastectomies, and three infections in 390 orthopedic operations.

While in 1936 only the larger operations in clean cases were per-

formed in a field of ultraviolet radiation, now many potentially contaminated operations such as intestinal resections are performed in such a field. This is done in order to avoid introducing the airborne organisms and also to reduce the number gaining access to the wound from the gastrointestinal tract.

We have recently analyzed the operations on the chest performed during the years 1942 through March, 1946, and these are also shown in Figure 446. (In evaluating these statistics, it should be kept in mind that thoracic operations as demonstrated in the period 1936 to 1941 have next to the highest infection rate of any of the groups of cases analyzed.) Following a total of 413 clean primary incisions there were only two infections, giving a rate of less than 0.5 per cent. Breaking

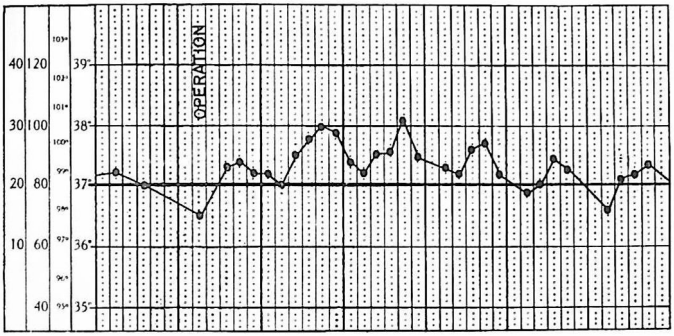

Fig. 447.—Temperature curve for one day before and six days after radical mastectomy on the patient described in Case I as showing a mild infection. This did not follow the clinical course of an infection. Bloody fluid was aspirated only once followed by complete healing without reaccumulation of fluid. It is recorded as infected since the culture report on the aspirated fluid was positive for Alcaligenes faecalis.

this down we find that there were 81 primary incisions for thoracoplasty with no infection; 163 radical mastectomies with one infection (Case I); 148 thoracotomies, 20 for tumor, 32 for vagotomy, and 96 for sympathectomy with only one infection in the latter group (Case II). Both of these infections were mild as is demonstrated by the following abstracts and temperature curves.

Case I.—A 59 year old white widow entered the hospital with a chief complaint of a "lump" in her left breast, first noticed two weeks previously. On November 4, 1944, a biopsy revealed undifferentiated carcinoma, and a radical mastectomy was performed. The temperature curve for the first six days is shown in Figure 447. The fine cotton skin sutures were removed on the sixth, and the stay sutures on the tenth postoperative day; on both occasions the wound was described as showing no evidence of separation or infection. On the fourteenth postoperative day, 60 cc. of "old blood" was aspirated from the superior portion of the

wound. Routine culture of this material was reported as showing Alcaligenes faecalis. There was no further accumulation of fluid, and the patient was discharged on the twentieth postoperative day, remaining in the hospital for this length of time in order to complete a course of x-ray therapy. The discharge note stated that the wound was well healed. The patient received chemotherapy in the form of oral sulfadiazine, 6 gm. a day, from the third to the twelfth postoperative day. The temperature remained between 37° and 37.5° C. (98.6° and 99.5° F.) except for two elevations to 37.9° and 38° C. (100.2° and 100.4° F.) on the eighth and ninth days respectively.

On the patient's return to the outpatient clinic one month following discharge, the wound was noted as being well healed with no evidence of infection.

Case II.—A 34 year old white paperhanger was admitted to the hospital for surgical treatment of hypertensive cardiovascular disease. On August 30, 1944, a transthoracic paravertebral sympathectomy was performed on the right side. The

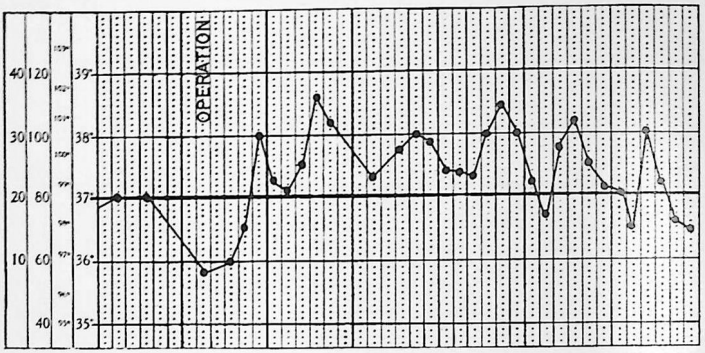

Fig. 448.—Temperature curve for one day before and six days after a transthoracic sympathectomy for hypertension (Case II). A small collection of fluid drained spontaneously from the superficial part of a catgut closed wound about the eleventh postoperative day and was described by the operator as infected, but no culture was obtained. Healing was complete by the eighteenth postoperative day, and there was no temperature elevation above 37° C. (98.6° F.) after the first six days following operation as shown.

postoperative course was complicated by the fact that drainage had not been instituted at operation, and, on the fourth postoperative day, a thoracentesis with the removal of 700 cc. of bloody fluid had to be performed. At this time he had a temperature elevation to 39.4° C. (102.9° F.). On September 23, 1944, a transthoracic paravertebral sympathectomy was performed on the left side, with a Pezzer catheter inserted between the eighth and ninth ribs for drainage of the thoracic cavity. The temperature during the first six postoperative days is shown in Figure 448. The drainage catheter was removed on the sixth postoperative day. On inspection of the lower wound on the eleventh postoperative day, a "small" abscess was found which had already opened. Warm saline compresses were applied and the infection promptly cleared with complete healing of the wound by the time of discharge on the eighteenth postoperative day. The patient was given oral sulfadiazine, 6 gm. a day from the second to the twelfth and penicillin, 30,000 units a day, from the fourth to the twelfth postoperative days. The temperature

dropped to 37° C. (98.6° F.) on the sixth postoperative day and remained at or below 37° C. for the remainder of his stay. On the patient's return for a check-up three months postoperatively, the incisions were observed as being well healed.

As further evidence of the value of ultraviolet radiation for reducing the bacterial contamination of the air with resultant improvement

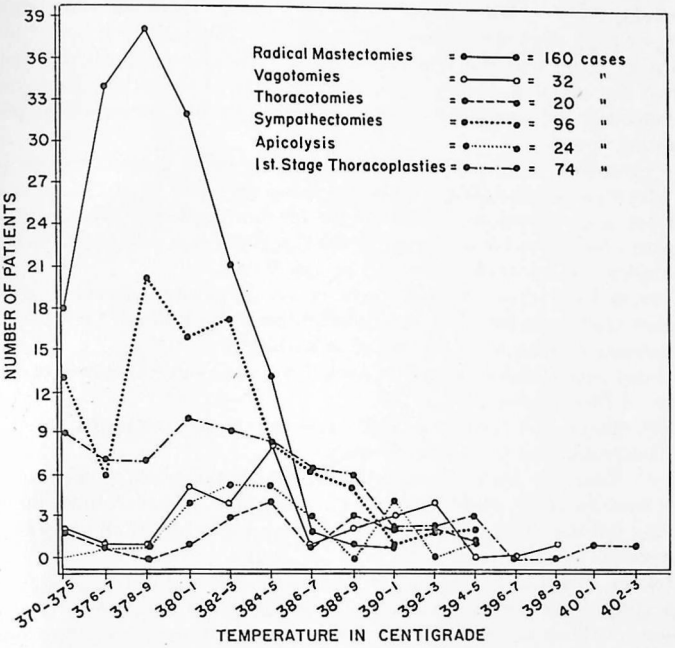

Fig. 449.—Maximum temperature elevations for each of the thoracic operations performed for the years 1942 through March, 1946, arranged according to operation as indicated. These were all extensive operative procedures, most showing a relatively slight temperature reaction. Attention is called to the fact that the patients having a thoracotomy that was not drained (vagotomies and thoracotomies for tumors designated as "thoracotomies") and those having an apicolysis with a foreign body implant ran slightly higher average temperatures than the patients having other thoracic operations. For 83 per cent of the entire group the postoperative temperature did not go above 38.5° C. (101.3° F.).

in wound healing two reports may be cited, one from the state sanatorium in North Carolina, as given in a personal communication, and the other by Overholt and Betts. The former report gave an infection rate of 25 per cent without radiation, whereas in the first 100 thoracoplasty stages after the introduction of radiation there was only one

infection, and that in a reopened wound. In the latter report Overholt gave 13.8 per cent infections in clean thoracoplasty wounds without radiation. By improvements in surgical technic leaving the wound in a better condition to cope with the contamination, this was reduced to 6.53 per cent. Then by the introduction of ultraviolet radiation to reduce the air contamination, this infection rate was reduced to 2.67 per cent. Most of the latter were slight and superficial with only 0.49 per cent clinically significant. From the illustration showing the operating room and the chart giving the reduction in bacterial content of the air, it is evident that the intensity of radiation used and the bacterial reduction obtained were less than has prevailed in our operating rooms.

As contrasted to these low infection rates, other recent reports in the literature are as follows: Wu and Besso Pianetto in 1943 reported 11.8 per cent infections in 339 stages of thoracoplasty; after certain measures had been taken to reduce the dangers from skin and air contamination, no infections occurred in 120 stages.

Cory in 1943 reported 69 per cent of thoracoplasty wounds showed primary healing before the use of sulfathiazole, and 93 per cent showing primary healing with the use of sulfathiazole.

Adams and Dufault in 1941 reported 9.9 per cent infections in 241 stages of thoracoplasty.

Dieffenbach and Crecca in 1941 reported 10 per cent infections in 100 thoracoplasties including all stages.

G. G. Finney in 1941 reported that in 104 thoracoplasties, all stages, there were fourteen slight, eight moderate and three severe infections. Leaving out the slight infections, which were probably stitch abscesses, he reported an infection rate of 10.6 per cent.

Meltzer in 1941 reported in 181 cases of thoracoplasty, all stages, three stitch infections, four subcutaneous infections and one severe infection resulting in death. In the latter case a tuberculous cavity was entered during the operation.

POSTOPERATIVE ELEVATION OF TEMPERATURE, AND ITS DURATION

As has been reported in a previous publication, the virtual elimination of airborne bacteria resulted in a great reduction in the postoperative temperature elevation and the duration of this elevation. The temperature curves on all patients having thoracic operations for the years 1942 through March 1946 were analyzed as a further method of evaluating their reaction to these relatively large and traumatizing operations with a very low bacterial contamination. From the chart (Fig. 449) it is seen that for the radical mastectomies (160), first stage thoracoplasties (74), and the sympathectomies (96) (thoracotomies where drainage of the pleural cavity was instituted to remove

any accumulation of blood), a total of 330 operations, 43 patients (13 per cent) did not have a postoperative temperature elevation above 37.5° C. (99.5° F.), 213 patients (65 per cent) did not run a temperature elevation above 38.1° C. (100.6° F.), while 289 patients (88 per cent) had their postoperative temperature remain at or below 38.5° C. (101.3° F.). Only 41 patients (12 per cent) had a postoperative temperature elevation above 38.5° C. (101.3° F.).

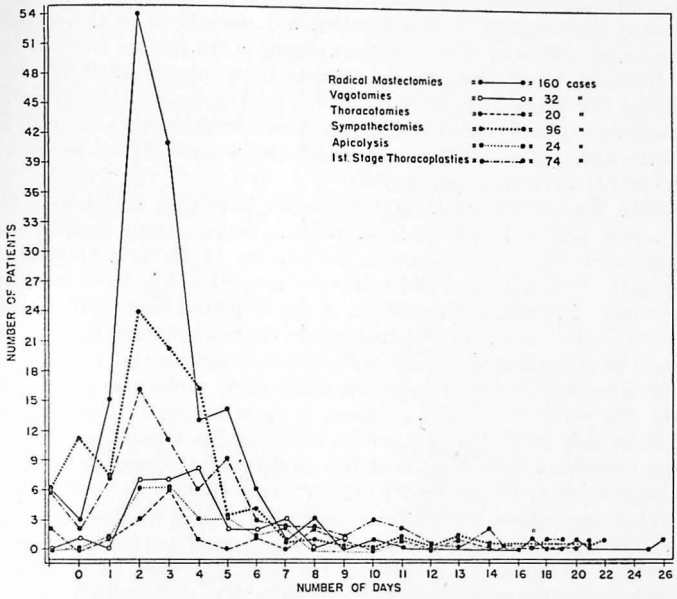

Fig. 450.—Showing the duration of any temperature elevation above 37.4° C. (99.3° F.) for each of the thoracic operations shown in Fig. 449 for temperature elevation. The patients having a thoracotomy without drainage of the pleural cavity and those with an apicolysis and foreign body implants experienced a temperature elevation for a somewhat longer average time. The temperature of 78 per cent of all the patients was down to 37.4° C. or below by the fourth day following operation.

Equally as striking as this predominantly slight temperature elevation in the postoperative course of most patients was the short duration of any elevation above 37.4° C. (99.3° F.) (Fig. 450). In this same group of radical mastectomies, first stage thoracoplasties, and sympathectomies, 18 patients (6 per cent) had no postoperative temperature elevation, while the temperature of 229 patients (70 per cent) was down to 37.4° C. (99.3° F.) or below by the third day postoperative. Thus only 30 per cent of these patients had any eleva-

tion of temperature above 37.4° C. (99.3° F.) for longer than three days postoperatively (Fig. 450).

It is seen from Figure 449 that the temperature elevation was slightly higher, and from Figure 450 that the duration of the temperature elevation was slightly longer for the thoracotomies performed without drainage to remove any accumulation of blood (vagotomies [32] and for removal of tumors [2—]) and for apicolysis (24) with methyl methacrylate plombage where a foreign body was left in the wound. This slightly greater reaction was thought to be due to either the accumulation of blood, or the presence of the foreign body or both.

In contrast with the seventeen deaths from "unexplained infections" during the years 1930 through 1935 (total operations 15,508) there has been no such death during the years 1936 through March 1946 where ultraviolet radiation was used* (approximately 15 per cent of the 69,743 operations performed).

With the low infection rates which we have now maintained for a ten year period in all types of wounds, even during epidemics of respiratory tract contamination, the number of bacteria entering our wounds obviously has been relatively low. This has been confirmed by wound irrigations and cultures of the irrigating fluid. With this fact established, it seemed to us that a smooth, nonirritating foreign body could be transplanted into the wound and would become encapsulated with a negligible risk of infection. This work, carried on by Dr. Wilson, the resident hospital surgeon, is summarized in a separate article in this issue. Up to April 1, 1946, we have performed twenty-four apicolyses, including those reported by Dr. Wilson, with the implantation of from eighteen to seventy-two spheres of methyl methacrylate per patient, each sphere measuring 2.5 cm. in diameter. These were designed for easy insertion and retention within the thoracic cage for the purpose of holding the cavitated lung in a collapsed position with the minimal risk of ulceration into the cavity.

Most of the patients in this series have had far advanced disease and have been considered unfavorable for thoracoplasty. The details of this operation are given in the papers of Dr. Wilson. So far no wound having methyl methacrylate plombage has become infected, no spheres have been extruded or ulcerated into the cavity, and all spheres have apparently become encapsulated.

SUMMARY

In conclusion the virtual elimination of airborne pathogenic bacteria by ultraviolet radiation has accomplished the following results:

1. Eliminated all deaths from "unexplained infections."

* Two such deaths occurred in patients operated on when ultraviolet radiation was not available: radical dissection of the glands of the neck for carcinoma and craniotomy for inoperable brain tumor.

2. Reduced "unexplained wound infections" to a fraction of 1 per cent.

3. Diminished greatly the severity of the infections that have occurred.

4. Improved wound healing in every case with less local and systemic reaction.

5. Made possible the implantation and encapsulation of nonirritating foreign bodies with virtual absence of the dangers of infection and extrusion.

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CHEST INJURIES

Application of Military Experience to Civilian Practice

CLARENCE E. GARDNER, JR., M.D., F.A.C.S.*

THE war has stimulated interest in traumatic surgery and has enabled surgeons in the military service to crystallize ideas and formulate policies in the care of the injured that would have taken years to develop in civilian life.

Chest injuries of all kinds have been seen in large numbers in military hospitals of the various echelons of medical care during the war. Our experience in a fixed hospital in England in the center of the Eighth Air Force area, where we received fresh battle casualties from crew members of high altitude bombing missions and plane crashes, afforded us opportunity to observe a wide variety of these injuries. In addition, this hospital acted as a chest center for ground force casualties evacuated from the continent during the latter months of the war in Europe.

TABLE 1.—RELATIVE INCIDENCE OF VARIOUS TYPES OF CHEST INJURIES IN AN ARMY HOSPITAL

	Fresh Injuries		Chest Center Casualties	Evacuated Casualties
	Penetrating	Non-penetrating		
Chest wall	32	31		
Pleural cavity (penetrating)	16		74	283
Contusion of lung	6	25		
Hemothorax	8	13	32	45
Pneumothorax		3		
Hemopneumothorax	6	7	20	18
Traumatic asphyxia		2		

Patients covered by this experience (Table 1) include 128 casualties with fresh chest injuries, 74 evacuated chest casualties received by the hospital in its capacity as a chest center, and 283 evacuated casualties

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with chest injuries, many incidental to other more serious injuries, treated in the chain of evacuation of battle casualties from front line installations. From this experience, and that of others working under similar circumstances, certain conclusions may be made which may be helpful in the management of chest injuries of civilian life.

In discussing chest injuries it is the usual practice to consider such injuries under two separate and distinct headings, penetrating and nonpenetrating wounds, as though the problems of the two were foreign to each other. As a matter of fact, with few exceptions the problems of both types of wounds are similar and it is better to consider them together.

The principal danger of a chest injury arises from a disturbance in the cardiorespiratory mechanism which follows the injury. Blood loss and infection may also be causes for concern, although they are rarely of significance in civilian injuries.

This disturbance in respiratory function may arise from a wide variety of combinations of circumstances. In our experience, excluding injuries to the heart, it most commonly follows any one or combination of the following conditions: contusion of the lung, loss of stability of the chest wall, pneumothorax, or hemothorax. All of these are common to both penetrating and nonpenetrating injuries.

A discussion of each of these conditions plus a brief consideration of the additional problems of the open chest wound (continued blood loss, retained foreign body, open pneumothorax and infection in chest wall or pleural cavity) will include a complete account of the commoner conditions to be encountered in chest injuries of civilian practice. Each will be discussed in the light of military experience.

In the recognition of each of these conditions and their changing nature from hour to hour and day to day, emphasis should first be placed on the importance of frequent bedside x-rays of the chest. Much can be learned from physical examination, and frequent examinations are necessary. However, their interpretation is too uncertain and it is only by combining physical findings with repeated x-rays that accurate information on the changing nature of the conditions present can be maintained.

CONTUSION OF THE LUNG

Contusion of lung tissue with some degree of laceration commonly follows injuries to the chest. It is present in all penetrating wounds of the lung and we found evidence of it in 30 per cent of nonpenetrating injuries from blows, crushing injuries or "bomb blast." It may be present without rib fracture. Edema and hemorrhage are present throughout the involved lung parenchyma. Pleural lacerations with pneumothorax, hemothorax or both may complicate the lesion. In the more severe injuries lung tissue is extensively lacerated and bronchi

are ruptured. At autopsy the lung is dark red and firm in consistency.

If the involved area is not large the only symptom is pain in the chest and bloody expectoration. If the injury is severe or widespread, serious interference with respiratory exchange may develop because of widespread contusion of lung tissue and filling of the alveoli and bronchi with blood and tissue fluids.

The syndrome of the "traumatic wet lung," in which fluids in the tracheobronchial tree are present in such excessive amounts that the patient may literally drown in his own secretions, is present in patients with severe lung contusion. Brewer, Burbank, Sampson and Schiff[1] have indicated that other factors beside lung contusion may enter into the picture. These are excessive reflex secretions of bronchial fluids secondary to trauma, anoxia or tracheal obstruction; and inability to expel fluids from the bronchial tree adequately because of pain or instability of the chest wall from multiple rib fractures, or from inhibition of the cough reflex by oversedation or head injury.

Management of this condition is by oxygen administration, relief of pain by intercostal block which often enables the patient to eliminate his secretions himself, and by catheter or bronchoscopic aspiration of blood and secretions in the tracheobronchial tree, if necessary.

It should be emphasized that any patient with chest injury who is having difficulty in eliminating tracheal or bronchial secretions must be given assistance if adequate respiratory exchange is to be maintained and atelectasis of lung segments prevented. It may be that relief of pain by support of the chest or by intercostal nerve blocks will enable the patient to empty the respiratory passages himself by coughing. Or changes in posture with firm but gentle fist percussion over the interscapular region of the back may assist in dislodging tenacious plugs of secretions which may then be expelled by coughing. If these measures are not effective, passage of a catheter into the tracheobronchial tree with suction as described by Haight[2] is advisable. If this is not possible, bronchoscopic aspiration should be prompt.

LOSS OF STABILITY OF THE CHEST WALL

Paradoxical respiration from loss of stability of the chest wall following trauma is not a frequent cause of respiratory distress. When present, however, its recognition is extremely important as it can usually be managed quickly and effectively. If left untreated, particularly if it exists with other types of chest trauma, as is usually the case, serious consequences may develop.

Multiple fractures of several adjacent ribs, or separation of the sternal plate from the thoracic cage because of multiple fractures of the ribs anteriorly on each side of the sternum, are the usual cause for loss of stability of the chest wall and the development of para-

doxical respiration. In this situation, when the thoracic cage is elevated and expanded as is necessary in inspiration, the detached segment of the chest wall does not elevate but in reality is sucked in. On expiration this segment, instead of falling in, is pushed out (Fig. 451). The detached segment moves in opposite direction to the chest wall. The net result is a serious impairment of respiratory ex-

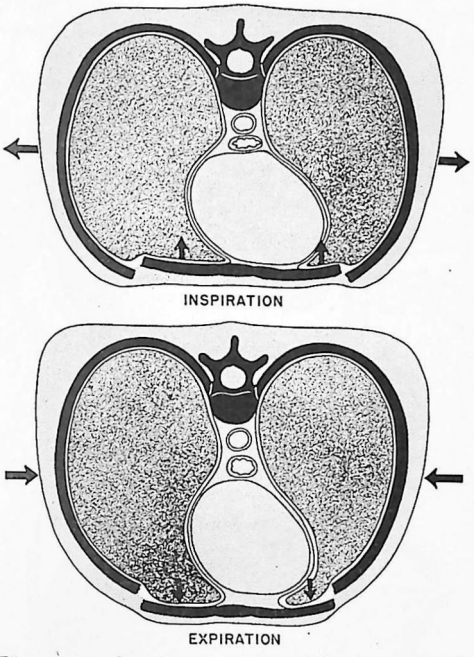

Fig. 451.—Diagrams to show loss of stability of the chest wall following a crushing wound. The detached sternal plate moves in opposite direction to the chest wall during respiration and produces a paradoxical respiration.

change. The patient is dyspneic, cyanotic and complains of pain at the site of injury.

Some method of stopping this paradoxical motion of the chest wall is urgently needed. If the mobile segment of chest wall is not too large it may be stabilized by strapping with adhesive. If this is not immediately satisfactory, as is usually the case with separation of the sternal plate, wires may have to be placed under the separated rib segments and attached to an overhead pulley with weights which will suspend and immobilize this segment.

Pain is usually relieved by such immobilization, though intercostal nerve block may be necessary. Oxygen is administered until respiratory exchange is normal. As in all chest wounds, frequent x-rays are necessary to detect the presence of an attendant pneumothorax, hemothorax or lung contusion which may also need treatment.

PNEUMOTHORAX

Air may escape into the pleural cavity from a tear in the lung or a hole in the chest wall. The lung may be ruptured from a crushing

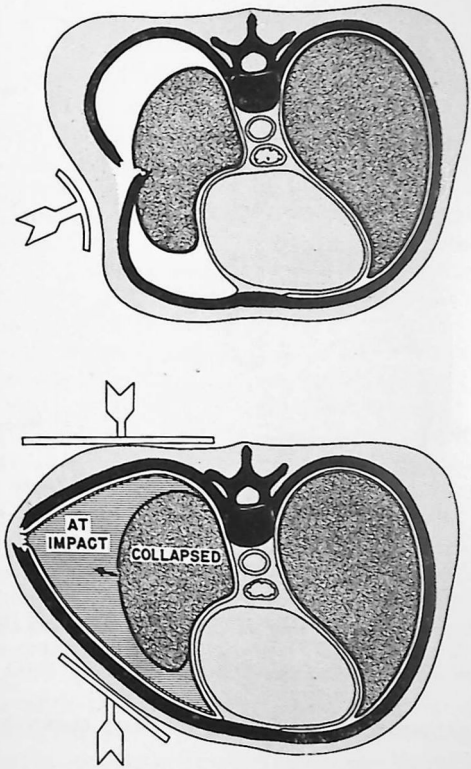

Fig. 452.—Diagrams showing two methods by which pleuropulmonary injury may follow nonpenetrating injury of the chest by direct blow or crushing injury.

injury with or without rib fracture, or it may be lacerated by the sharp ends of indriven rib following a direct blow (Fig. 452). Ordinarily, unless a tension pneumothorax develops or other chest injuries are severe, the presence of air in the pleural cavity is not a serious

complication. If it is causing respiratory embarrassment, the air may be withdrawn. Otherwise, it ordinarily is rapidly absorbed.

Tension Pneumothorax.—Sometimes a valvelike action at the pleural tear in the lung allows air to enter the pleural cavity with each inspiration but not to escape during expiration. Air gradually builds up in the pleural cavity under positive pressure. The lung on the affected side becomes collapsed, the mediastinum becomes displaced to the unaffected side and serious interference with respiratory exchange develops.

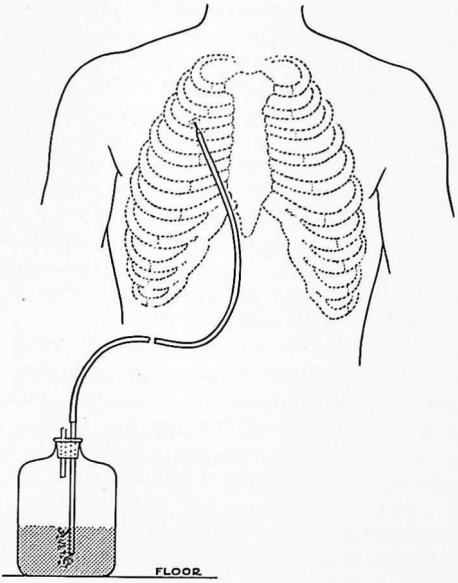

Fig. 453.—Sketch of the method used in releasing air from a tension pneumothorax.

Air must be withdrawn from the pleural cavity promptly if the patient is to escape death from suffocation. This can be easily accomplished by inserting a needle through the second or third interspace anteriorly and connecting the needle to a finger cot or condom which has a slit in its end, or to a tube whose end is placed under the surface of a flask of sterile fluid on the floor at the bedside (Fig. 453). If the escape of air has not stopped in forty-eight hours, open thoracotomy may be advisable either to remove indriven rib fragments which may be keeping the pleural leak open or to resect an area of damaged lung tissue or suture lacerated bronchi. Open operation is rarely necessary, however.

Subcutaneous emphysema is commonly present when ribs are fractured. If it is increasing rapidly, the presence of a tension pneumothorax must be suspected and a needle inserted into the pleural cavity with underwater seal, before generalized subcutaneous emphysema develops.

HEMOTHORAX

Bleeding into the pleural cavity in patients who survive long enough to reach a hospital usually occurs either from the lung or from intercostal or internal mammary vessels of the chest wall. The dangers of its presence include acute blood loss, interference with respiratory exchange, and loss of lung function with possible infection if a massive clotted hemothorax or a fibrothorax develops.

Bleeding from the lung stops spontaneously as the lung collapses, while bleeding from the chest wall may have to be controlled at operation. If the patient is received in shock and the blood pressure, once restored by transfusion, drops again, the possibility of continued bleeding from an intercostal or internal mammary artery must be considered. If blood in the pleural cavity reaccumulates rapidly after repeated aspiration, the suspected area must be explored, bleeding vessels ligated and blood and blood clot evacuated. It is surprising, however, how rarely this complication develops.

The treatment of hemothorax unattended by continued bleeding has been a subject of controversy in the past. Some have advised leaving the blood alone if it causes no respiratory embarrassment.[3, 4] Others have recommended withdrawing the blood, but only after three or four days, and then replacing it with air in the belief that reexpansion of the lung would cause bleeding from the lung to begin again.[5]

As a matter of fact, we have never seen bleeding from a lung recur after early aspiration of a hemothorax, while we have repeatedly been impressed by the harmful effect of allowing blood to remain within the pleural cavity.

Contrary to popular belief, blood which escapes into the pleural cavity clots promptly in most cases. As it clots, the churning motions of heart and lung defibrinate the clot so that fibrin is deposited on parietal and visceral pleuras and liquid defibrinated blood remains in the pleural cavity.[6, 7] In most instances of small or uncomplicated hemothorax this defibrinated blood and the fibrin are absorbed without deleterious effect. However, it has been demonstrated that this liquid defibrinated blood acts as an irritant within the pleural cavity. The inflammatory exudate which it stimulates contains more fibrinogen which causes secondary clotting to occur with deposition of additional layers of fibrin over pleural surfaces. Sellors[7] has shown that the fibrinogen content of untapped hemothoraces rises from an initial

level of zero to a level higher than that in the blood after a week or so. Increase in pleural reaction with thickening from layered deposits of fibrin thus may result when blood is left within the pleural cavity.

This harmful effect of leaving blood in the pleural cavity is probably of greater importance in war wounds where other causes of inflammation are present within the pleural cavity (foreign bodies, traumatized tissue, low grade infection), in addition to blood. However, this effect emphasized the advisability of early and repeated aspirations of blood in the hemothorax of civilian injuries as well as military ones. If air is introduced the only result is an apical collapse and a more prolonged period of time before expansion of the lung can be obtained.

As a result of these facts it is now generally agreed among military surgeons[8, 9, 10, 11, 12, 13, 14] that a hemothorax is best managed *by early and repeated aspirations* in an effort to keep the pleural cavity dry and the lung fully expanded at all times. It has been our policy to withdraw all the blood that can be obtained beginning twenty-four hours after the injury (earlier if it causes respiratory embarrassment). The volume of blood removed is determined by the patient's reaction. A complaint of tightness in the chest is taken as an indication to stop the aspiration. From 500 to 1000 cc. can usually be removed at each thoracentesis. Aspirations are continued daily or every second day until the chest is dry and remains so.

Clotted Hemothorax or Chronic Fibrothorax.—In most cases blood in the pleural cavity, though it clots at first, quickly becomes liquid as it becomes defibrinated by the action of the lung and heart. In a small proportion of cases, about 5 per cent, either massive clotting of the blood occurs immediately, or a large accumulation of fibrin develops later which prevents its removal by aspiration. In the first instance, clotting of the hemothorax occurs immediately probably because of the sudden development of a massive hemothorax which completely collapses the lung and thus eliminates the defibrinating action of its motion (Fig. 454, *A*). In others, usually as a result of delayed aspiration, a time is reached about four or five weeks after injury when massive accumulations of fibrin and isolated pockets of serum develop within the pleural cavity which cannot be aspirated (Fig. 455, *A*). In this latter event, the fibrinogen introduced into the pleural cavity with the inflammatory exudate caused by the trauma and retained liquid blood causes a secondary clotting and deposition of additional fibrin over pleural surfaces. In either event the lung is crippled and held collapsed and the chest wall and diaphragm are immobilized by the dense fibrous scar which forms over parietal and visceral pleural surfaces.

In the case of a massive clotted hemothorax (Fig. 454, A) the thorax on the affected side is ballooned out at first and moves freely

with respiration. In the case of the chronic fibrothorax, which develops after four or five weeks, the affected side of the thorax is smaller and moves little or not at all on respiration. Intercostal spaces are nar-

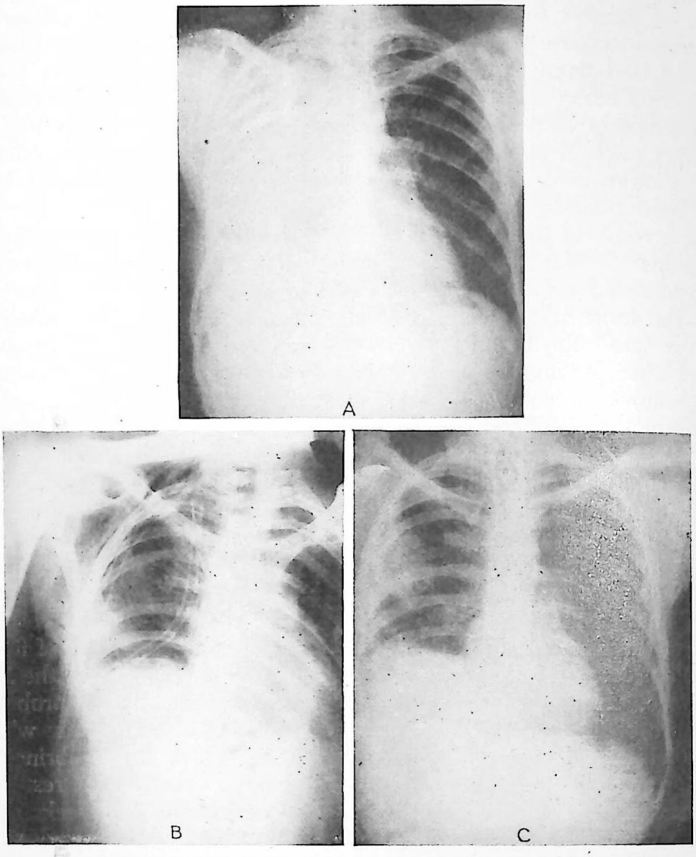

Fig. 454.—*A*, Massive clotted hemothorax in an infantry soldier which developed on the night of thoracotomy for perforating wound in a field hospital on the continent three weeks previously. *B*, Same patient on day of evacuation of the clot and decortication showing the three drainage tubes in place. *C*, Same patient three weeks after operation.

rowed and the trachea is sometimes deviated to the affected side (Fig. 455, A).

In the past these conditions have been poorly understood and usually badly managed because no one surgeon saw enough of them to formulate a policy for their management. One of the real contribu-

tions of military medicine[15, 16] has been the development of the concept that if infection in lung and pleural cavity is to be prevented and if the imprisoned and collapsed lung is to be reexpanded, this

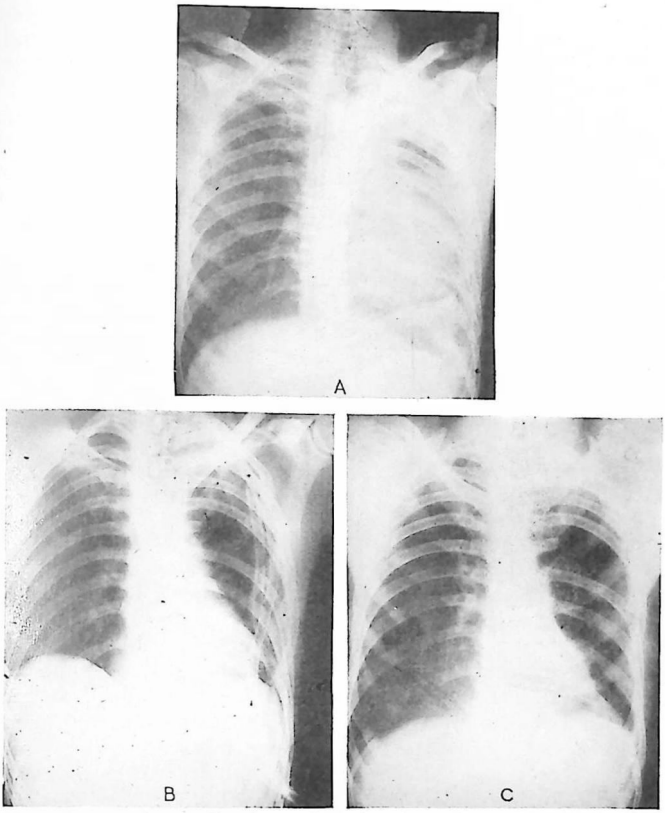

Fig. 455.—*A*, Chronic fibrothorax thirty-five days after multiple shell fragment wounds with unrecognized and untreated hemothorax. The apex of the lung is collapsed, the interspaces are narrowed, the diaphragm elevated and trachea and mediastinum are displaced toward the affected side. *B*, Same patient on day of decortication showing the three drainage tubes in place. *C*, Same patient twenty-five days after operation.

thickened scar which envelops the lung and coats the chest wall and diaphragm must be removed. The procedure is called *decortication*. It includes the removal of all clot, the careful dissection of the thickened pleural scar off the entire lung and the removal of the scar from

mediastinum, chest wall and diaphragm. The same procedure is used in cases of infected, clotted hemothorax or fibrothorax.[17]

The clot and fibrin usually occupy a posterolateral position in the pleural cavity and extend from diaphragm to apex, being widest at the base of the thoracic cavity. In order to obtain adequate exposure for their removal, a long segment of the sixth rib is resected through a posterolateral incision. On entering the pleural cavity, clotted blood and fibrin are removed manually. A line of cleavage is developed between visceral pleura and the fibrous scar which encases the lung. This scar tissue is usually 1 to 3 mm. in thickness. It is stripped off the lung by a combination of sharp and blunt dissection using care not to tear into the lung. The dissection frees the lobes and also portions of the lung margins which are often folded back upon themselves or telescoped into collapsed segments. The entire lung is freed. When this is done the anesthetist inflates the lung and the full and complete expansion of each lobe is demonstrated. The scar covering diaphragm and parietal pleura is usually at least twice as thick as that covering the lung. It can usually be peeled off the chest wall with the finger without difficulty. Its removal is important if full motion of the chest wall is to be attained. At the close of the operation the pleural cavity is irrigated with saline solution and 100,000 units of penicillin left in the pleural cavity.

It has been our uniform practice to drain the pleural cavity for forty-eight hours after operation. Since one of the main purposes of the operation is to attain full expansion of the lung and since this may be defeated by collections of blood or serum or by air which may leak from tears in the lung which are almost inevitable in the dissection of the pleural scar, we feel this drainage is imperative (Figs. 454, 455). We usually use three large tubes, with multiple openings, extending from apex to base and emerging just above the diaphragm. One is placed anteriorly, one laterally and one posteriorly. Each is attached to an underwater seal. If air escapes and negative pressure is not attained in each of these tubes an artificial source of negative pressure is attached to these tubes until the pleural leak is sealed. This has always occurred by the third day, in our experience.

The patient is permitted to leave his bed on the second postoperative day. Chest exercises to obtain full motion of the affected side of the thorax are begun immediately and rigorously continued throughout the remainder of the hospital stay.

PENETRATING WOUNDS

Penetrating wounds add to the conditions already discussed, the possibility of infection, retained foreign body, or open pneumothorax with possibly a sucking wound and mediastinal flutter.

of the penetrating wounds in civilian life (ice picks, "switch" small caliber missiles) will not require operative treatment. chanics of how a sucking wound produces asphyxia is well and the need to close it promptly is taught in all first aid Fortunately this condition is rarely seen in civilian practice. ound is large or sucking or if ribs are splintered, débridement hest wall with closure of the pleural cavity is necessary. Mili- erience has shown that irregular shell fragments larger than n diameter and indriven rib fragments should be removed, retention often leads to infection or hemorrhage. This can be done through the wound of entrance, unless the entrance gh the apex, in which case a thoracotomy at the site of elec- ndicated. In civilian practice smooth, small caliber bullets of an a centimeter in length can probably be left alone with nless they occupy a position close to a major vessel or s.

SUMMARY AND CONCLUSIONS

ating chest injuries in civilian practice rarely require opera- tment. The principal problems of nonmilitary thoracic injuries trauma of the lung, loss of stability of the chest wall, tension horax, hemothorax, or a combination of any or all of these

appraisal of the nature of these injuries and their progress ır to hour or day to day, frequent bedside x-rays of the chest ssary.

gnificance of lung trauma, "traumatic wet lung," as a cause atory embarrassment has been emphasized and its manage- rified by military experience.

er or bronchoscopic aspiration of blood and secretions from eobronchial tree is a valuable therapeutic adjunct in all types trauma if the patient has difficulty in eliminating these secre- nself.

management of hemothorax, military experience has empha- need for early and repeated aspirations of blood to keep the avity dry and the lung fully expanded at all times.

l hemothorax and chronic fibrothorax have been poorly un- and badly managed in the past. Military experience has ized an operative procedure and demonstrated its value in ses in which the lung is held collapsed and chest wall and m are immobilized by dense layers of scar tissue which have l down as a response to blood retained in the pleural cavity periods of time.

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PLASTIC SURGERY OF THE BREAST

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THE breast in disease is an object of the general surgeon's most serious concern. In contrast, the correction of various abnormalities and deformities of the breast, in the absence of neoplastic processes, is a more specialized field lying within the province of the plastic surgeon, who may relieve the patient of physical disability, discomfort and mental embarrassment. To allow a woman to make the best of hypertrophied breasts, that weigh as much as fifty pounds (Fig. 456), or lesser abnormalities which may alter her posture, impair her

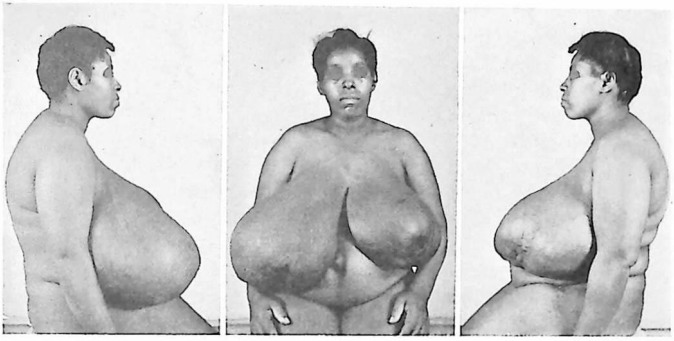

Fig. 456.—Massive gravid hypertrophy of the breasts in a Negress. Any movement was extremely laborious and awkward. Pain was intense and constant. An overhead traction apparatus was designed to relieve respiratory embarrassment. The right breast weighed 35 pounds (15.9 kg.); the left weighed 25 pounds (11.4 kg.).

attractiveness, limit her economic or social opportunity, or destroy her happiness, is not justifiable. The medical profession in general has not given full attention to the prevalence and attendant discomforts of the various non-neoplastic conditions of the breast, and many physicians are unaware of the safe and successful methods of repair which are available. This may be due, at least in part, to the appear-

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ance in the American literature until the past decade of few articles on plastic surgery of the breast. With the evolution of the various surgical procedures for mastopexy, reviewed by Thorek,[1] and the advances in various technics and principles, the operation has developed from simple removal of excess skin to complete reconstruction of the breast.

COMPARISON OF SURGICAL PROCEDURES FOR THE CORRECTION OF THE PENDULOUS BREAST

The two main *procedures of choice* for the correction of the pendulous hypertrophied breast, among the numerous technics applied from time to time, are generally considered to be (1) the transposition of the nipple and areola to an elevated position while still attached to the underlying breast, and (2) free transplantation of the detached nipple. In some instances, however, it may be impractical either to transpose or transplant the nipple, and as in the instance of the case to be described there is no alternative other than the construction of an artificial nipple—a *procedure of necessity.* Regardless of the method of repair utilized for the correction of the pendulous hypertrophic breast, the procedure should embrace the principles emphasized by Maliniak[2]: (1) preservation of the blood supply of the breast to prevent necrosis of any part; (2) avoidance of extensive injury to the ducts to preserve mammary function, if it is present; (3) firm fixation of the reconstructed breast in its new location to prevent recurrence of pendulousness; (4) minimization of scarring; and (5) reduction of all diameters of the breast proportionately to insure an esthetic end result. Since no single surgical procedure can be applied in all cases, these principles must be borne in mind in evaluating the procedures to be described.

Transposition of the Nipple Through a Buttonhole Incision.—Transposition of the nipple and areola while attached to the underlying breast to a higher position through a buttonhole incision was originally described by Morestin[3] and subsequently adopted with modifications by Dartigue,[4] Passot,[5] Maliniak[2] and Lamont.[6] A large flap is made on the anterior aspect of the breast, and all of the skin is removed from the posterior surface, permitting reduction and modeling of the breast in all directions. The nipple and areola are inserted into a buttonhole incision in the anterior flap, and the gland, around which a circular incision has been made, is firmly sutured to the pectoral fascia to prevent recurrence of ptosis. Scarring is minimized by suturing the flap into the submammary fold. When the operation is performed in one stage, there is great danger of necrosis. To avoid this serious complication, the authors believe that the two stage operation of Maliniak[2] or that of Lamont[6] is the *procedure of choice* since either may be used in the great majority of patients. Both

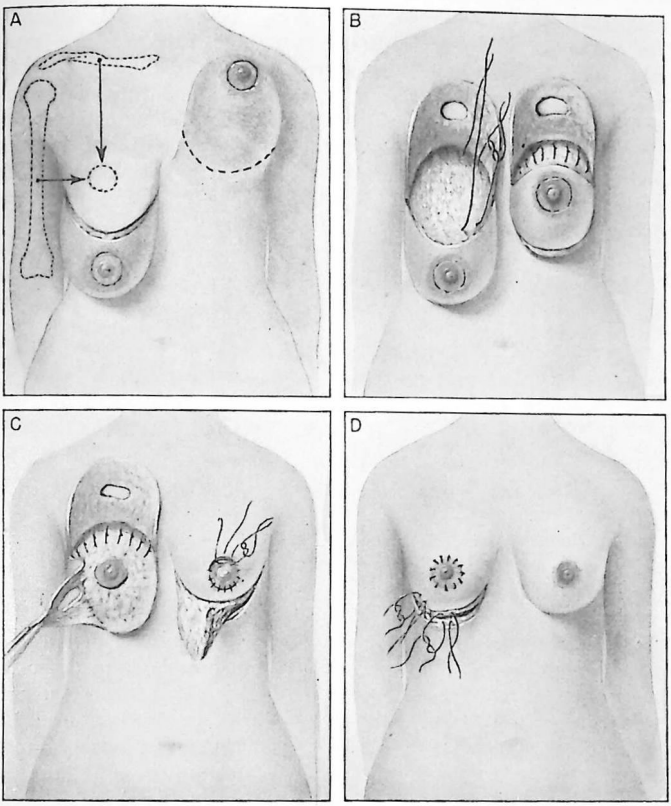

Fig. 457.—The Maliniak mammoplasty, a two-stage method for reconstructing pendulous hypertrophic breasts. *A*, A suitable position for the transposed nipple is determined with the patient in the erect position. A circular incision is made around the areola. A concave incision on the anterior surface of the breast extends from the lateral side of the submammary fold almost to the xiphoid process. *B*, A heavy skin flap is separated as far as the second rib. The breast is mobilized, and its upper portions are fixed to the pectoral fascia. The anterior flap is then brought down over the elevated breast, and if the predetermined position of the new nipple site is correct, a buttonhole is made here and into it the transported areola is sutured. *C*, The incision on the posterior aspect of the breast is made several centimeters above the submammary fold (*A*), the chief consideration being the avoidance of tension on the lines of suture. The second stage of the operation is performed several weeks later. The excess skin, fat and glandular tissue are removed through a crescent-shaped incision in the submammary fold (*C*, *D*).

methods allow for breast reconstruction with the desired symmetry, size, and shape.

The *Maliniak operation,* involving two stages of reconstruction, is based chiefly on the principle of the preservation of the blood supply in the prevention of necrosis. Maliniak abandoned the single-stage procedure because his patients developed areas of slough in the flaps due to circulatory insufficiency. Torsion of the pedicle is a factor in reducing the blood supply and can be avoided by taking suitable precautions against rotating the pedicle as the nipple and gland are transposed.

The first stage of the repair is limited to transposition of the partially diminished breast (Fig. 457). A suitable position for the transposed nipple is determined by the intersection of the horizontal line drawn halfway between the clavicle and the elbow and the vertical line through the middle of the clavicle (Fig. 457, *A*). This point, determined with the patient in an erect position, is marked with a suitable dye, such as a 5 per cent alcoholic solution of brilliant green. The center of the transposed nipple should never be higher than this point. At operation a sandbag is placed between the shoulders, and after aseptic preparation of the field, a circular incision is made around the areola, reducing it to approximately 4 cm. in diameter. A concave incision on the anterior surface of the breast extends from the lateral side of the submammary fold almost to the xiphoid process (Fig. 457, *A*). A heavy skin and subcutaneous flap is separated superiorly, extending as high as the second intercostal space. The breast is mobilized, and its upper portions are fixed to the pectoral fascia with heavy silk (Fig. 457, *B*). A buttonhole is made, about 1 cm. smaller in size than the originally circumscribed areola, at or below the predetermined point, and into it the areola is sutured. The position of the incision on the posterior surface of the breast is determined in each case by the size of the transposed organ, the chief consideration being the avoidance of tension on the lines of suture (Fig. 457, *A*). As a rule, this incision is placed several centimeters above the submammary fold. Any reduction of the gland at the first operation is limited to the lower pole. The main branches of the lateral thoracic and the internal mammary arteries are not disturbed. The external angle of the incision is drained.

The second stage is carried out from four to six weeks later, when the nipple has "taken" in its new location. The excess skin, fat and glandular tissue are removed through a crescent-shaped incision in the submammary fold (Fig. 457, *C, D*). Maliniak[2] states that when the correction is bilateral, this procedure does not lengthen the surgical period. In the one-stage operation, the corrections are usually performed separately on each breast, thus requiring two surgical procedures for completion. If one performs the first stage of the

operation on each breast at the same time, the repair on both breasts is finished together, and the total time required is the same as with the one-stage method (Fig. 458).

The *Lamont mastopexy,* though differing in the details of technic from the operation of Maliniak, is likewise designed to allow maintenance of the circulation. The proposed lines of incision, which are similar to those described, are marked out the day before operation.

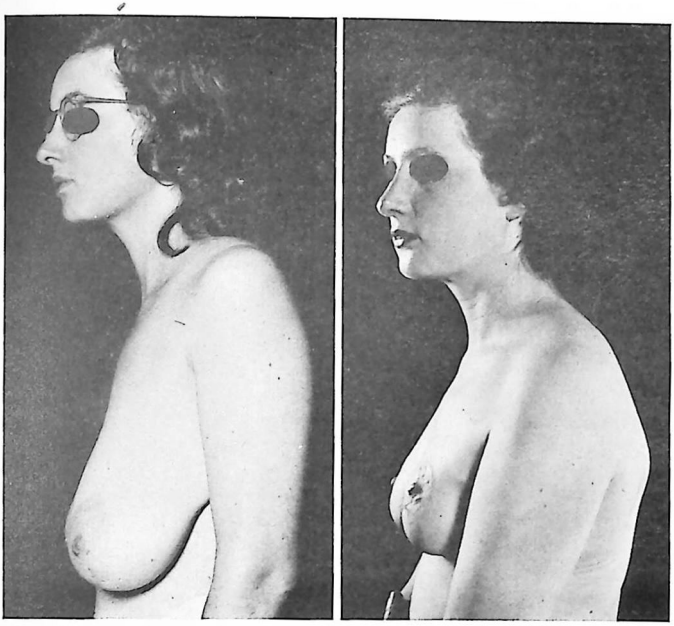

Fig. 458.—Virginal hypertrophy. The enlarged breasts caused pain, physical disability, and embarrassment. The two-stage Maliniak operation was used to reconstruct the breasts. All diameters of the breasts were proportionately reduced to obtain the esthetic result. The scars are located in the inframammary folds. The nipples have normal erectile power.

The patient is placed on the table in semi-Fowler position with the arms akimbo. A circular incision is made around the areola and from it another is made perpendicularly upward to the new nipple site (Fig. 459 *A*). The skin of the breast is undermined in a thick flap. The breast, denuded of skin and with its nipple and areola attached, is pushed up to the desired position on the chest. This allows the operator an opportunity to evaluate the amount and area of breast tissue to be removed. Either two or three triangular wedges of tissue

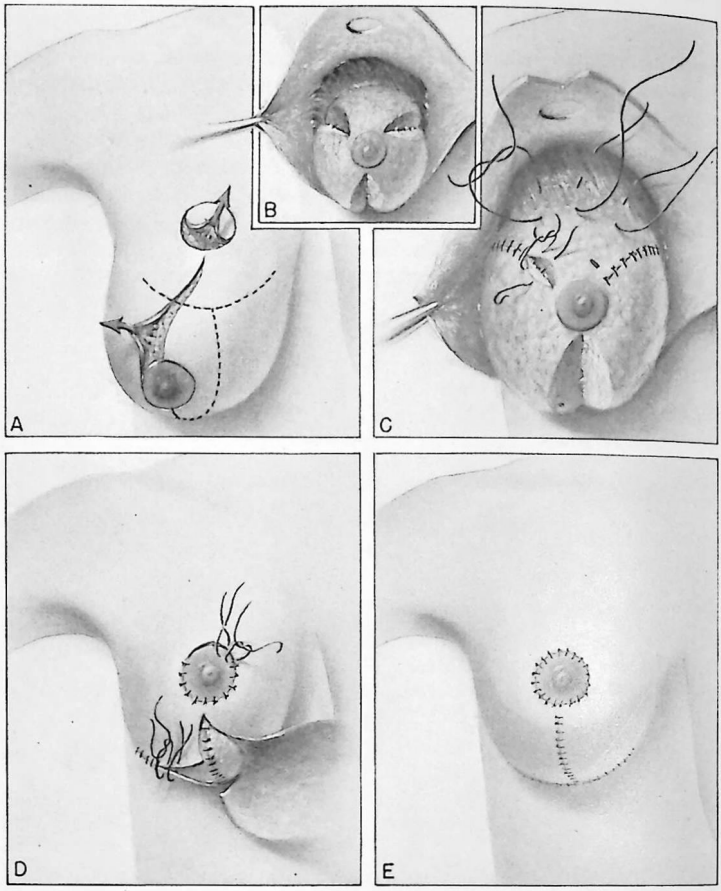

Fig. 459.—The Lamont mastopexy. A suitable position for the transposed nipple and the proposed lines of incision are marked out the day prior to operation. *A*, A circular incision is made around the areola and from it another is made perpendicularly upward to the new nipple site. The posterior incision begins at the inferior margin of the areola and extends downward to just above the inframammary fold, where it extends in either direction in the form of an inverted T. The skin of the breast is undermined in a thick flap. Depending on the amount of breast tissue to be removed, two or three triangular wedges of tissue extending down to the pectoral fascia are resected (*B*). The breast, now reduced in size, is elevated to the desired position and fixed to the pectoral fascia using heavy silk sutures (*C*). A circular or oval button of skin, previously marked, is removed to serve as the new location of the nipple, and into it the areola is sutured (*C*). The skin flaps are so cut as to adjust themselves to the new size, contour and position of the breast (*D*). In instances of very large breasts or where revision is necessary, the second stage of the reconstruction is performed several weeks later by reopening or excising the inframammary incision and making an incision from its center upward to form an inverted T (*D*). Depending upon the amount of breast to be removed, additional wedges or a crescent are resected. The flaps are trimmed and sutured without tension (*E*).

extending down to the pectoral fascia are resected. These wounds are closed with interrupted sutures of silk (Fig. 459, *B*). Three heavy silk sutures are inserted through the pectoral fascia over the second rib and carried through the upper poles of the breast, fixing the breast in its new position (Fig. 459, *C*).

A circular button of skin, previously marked, is removed to serve as the new location of the nipple which is sutured at the periphery (Fig. 459, *D*). The skin flaps on either side are brought around the breast,

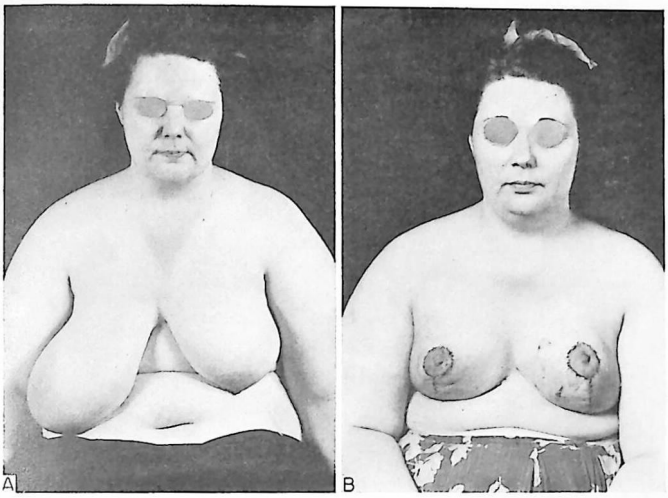

Fig. 460.—*A*, Asymmetrical pendulous adipose breasts. The Lamont operation was used to reconstruct both breasts. The first dressing was performed on the fifth postoperative day at which time the drains and every other black silk suture were removed. *B*, Appearance of the patient on the tenth postoperative day prior to removing the remaining sutures. The horizontal lines of the inverted T incision are concealed in the submammary fold.

meeting in the center where the excess is excised. Interrupted sutures of silk are used for the closure. A drain is inserted beneath the flaps.

In instances of very large breasts or where revision is necessary, Lamont performs the second stage of the reconstruction several weeks later by reopening the inframammary incision and making an incision from its center upward to the outer edge of the nipple to form an inverted T (Fig. 459, *E*). Heavy skin and subcutaneous tissue flaps are reflected, and, depending upon the amount of breast to be removed, additional wedges or a crescent are resected from the inframammary region. The flaps are trimmed and resutured without tension (Fig. 460).

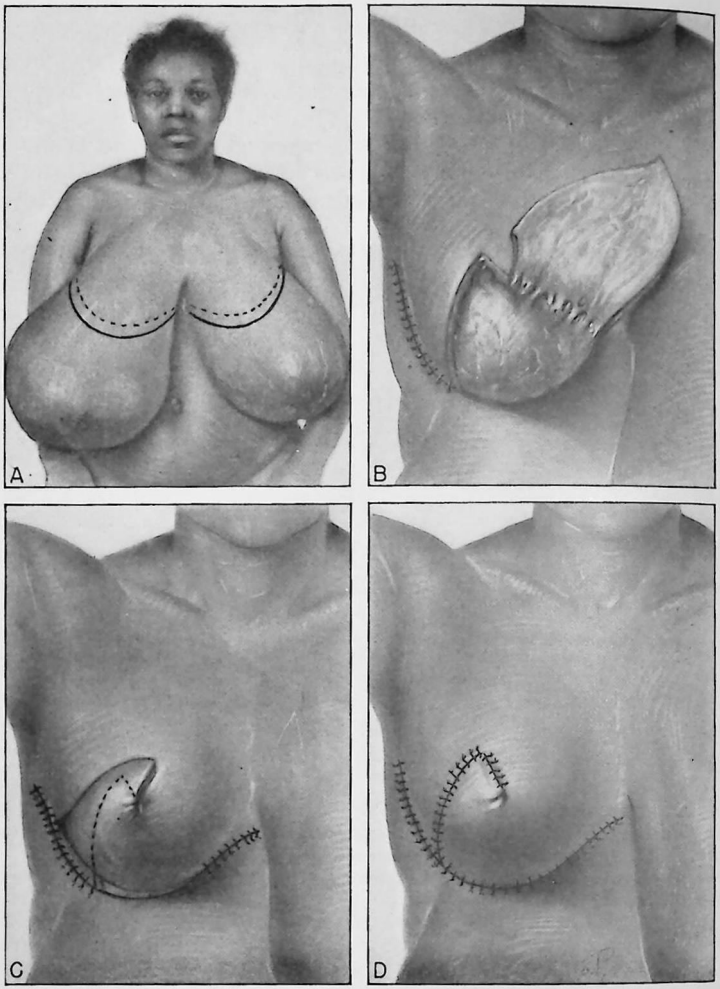

Fig. 461.—Right mammoplasty: subtotal amputation of the breast with construction of an artificial nipple. *A*, A crescent-shaped incision was made anteriorly over the right breast from the axilla to the xiphoid process. A heavy skin flap was mobilized superiorly as far as the clavicle. With the breast lifted upward, a second crescent-shaped incision was made several centimeters above the submammary fold. Subtotal amputation of the breast was performed, removing all of the tissue between the two incisions. The small amount of breast which remained was advanced upward and fixed to the pectoral fascia over the second and third ribs using braided silk sutures. Because of the leather-like texture of the nipple, it was not advisable to use it as a free graft. To create the illusion of the presence of a

Free Transplant of the Nipple; Construction of an Artificial Nipple.—This operation, first described by Thorek,[1] has been used also by Updegraff[7] and Adams[8] in cases of marked hypertrophy. The writers have avoided use of this procedure through fear of necrosis due to the unsuitable character of the transplant advocated[8] which, to provide a suitable effect, should involve the nipple, areola and muscular tissue. For this reason, the authors do not regard the procedure as one of choice but as one of necessity. In some instances, satisfactory results in the treatment of massive hypertrophy of the breasts can be attained only by subtotal excision of the enlarged organ and construction of an artificial nipple. An illustration of this is given in the following case report.

CASE REPORT.—*Subtotal Removal of Breasts Weighing 54 Pounds (24.5 Kg.).*—A 22 year old married Negro woman was admitted to the Obstetrical Service of the Duke Hospital March 6, 1945, at which time she was eight and one-half months pregnant. She had experienced five previous pregnancies, each of which terminated in a normal full-term delivery. The first child was born January 2, 1936. The first four infants were breast-fed for periods ranging from three to twelve months. The last child was born May 6, 1943, and after several weeks was placed on a bottle because of "convenience."

The present pregnancy began in July, 1945, at which time the patient's breasts were about the "size of a grapefruit or a small head of cabbage." Although there was some increase in size associated with the progression of the pregnancy, the breasts did not begin to increase rapidly in size until she had reached the seventh month. Within three to four weeks they then reached tremendous proportions sufficient to incapacitate the patient almost completely and to necessitate hospitalization. An overhead suspension apparatus was designed to relieve the patient of the great weight. Pregnancy terminated in a normal delivery on March 22, 1945. Attempts to aspirate the breasts on several occasions during the following week yielded only 12 to 15 cc. of milk. The patient was fitted with a home-made breast support and allowed to leave the hospital March 29, 1945. Detailed contraceptive instructions were given.

An endocrine survey during the patient's hospitalization disclosed no abnormalities. It was the opinion of most observers that the breasts would regress in size during the postpartum period, but that, if this did not occur, plastic reconstruction of the breasts should be performed within six months. The patient did not return until December 12, 1945, when she again was about five months pregnant. Her breasts were now even larger than on her previous admission (Fig.

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nipple and to obtain the desired contour in reconstruction, a vertical incision was made in the anterior skin flap up to the approximate position of the constructed nipple (*B*). The incision in the submammary fold was then closed, using interrupted sutures of silk placed obliquely so that the lateral flap was drawn medially and the medial flap laterally when the sutures were tied (*C*). The vertical limb was closed next. A "dog ear" to simulate a nipple and areola was then formed by making a small incision obliquely downward (*D*). Since this skin is loose, the pigmentation is deeper and the illusion is quite effective. The specimen weighed 32 pounds (14.5 kg.). The incision healed per primam.

Three weeks later a similar procedure was performed on the left breast. The specimen weighed 22 pounds (10 kg.).

456). Inasmuch as the breasts were already of great size, and movement was laborious and awkward, operation was decided upon despite the realization that miscarriage would follow.

Operation: Mammoplasty, right breast. Weight of specimen 32 pounds (14.5 Kg.).—On December 17, 1945, with the patient anesthetized with cyclopropane and ether, a subtotal excision of the right breast was performed and followed by plastic reconstruction of the part that remained. Ice tongs were used to lift the breasts at operation.

A low crescent-shaped incision was made anteriorly over the right breast from the anterior axillary fold to the xiphoid process (Fig. 461, *A*). The vessels in the subcutaneous tissues were markedly enlarged. The anterior skin flap was then dissected superiorly as far as the clavicle. With the breast lifted upward and forward, a second crescent-shaped incision was made about 3 cm. above the submammary fold. A subtotal excision of the breast was performed as rapidly as pos-

Fig. 462.—Postoperative photographs taken about seven weeks following subtotal amputation and reconstruction of the right breast, and about two weeks following the same operation on the left breast (compare with Fig. 456). The artificial nipple and areola on the left side are high as compared with the location on the right. This was due to an error in judgment, which could easily be corrected. The patient, however, is so pleased with the result that she does not desire any further operations.

sible. On section, there were many large lobules of hyperplastic tissue, many of which measured 8 cm. in diameter. The adipose tissue was scanty and occupied only the spaces between the hyperplastic lobules. Large quantities of clear straw-colored fluid escaped as the breast tissue was sectioned. The specimen weighed 32 pounds (14.5 Kg.).

Because of the thick leather-like texture of the nipple, it was not advisable to transpose or use it as a free graft. To create the illusion of the presence of a nipple and to obtain the desired contour in the reconstruction, the following steps were carried out. That small amount of breast which remained attached to the chest wall was advanced upward and anchored to the pectoral fascia over the second and third ribs with several braided silk sutures. The remaining gland was trimmed to a mound about the size of two clenched fists. The skin flap was then brought downward and an indelible mark was made for the approximate position of the constructed nipple. After the skin flap was incised up to this point (Fig.

461, *B*), the flaps were brought toward each other, overlapped, and the redundant parts removed. The horizontal incision just above the mammary fold was closed first, using interrupted sutures of silk placed obliquely so that the lateral flap was drawn medially and the medial flap laterally when the sutures were tied (Fig. 461, *C*). The vertical limb of the incision was closed next with the same suture materials. A "dog ear" to simulate a nipple and areola was then formed by making a small incision obliquely downward (Fig. 461, *D*). Since this skin was loose, the pigmentation was deeper and the illusion quite effective.

Histologic sections showed an "extreme degree of adenomatous hyperplasia." The incisions healed per primam, and the patient was discharged on the sixteenth postoperative day. The fetal heart could not be heard at this time, although the patient thought she experienced fetal movements.

Operation: Mammoplasty, left breast. Weight of specimen 22 pounds (10 Kg.). —The patient returned in about three weeks for the operation on the left breast, and on January 24, 1946, a mammoplasty using cyclopropane as the anesthetic agent was performed. The specimen weighed 22 pounds (10 Kg.). The same type of operation was performed as upon the previous occasion. Two days later, a macerated fetus was extruded. The operative incisions healed per primam and the patient was discharged on the seventeenth postoperative day, February 10, 1946. Photographs taken several days before discharge (Fig. 462) show the left artificial nipple and areola high as compared with the location on the opposite side. This was due to an error in judgment, and although the patient writes that it has descended to a more normal position, she is so pleased with the present result that she does not desire any further operative procedures.

VIRGINAL AND GRAVID HYPERTROPHY

While the majority of cases of virginal hypertrophy (Fig. 458) have their onset during adolescence, a similar condition may also occur during pregnancy (Fig. 456). Virginal hypertrophy must be distinguished from adipose breasts (Fig. 460). Enlargement of the breasts due to deposition of fat may occur in cases of pituitary disturbance, where there is an increase of fat about the hips and in the mammary glands, but the excessive growth seen in virginal hypertrophy does not occur.

"Because the end-organ rather than the hormonal functions is at fault in virginal and gravid hypertrophy, endocrine therapy is unsuccessful."[9] Surgery, therefore, is the only other alternative.

COMMENT

Benign and malignant breast tumors have at least one feature in common: they are formed by abnormal and purposeless multiplication of cells previously derived from normal cells. Benign tumors resemble closely the tissue from which they originate. The cells are arranged in a relatively orderly fashion, and although the tumor may attain great size, it rarely jeopardizes the life of the host except by interference with vital functions by pressure. In contrast, however, malignant neoplasms consist of abnormal cells which may tend to approach the undifferentiated embryonic type. They are not orderly in growth but

invade and destroy adjacent tissues or metastasize to different parts of the body, and finally lead to the death of the patient.

Massive hypertrophied breasts are in most instances comparable to benign tumors and should be considered and treated as such. The increased size may be due to enormous deposits of fat, or to marked proliferation, hyperplasia and hypertrophy of the breast tissue proper (Figs. 456, 458, 460). Massive breasts not only incapacitate the bearer but are conspicuous and unsightly. The breasts cause self-consciousness in the bearer, are a source of pain and discomfort, and may cause scoliosis, kyphosis or lordosis. The excessive perspiration is unpleasant, and the patients avoid society, become depressed and morose, and an ensuing psychosis may develop.

The indication for surgical removal or correction of hypertrophied breasts is just as real and as fully justifiable, especially in young women, as the indication for many ordinary or well recognized surgical procedures, such as the correction of gynecomastia in the male, or the reduction in size of an elephantoid extremity due to lymphatic obstruction. Thorek[1] has stated that "the average woman regards grace and beauty of form as one of the essentials of life. The fact that thousands of young and middle aged women adopt reducing diets in order to preserve or restore slimness of figure is proof in point." Rather than simply to amputate such breasts, it is much better to remove them in a manner that leaves a pleasing instead of an ugly appearance at their site, if this can be accomplished without increase in the risk. Surgical correction of enlarged breasts is indicated when the hypertrophy leads to a disfiguring or disabling deformity and when there is a reasonable probability that the operation will restore the affected parts approximately to normal without undue danger to the patient. The operation is designed to restore physical as well as psychological balance, and, properly executed, it will accomplish these objectives.

CONCLUSIONS

Markedly hypertrophied breasts are, in many instances, comparable to benign tumors. Plastic surgical correction is indicated when the hypertrophy leads to a disfiguring or a disabling deformity. Three methods of reconstructing pendulous hypertrophic breasts are presented.

The suppression of mammary function is not a contraindication for reconstruction, as normal function is rarely present in the pendulous hypertrophic breast.

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COMPLICATIONS OF THORACOTOMY OBSERVED DURING OPERATIONS UPON THE SYMPATHETIC AND VAGUS NERVES

KEITH S. GRIMSON, M.D., F.A.C.S.*

THORACOTOMY was considered a hazardous procedure during the early years of development of modern surgery. It was usually employed only for treatment of empyema or of penetrating wounds of the thorax. Increasing knowledge concerning the physiology of respiration and circulation, and concerning aseptic surgical technic, anesthesia and chemotherapy has gradually decreased the risk of thoracotomy. Structures within the chest are being approached with increasing safety.

There are several examples of the development of the use of thoracotomy. Difficulties encountered during early operations on thoracic portions of the esophagus were studied by Sauerbruch[1] in 1905. They were gradually overcome and Torek[2] in 1913 reported the first resection of the thoracic esophagus. Graham and Singer[3] reported the first successful pneumonectomy in 1933. Surgery directed toward the formation of extra coronary blood supply for the heart was begun in 1935 by Beck.[4] Rienhoff[5] in 1938 reported resection of the pulmonary plexus for asthma. The larger arteries in the thorax have been successfully approached for aneurysm by Alexander and Byron,[6] for malformations of the heart, particularly pulmonary stenosis, by Blalock,[7] and for coarctation of the aorta by Gross.[8]

These and other operations demonstrate the prevalent opinion that a transthoracic approach to the thoracic viscera is relatively safe.

The operations described above are associated with a possibility of direct contamination from the esophagus or the lung, or of complications related to major changes of respiration and circulation. The complications or the risk that might be associated with thoracotomy itself are therefore not easily determined.

Transthoracic sympathectomy for hypertension (Grimson[9]) and transthoracic vagotomy for peptic ulcer (Dragstedt[10]) are two operative procedures in which the chance of complications related directly to thoracotomy might better be evaluated since unrelated complications are less likely. This report deals with the use of these two operative procedures and particularly with a study of complications observed that seem to be related directly to thoracotomy.

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TOTAL THORACIC AND PARTIAL TO TOTAL LUMBAR SYMPATHECTOMY AND CELIAC GANGLIONECTOMY IN THE TREATMENT OF HYPERTENSION

Complete removal of the two paravertebral sympathetic chains and the splanchnic nerves of cats was first described in 1929 by Cannon and his associates.[11] They used two transthoracic operations to remove the thoracic sympathetic nerves, and a transabdominal approach for the lumbar chains. Experimental evidence obtained from the use of this total sympathectomy in normal dogs and in dogs with experimental hypertension[12,13] led in 1940 to the use of the two transthoracic stages and occasionally also the abdominal stage for sympathectomy of patients with hypertension.[9] The rationale for the use of this operation has recently been reviewed.[14,15]

Fifty-six patients have been treated by total thoracic and partial to total lumbar sympathectomy, splanchnicectomy, and celiac ganglionectomy. The thoracic operations are carried out in two stages at intervals of two to four weeks. The operative technic for transthoracic sympathectomy will be presented in some detail to aid evaluation of the complications of thoracotomy that will be discussed.

Operative Technic.—The operation is performed with the patient anesthetized by ethylene and ether administered through a closed system with moderate positive pressure. Intravenous saline and blood are given routinely. The operation is begun by an incision over the third rib at right angles to the midaxillary line. This is deepened to permit removal of 4 or 5 inches of the rib. The adjacent intercostal nerve is resected and the chest is opened by dividing the periosteum and pleura of the rib bed. The lung is retracted and the upper posterior wall of the thorax is exposed. The pleura overlying the paravertebral sympathetic chain and the upper seven or eight sympathetic ganglia is then divided. The stellate ganglion and the chain down to and including the seventh or eighth thoracic ganglia and also the upper branches of the splanchnic nerve are freed by dissection. The bed of the third rib is closed by a continuous double suture of No. 0 chromic catgut and reinforced by interrupted sutures approximating the divided muscles of the chest wall. Stay sutures between ribs are not employed. A second similar incision is then used to resect 7 inches of the tenth rib and expose the lower posterior wall of the thorax. The sympathetic chain and the splanchnic nerves that were freed through the upper incision are picked up and dissected down to the level of the diaphragm. The fibers of the diaphragm about the splanchnic nerve are split. Traction on the splanchnic nerve brings the major portion of the celiac ganglion through the diaphragm for resection. The posterior attachment or reflection of the diaphragm is partially divided transversely and the diaphragm is retracted downward and inverted. The thoracic paravertebral sympathetic chain is

then picked up and dissected downward to locate and remove the first or the first and second lumbar ganglia. After the sympathetic nerves and ganglia are removed a No. 32 Pezzer catheter is usually placed through a stab wound in the midaxillary line between the eighth and ninth ribs for sterile chest drainage. The defect in the pleura of the

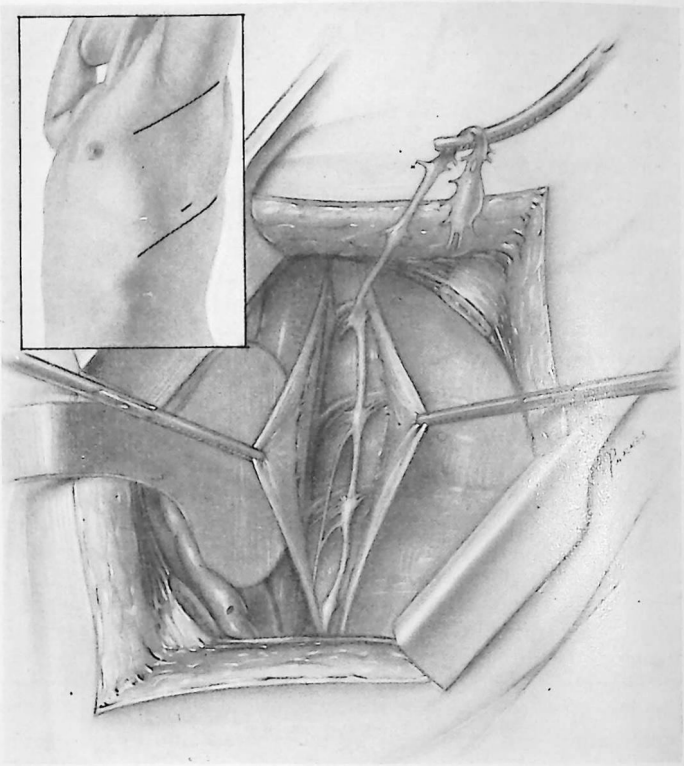

Fig. 463.—Thoracotomy through the bed of the third rib for removal of the stellate and upper thoracic sympathetic chain and ganglia is illustrated. The inset shows the location of the incision and also the location of a second incision over the tenth rib used to enter the lower thorax. The stab wound for continuous sterile chest drainage is located just above the lower incision.

posterior chest wall cannot be repaired. The incision in the chest wall is finally closed using fine chromic catgut. The operation is illustrated in Figs. 463 and 464.

After operation the Pezzer catheter when employed is attached to a sterile chest suction apparatus (Fig. 465). The catheter is removed

on the third or fourth day after operation. Intranasal oxygen is usually used for twenty-four to forty-eight hours. The patients are routinely turned each hour for forty-eight hours.

One hundred and eleven thoracotomies for this type of sympathectomy were performed on fifty-six patients with hypertension. The

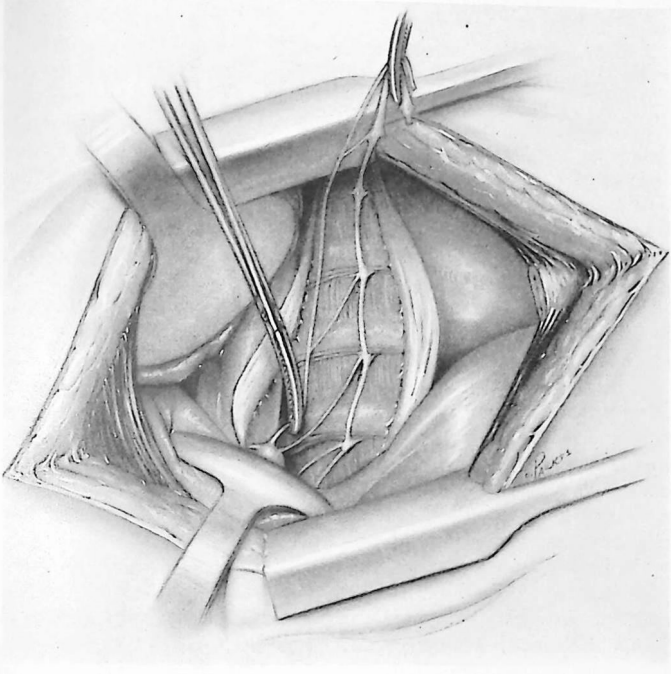

Fig. 464.—The exposure of the sympathetic chain, splanchnic nerve, and celiac ganglia obtained by thoracotomy through the bed of the tenth rib is illustrated. This exposure is used for the lower part of the operation for total thoracic and partial to total lumbar sympathectomy and celiac ganglionectomy illustrated in Figure 463. It is also used for those patients in whom splanchnicectomy alone is elected.

patients and the complications that developed will be presented in two groups. The first group includes nineteen patients who were treated at the University of Chicago between May 1940 and June 1942. These nineteen will be discussed briefly since their hospital records are not now available for detailed study. Their care differed from the later group in that ultraviolet bactericidal radiation was not

used in the operating room and chemotherapy employing only sulfanilamide or sulfathiazole was less frequently employed after operation. Intratracheal intubation was not employed during anesthesia.

There were three deaths during the period of hospitalization for operation. One followed a uremia and pneumonia that developed two weeks after the first stage of the sympathectomy. Death occurred five

Fig. 465.—The sterile gravity suction apparatus employed during the first several days after thoracotomy to minimize complications from pleural effusion is illustrated.

weeks later. Two followed a sudden arrest of respiration that occurred on the third and the fifth day respectively after the second stage. Both of these deaths occurred in patients who had had repeated episodes of hypertensive encephalopathy and also two or more cerebral vascular accidents. Autopsy revealed minimal pulmonary pathologic change. Each brain demonstrated evidence of increased intracranial

pressure and of advanced atheromatous obstructive vascular disease of the arteries of the circle of Willis. It seems probable that these two deaths from abrupt failure of respiration were caused by the lowered blood pressure and the increased intracranial pressure with resulting ischemia of the respiratory center. The three operative deaths among these first nineteen patients seem to be related directly to the hypertensive disease process and the sympathectomy and not to the thoracotomy.

Continuous sterile chest drainage was used in all but two of these nineteen patients. Serious complications related to the use of the drains did not occur.

Complications that are evidently related to the thoracotomy did occur. Superficial wound infections developed in four patients. A localized empyema developed beneath the third rib bed in one. It required secondary open drainage. Bronchitis with tenacious mucus and severe dyspnea occurred in five. This precipitated cardiac failure and acute pulmonary edema in one. Varying degrees of pleural effusion occurred in all patients. Elevation of temperature developed in many and lasted from several days to two weeks.

The second group of the fifty-six patients who were treated by total thoracic and partial to total lumbar sympathectomy and celiac ganglionectomy consists of thirty-seven treated in Duke Hospital since June 1942. The anesthetic and the technic of operation have not been altered. Bactericidal ultraviolet radiation as described by Hart[16,17] was used in the operating room during each operation. Intratracheal intubation was employed during anesthesia for the first operation in three patients, for the second in five, and for both operations in one. Intravenous saline or glucose and also blood were given during each operation. As the sympathectomy progressed, blood pressures were lowered. The reduction reached shock levels in two patients during the first operation and in twenty-six during the second sympathectomy. In each instance the sympathectomy was discontinued for ten to thirty minutes to permit recovery and stabilization of pressure and then completed.

Penicillin was employed prophylactically or therapeutically in seventeen patients during the first several days after each operation. Sulfamerazine, sulfathiazole or sulfadiazine was given to ten patients along with penicillin and to five who did not receive penicillin. Fifteen patients did not receive penicillin or chemotherapy. The interval between the thoracotomies ranged from fourteen to seventy-two days and averaged twenty-four days.

Continuous sterile chest drainage was employed after each operation in all but two of the seventy-four thoracotomies in these thirty-seven patients. There were no complications or significant observations related to use of the drains in sixty-six thoracotomies or twenty-

nine patients. The amount of drainage ranged from 100 cc. to 600 cc. and the amount for each operation was usually around 300 cc. Significant developments occurred with the drainage of one or the other side of the chest in eight patients. One bled during the first twelve hours. The drain removed 750 cc. of blood. Transfusion of an equivalent amount was given intravenously and recovery was then uneventful. In five the drain became blocked by a fibrin-like plug. When it was removed on the third or fourth day between 200 and 700 cc. of serous fluid leaked out through the stab wound. Sterile dressings were applied and the patients were turned upon that side of the chest. Drainage ceased after several hours. Pneumothorax or infection of the pleural cavity did not occur. In the remaining two patients the drain was omitted during the first operation. Effusion occurred in each requiring several thoracenteses with aspiration of totals of 1400 cc. and 2185 cc. respectively. Because of persistent effusion in one patient the second operation was delayed seventy-two days. Drains were used after the second operation in these two patients. Amounts of 400 and 1200 cc. respectively were obtained during the first three days. There was then no recurrence or persistence of effusion.

There was one operative mortality among the thirty-seven patients. This resulted from a coronary occlusion four days after the second operation. At autopsy the chest drain was sealed by adhesions, with no free fluid in the pleural cavity of the side of the last sympathectomy. It is of interest that effusion had occurred in the pleural cavity on the side of the original operation. This effusion measured 400 cc.

The clinical course of the thirty-seven patients has indicated that the response to thoracotomy under the conditions described above has varied. The procedure was well tolerated in twenty-eight as evidenced by a maximum temperature that was less than 101° F., and a maximum rate of respiration of less than 30 per minute. Twenty-four of these patients had a maximum pulse rate that was less than 110 per minute. The remaining four demonstrated a pulse rate somewhat above normal before operation and little increase of rate after it.

Thoracotomy was less well tolerated in nine patients as judged arbitrarily by temperatures over 101° F., or rates of respiration over 30 per minute, or rates of pulse over 110 per minute. The temperature ranged from 101° to 103.2° F., the pulse from 110 to 134, and the respiration from 30 to 40. The averages were respectively: temperature 101.7° F., pulse 122.7, and respiration 34.2. The elevations lasted one to ten days, with an average of five. The major cause of the elevation of temperature seemed to be residual pleural effusion in six patients, an asthma-like respiratory disorder in one, a chill in one, and the coronary thrombosis that ended fatally in one.

In addition, one of the thirty-seven patients developed a super-

ficial wound infection and another a wound hematoma that became secondarily infected. There were no infections of the pleural cavity. Examination by x-ray between and after operations revealed some degree of clouding of the costophrenic angle and adherence of the diaphragm in all patients. Clinically recognizable pneumonia did not occur. Pleural effusion sufficient to cause some shift of the mediastinum occurred in three. Atelectasis with shift of the mediastinum occurred in one. Three patients developed bronchitis with accumulation of tenacious mucus. This was treated by suction through a Levin tube passed through the nose into the trachea. Abdominal distention gave minor difficulty on five occasions.

Each of these patients complained of severe pain on the side of the operation. This pain was referred along either incision to the midline in front and often to the upper abdomen. It usually reached its maximum intensity about a week after operation and then gradually disappeared over several weeks. Occasionally it persisted in a moderate degree for several months to a year.

SPLANCHNICECTOMY WITH RESECTION OF THE LOWER THORACIC AND UPPER LUMBAR SYMPATHETIC GANGLIA, THE SPLANCHNIC NERVES AND FREQUENTLY THE CELIAC GANGLION

During the last two years thoracotomy has been adopted for splanchnicectomy in those patients with hypertension in whom this partial sympathectomy seemed indicated. It has been used in preference to the retropleural and retroperitoneal posterior or lumbar approach described by Smithwick[18] that had been used earlier. This affords an opportunity to study the complications of thoracotomy as employed for a less extensive sympathectomy than that described above and also to compare the complications with those of the retropleural operation of Smithwick. The transthoracic operation is performed through the bed of the tenth rib. The technic does not differ from that described above for the second or lower incision of the total thoracic and partial to total lumbar sympathectomy, splanchnicectomy and celiac ganglionectomy (Fig. 464). Sterile chest drainage through a Pezzer catheter, however, arbitrarily has not been employed. Splanchnicectomy has been performed upon nine patients by this lateral transthoracic approach and upon sixteen by the Smithwick posterior lumbar approach.

Splanchnicectomy by Thoracotomy.—There were two deaths among the nine patients. One occurred in a young man with advanced hypertensive encephalopathy. He had been treated in the hospital for four months by medical means and by craniotomy and cerebral decompression without improvement. Sudden arrest of respiration from relatively increased intracranial pressure occurred immediately after the first operation. The other death occurred in a patient who also

had advanced encephalopathy resistant to medical management. It occurred nine days after the first operation with evidences of increased intracranial pressure and a cerebral vascular accident. These deaths are related to the disease and the sympathectomy rather than to the thoracotomy. Of the remaining seven patients thoracotomy was well tolerated in three as judged by a maximum elevation of temperature to less than 101° F. The remaining four developed an elevation of temperature over 101° F. Two of these developed an elevation of pulse over 110. The rate of respiration did not exceed 30 in any patient. The interval between operations ranged from thirteen to twenty-three days, with an average of eighteen. X-ray studies of the seven patients demonstrated moderate clouding of the costophrenic angle in six and fluid sufficient to produce shift of the mediastinum in one.

Infections of the pleural cavity or of the superficial wounds did not occur. There was no clinically recognizable pneumonia. Two patients developed mucus in the trachea and cough. Four patients were given penicillin. Intratracheal intubation was employed during operations in two patients. Blood pressure was not reduced to shock levels in any patient. Abdominal distention occurred in three. Each patient complained of pain in the chest wall or upper abdomen.

Splanchnicectomy by Lumbodorsal Approach.—Sixteen patients were operated upon through the posterior hockey-shaped incision described by Smithwick.[18] After dissecting free and retracting the heavy lumbar muscles the twelfth rib was resected and the diaphragm was detached. The sympathetic and splanchnic nerves were removed from beneath the pleura and the peritoneum. In one-half of the patients the celiac ganglia were also removed. Small openings into the pleura developed during five operations. The course of these five patients did not differ from the others. Ethylene-ether anesthesia and bactericidal radiation were used during each operation and blood and intravenous fluids were routinely administered. Intratracheal intubation was employed for anesthesia in seven patients. The two stages were performed at intervals of ten to twenty-eight days, the average being seventeen days. Reduction of blood pressure to shock levels occurred in six patients during the second stage of the sympathectomy.

One patient died two weeks after the first operation with uremia. The reactions of the remaining fifteen will be described. Seven tolerated operation favorably as judged by a maximum temperature of less than 101° F. Eight developed temperatures over 101° F. that lasted three to fourteen days. Of these eight, three developed a rate of respiration over 30 per minute. Nine of the fifteen patients developed tachycardia of more than 110. Penicillin or chemotherapy was employed in eight patients.

Two wounds disrupted and became secondarily infected. A hemat-

oma occurred in another that also developed infection. X-rays after operation revealed pleural effusion in all patients. This was sufficient to produce a shift of the mediastinum in one. Three patients developed pneumonia. Two others developed bronchitis and severe cough. All of the patients also complained of pain in the lower chest, in the abdomen, and occasionally around the iliac crest. Abdominal distention occurred in five.

TRANSTHORACIC VAGOTOMY

The operations described above have all been sympathectomies performed in patients with hypertension. A transthoracic approach for resection of the lower thoracic vagus nerves and their branches has been devised by Dragstedt[10] for treatment of patients with peptic ulcer. The therapeutic and physiologic effects of this operation have been reviewed by Thornton, Storer and Dragstedt,[19] Grimson, Taylor, Trent, Wilson and Hill,[20] and by Moore, Chapman, Schulz and Jones[21] and need not be discussed in this report. Vagotomy affords an opportunity to study the complications of thoracotomy in patients who have peptic ulcer and who do not have hypertension or undergo sympathectomy.

Thirty-three patients have been treated by vagotomy in Duke Hospital since July 1944 without mortality. The operative approach is illustrated in Figure 466. Anesthesia and supportive therapy were the same as for sympathectomy except that blood transfusions were not often used. Blood pressure was reduced to shock levels during operation in only one patient. Sterile chest drains were arbitrarily not employed. Penicillin was used in eleven patients and chemotherapy in ten. Intratracheal intubation was employed during anesthesia in nine.

Two of the thirty-three patients had vagotomy because of tertiary lues with severe gastric crises. The remaining thirty-one had vagotomy because of duodenal, stoma or gastric ulcers. In three instances vagotomy was performed immediately after laparotomy and gastroenterostomy and in one after exploratory laparotomy. Since these procedures may have altered the postoperative course these four operations will be omitted and only the remaining twenty-nine vagotomies will be included in the analysis.

The thoracotomy was well tolerated in thirteen patients as judged by a maximum temperature of less than 101° F. Sixteen patients had temperatures over 101° F. Elevations lasted from two to ten days. Nine patients had pulse rates of over 110 and seven had rates of respiration that exceeded 30. Bronchitis with accumulation of thick mucus in the trachea occurred in six patients. In addition clinically recognizable pneumonia occurred in five. In three it was located in the right lower lobe. Accumulation of some fluid in the pleural cavity on the left side occurred in all patients. In three it was sufficient to

produce shift of the mediastinum. Atelectasis was observed by x-ray on five occasions. Infections of the pleural cavity or of the operative wounds did not occur. Pain on the side of the operation occurred and persisted several weeks. Abdominal distention occurred but seemed to be related to the effect of the vagotomy on the stomach rather than to the thoracotomy.

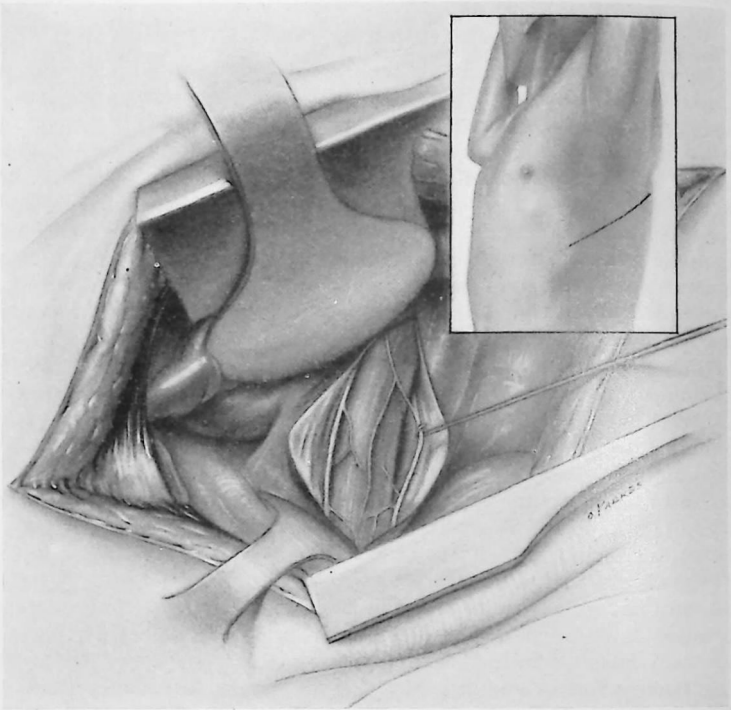

Fig. 466.—Thoracotomy through the bed of the eighth or ninth rib for resection of the vagus nerves and their branches about the lower esophagus is illustrated.

COMMENT AND SUMMARY

Certain complications have developed after thoracotomy employed for sympathectomy or vagotomy. Also certain complications have occurred after the Smithwick retropleural transdiaphragmatic splanchnicectomy. A comparison of the complications observed after the various forms of thoracotomy and an analysis of the value of certain prophylactic measures will be attempted. The complications and their prophylaxis will be summarized and discussed separately.

Infection.—Nineteen patients had thirty-seven thoracotomies performed with conventional aseptic surgical technic but without ultraviolet bactericidal radiation in the operating room. Four developed superficial wound infections and one developed a localized empyema. Seventy-five patients had 119 thoracotomies performed using conventional aseptic surgical technic reinforced by ultraviolet bactericidal radiation in the operating room. One developed a wound infection and another developed a wound hematoma that became secondarily infected. Empyema did not occur. Chemotherapy was not consistently used in either series of patients. It therefore seems probable from this reduction of rate of infection that ultraviolet bactericidal radiation during operation is a useful prophylactic adjunct to thoracotomy.

Pleural Effusion.—Varying degrees of pleural effusion occurred after each of the operations described. Sterile chest drainage (Fig. 465) was usually employed in thoracotomies for removal of the entire thoracic paravertebral sympathetic chains, the splanchnic nerves, the celiac ganglia, and the upper lumbar ganglia. Drainage was arbitrarily not employed after the less extensive thoracotomies for splanchnicectomy or vagotomy. A comparison is therefore possible between the complications in thirty-seven patients or seventy-two thoracotomies performed with continuous chest drainage for the total thoracic sympathectomy and the complications in thirty-seven patients or forty-four thoracotomies performed without continuous drainage for splanchnicectomy or vagotomy. Nine of the thirty-seven patients with drainage developed temperatures over 101° F. Twenty of the thirty-seven patients without drainage developed temperatures over 101° F. even though thoracentesis after operation was conventionally but not routinely employed. Among the patients with sterile chest drainage pleural effusion sufficient to cause shift of the mediastinum occurred in three in whom the drainage catheters became blocked. Clinically recognizable pneumonia did not occur. Among the patients without sterile chest drainage fluid sufficient to cause shift of the mediastinum occurred in four and clinically recognizable pneumonia in five. Routine x-rays demonstrated least accumulation of fluid in the patients with drainage except for three in whom the drain became blocked. X-rays demonstrated the greatest accumulation of fluid in the less extensive thoracotomies performed without sterile chest drainage for splanchnicectomy or vagotomy. It therefore seems probable that continuous chest drainage is a valuable prophylactic measure during the first 2 or 3 days after these varieties of thoracotomy.

It is of interest that varying degrees of pleural effusion also occurred in the patients treated by the retropleural splanchnicectomy described by Smithwick. It is possible that open thoracotomy with provision for continuous drainage may prove preferable to extensive retropleural dissection.

Embarrassment of Respiration.—Embarrassment of respiration during thoracotomy has occurred only occasionally. Intratracheal intubation was employed during operation for twenty of the 156 thoracotomies. On sixteen occasions it was elected by the anesthetist before operation. On four occasions it was deemed advisable during induction of anesthesia or during operation.

Embarrassment of respiration was of greater significance after operation. Varying degrees of splinting or limitation of excursion of the chest wall occurred. This restriction of normal inspiration and expiration was partially responsible for the elevations of rate of respiration observed. Among the seventy-two thoracotomies in which incisions through the third and the tenth rib bed and sterile continuous chest drainage were employed, increase of the rate of respiration over 30 per minute occurred during the first several days after operation in nine. Among the forty-five thoracotomies in which incisions were made through one rib bed for splanchnicectomy or vagotomy a similar increase of the rate of respiration occurred in seven. These increases of respiratory rate were related to pleural effusion or to pulmonary disease more than to limitation of motion of the chest wall. It, nevertheless, seems advisable that sufficient time be allowed between stages of bilateral thoracotomies to permit recovery of motion of the chest wall of the side of the first operation. The average time between the thoracotomies using two incisions was twenty-four days and between the thoracotomies using one incision for splanchnicectomy was eighteen days. It seems advisable that if complications have occurred after the first operation the second should be deferred longer than these averages.

Embarrassment of Circulation.—Embarrassment of circulation with reduction of blood pressure to shock levels occurred frequently during thoracotomies for sympathectomy. It seemed to be related to the extent of the sympathectomy and to the amount of blood lost during the operation. Lowering of blood pressure occurred during the first stage of the thirty-seven bilateral total thoracic sympathectomies in two patients and during the second stage in twenty-six. It occurred during six of the fifteen second stages of the transdiaphragmatic retropleural splanchnicectomies with their associated extensive dissection of heavy muscles of the back. It occurred in only one of the splanchnicectomies through a thoracotomy incision and in one of the vagotomies.

Embarrassment of circulation, therefore, does not seem to be a major complication associated with thoracotomy alone. Similarly, elevations of pulse rate after operation seem to be secondarily related to other complications of thoracotomy or to the vasomotor imbalance caused by splanchnicectomy. Tachycardia occurred least often after the more extensive and uniform total thoracic sympathectomy.

Pulmonary Complications.—Accurate determinations of the exact nature of the pulmonary complications that occurred after the 156 thoracotomies or the thirty-one posterior retropleural operations for splanchnicectomy is difficult. Details of the changes in the lung were often obscured by fluid. Also chemotherapy was usually given whenever elevations of temperature were observed. This interfered with the development of diagnostic signs. Nevertheless, clinically recognizable penumonia occurred after five of the thoracotomies. These five were in patients treated by vagotomy. Interference with the motor nerves to the stomach and regurgitation and aspiration of gastric content seems more important in these five than the thoracotomy itself. It is of interest that clinically recognizable mild pneumonia also occurred after three of the retropleural splanchnicectomies. The pneumonias all responded readily to chemotherapy.

Greater difficulty was experienced with a form of bronchitis associated with dyspnea produced by accumulation of tenacious mucus in the trachea. This occurred after total thoracic sympathectomy in seven patients, after transthoracic splanchnicectomy in two, and after vagotomy in six. It seemed to be associated with pain and splinting of the chest wall and interference with coughing. Breathing exercises, inhalation of carbon dioxide, routine turning of the patient, narcotics to relieve pain, intranasal oxygen, and forced coughing have been employed as prophylactic measures. Inhalations of steam, administration of ammonium chloride, enforced coughing with the operative site stabilized by manual pressure, and when necessary intratracheal suction through a nasal catheter manipulated into the trachea or through a bronchoscope have been employed as treatment.

It has not been possible to determine the frequency with which atelectasis has occurred. The shifts of the mediastinum described have been attributed to pleural effusion. Massive atelectasis has not developed. Varying degrees of atelectasis have certainly been responsible for some of the symptoms observed.

After thoracotomy for operations upon the sympathetic or the vagus nerves the lung that has been beneath retractors is usually compressed. As a prophylactic measure against atelectasis, positive pressure has been routinely increased toward the end of the operation to 8 or 10 cm. of water. Gentle manual massage of the compressed areas of the lung then permits re-entry of air so that the dark compressed areas have a normal appearance.

The routine, prophylactic use of chemotherapy and penicillin whenever elevation of temperature was observed is probably an important factor in the decrease in incidence and severity of the pulmonary complications of thoracotomy.

Abdominal Distention.—Distention of the abdomen by gas in the stomach and intestine occurred after seven of the thoracotomies for

sympathectomy and after five of the retropleural splanchnicectomies. Distention did not appear immediately after the positive pressure anesthetic. It is evident that the denervation of abdominal viscera incident to the sympathectomies may temporarily interfere with normal peristalsis. It is therefore not possible to determine whether the observed abdominal distention is a complication of sympathectomy or of thoracotomy.

Pain.—The most distressing complication of thoracotomy from the point of view of the patient has been pain. Each of the patients described in this report have had pain in the chest and many of them have also had pain referred to the abdomen or to the shoulder and arm. The pain is usually most intense during the second week after operation. When bilateral thoracotomies are used it shifts to the side of the last operation. It usually lasts many weeks. The occasional patient will complain of soreness at times as long as a year or more after thoracotomy.

The pain is more intense after sympathectomy than after vagotomy. Since this operation is upon nerves that contain sensory fibers, the pain cannot be attributed entirely to thoracotomy. Nevertheless, prophylactic measures have been attempted. The intercostal nerve inferior to the incision is routinely excised or avulsed. In some patients the intercostal nerves adjacent to the incision have been crushed. In others they have been injected with alcohol. Neither procedure has effected definite relief. Salicylates, heat, diathermy and psychotherapy have all been employed as adjuncts to the use of narcotics.

CONCLUSION

Thoracotomy as employed for operations upon the sympathetic and the vagus nerves has been associated with a relatively high incidence of occurrence of complications. The incidence may be lowered by prophylactic measures. Continuous sterile chest drainage seems to be an important precaution that should be used during the first several days after operation. The complications that develop usually are not serious and can be adequately treated. The evidence would indicate that thoracotomy may be employed as a relatively safe surgical procedure.

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SYMPOSIUM ON GASTROINTESTINAL SURGERY

ESOPHAGOGASTROSTOMY FOR LESIONS OF THE UPPER END OF THE STOMACH AND LOWER END OF THE ESOPHAGUS

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THE operation of esophagogastrostomy for lesions of the cardiac end of the stomach and the terminal portion of the esophagus has been recognized for many years as both a desirable and feasible procedure, but only by a small group of surgeons. As evidence of this is the fact that from 1907 until 1940 only twenty successful esophagogastrostomies had been reported and these had been performed by eleven surgeons. The first such case was reported by Voelcker[1] in 1907 and from that date until 1934 four additional cases are to be found in the literature. The remaining fifteen successful operations were reported from 1934 to 1940. In the past six years this operation has gained in popularity and has been extended to include esophageal lesions as high as the upper third of this organ. At present this procedure is regarded not only as feasible but as the preferable means of dealing with certain lesions of the esophagus and cardiac portion of the stomach. Only recently Sweet[2] reported thirty-eight cases in which esophagogastrostomy was performed. Garlock[3] has reported fifty-five cases and many reports of smaller series have appeared.

In the first four successful cases reported in the literature the operation was performed by means of a transabdominal approach, but in the subsequent ones a transthoracic approach was utilized. In our opinion the latter approach is the superior one and has been employed in all of our cases. Obviously the transthoracic approach must be utilized for operations upon the lesions that occur at a high level in the esophagus. The great advantage of the transthoracic approach for those lesions that lie in the cardiac end of the stomach and terminal portions of the esophagus is the wide exposure and easy access thus

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afforded. With this approach not only can all portions of the organs involved be readily exposed but the regional lymph nodes can be visualized and removed. The glands which are involved lie both within the thorax and in the abdomen beneath the diaphragm. The former cannot be removed by a transabdominal approach nor can the latter if only the thorax is entered. This point was strongly emphasized by one of us[4] in 1940 in commenting on the Torek operation. When a transthoracic route is utilized and the diaphragm is widely opened, one has before him the entire stomach and the entire thoracic esophagus, together with the lymph glands along the lesser curvature and those in the mediastinum.

As indicated above, the operation of esophagogastrostomy was originally designed for patients having lesions, chiefly carcinoma, of the cardiac portion of the stomach. Subsequently its indications were extended to include carcinoma of the lower third of the esophagus and at present it is considered the operation of choice in dealing with carcinoma of the esophagus occurring as high as the upper third. Other indications for esophagogastrostomy may be benign stricture of the esophagus, large diverticula of the esophagus occurring in the lower third, and chronic ulcer of the cardiac end of the stomach. In the latter condition considerable discussion obtains as to whether resection of the ulcer-bearing cardia and esophagogastrostomy performed with the remaining portion of the stomach is preferable to a palliative subtotal gastric resection, leaving the ulcer in situ and relying on the reduction in gastric acidity to produce healing of the ulcer. In considering this operation for ulcer of the stomach one must bear in mind that during the operation of esophagogastrostomy both vagi are of necessity sectioned. In view of recent experimental and clinical work on the effects of vagotomy it would appear that beneficial effects might well result in the way of subsequent reduction in gastric acidity. Following section of both vagi in a series of experimental esophagogastrostomies performed in dogs, considerable difficulty with dilatation of the remaining stomach pouch was encountered in several animals. Similar difficulties in the case of human beings subjected to the operation have not been evident. However, a Levin tube has been left in the stomach for several days after operation and this may be responsible for the absence of dilatation.

There are methods of treating benign stricture of the esophagus other than by an esophagogastrostomy. Among these are repeated dilatation, a short-circuiting operation, and the formation of an antethoracic esophagus. However, where stricture is limited to one portion of the esophagus and is of considerable extent, resection of the involved area followed by an esophagogastrostomy may be the method of choice. Similarly, whereas the majority of large diverticula of the lower third of the esophagus are best managed by resection of the sac

or by changing its direction, there are instances where resection and esophagogastrostomy are to be preferred.

PREOPERATIVE PREPARATION

The one lesion for which surgery is imperative is carcinoma, and this will serve as a type lesion with which to illustrate the applicability of surgery to this anatomic area. An extensive discussion of the pathogenesis or clinical symptomatology of carcinoma of the lower esophagus and cardiac end of the stomach is outside the scope of this discussion. Certain details of these aspects of the problem, however, have sufficient therapeutic significance to warrant brief reference. The diagnosis of carcinoma of the lower esophagus and cardiac end of the stomach depends upon the history, the roentgenologic evidence of partial or complete obstruction, and the obtaining by esophagoscopy of a biopsy specimen containing carcinoma cells. Since, in this area, certain functional disturbances such as cardiospasm can and frequently do present a clinical and roentgenographic pattern indistinguishable from carcinoma, the final determining diagnostic factor has generally been considered to be esophagoscopy and biopsy. Modern surgical opinion, however, is more critical than formerly. When a positive biopsy is obtained, the diagnosis is of course established. A negative biopsy, however, does not necessarily eliminate carcinoma from consideration, particularly in early lesions of the cardia and terminal esophagus. Every thoracic surgeon has repeatedly had the experience of seeing a patient in middle or late life, in whom a diagnosis of cardiospasm has been accepted on the basis of a negative biopsy, who proved at operation to have inoperable carcinoma. We, in this clinic, share in the opinion of most surgeons familiar with this area, that, where doubt exists, exploration represents the lesser risk.

Another item of therapeutic importance in the clinical pattern presented by these patients is the development of early and profound cachexia, frequently out of all proportion to the extent or duration of the malignant process. This fact has a double significance. First, in these lesions, great loss of weight and emaciation do not constitute "prima facie" evidence of inoperability. Secondly, such profound nutritional and metabolic disturbances should, if possible, be corrected before the extensive resection and anastomosis necessary for the eradication of the malignancy is undertaken.

Largely because of the foregoing considerations, we believe that there is much to be gained in such patients by the institution of a preliminary *nutrient jejunostomy*. The operation is exceedingly simple; it can be done with local anesthesia; it is attended by practically no risk to the patient; and it affords the surgeon certain great diagnostic and therapeutic advantages. Through the short upper left rectus incision used to perform the enterostomy, it is quite easy to explore the

entire upper abdomen. The presence or absence of metastases in the liver and in the subphrenic lymphatic chains can be determined. Especially in lesions of the terminal esophagus and cardia the extent of the process can be established, at least grossly. We have had several experiences in which a tumor, thought to have been reasonably circumscribed, was found to have spread so extensively that practically the entire posterior wall of the stomach and the greater part of the pancreas were involved. Thus, by a simple operative maneuver, a patient who obviously was inoperable was saved the much more extensive procedure of a wide transthoracic exploration of the thorax and abdomen. Furthermore, when the diagnosis is in doubt—an occurrence most frequently encountered when the lesion is at or just below the cardiac orifice—the doubt can be largely resolved by such exploration. The entire stomach can be palpated directly and, if need be, visualized. By invaginating the anterior gastric wall through the diaphragmatic hiatus, the surgeon can palpate the lower 1½ to 2 inches of the terminal esophagus, which is the "blind" area, endoscopically and roentgenographically. It should be emphasized that, given a patient 40 years of age or older who develops obstruction at or about the gastric inlet, carcinoma is the assumed diagnosis until absolutely disproved.

The basic purpose of the jejunostomy, however, is to provide a means of restoring the patient's nutrition to normal as rapidly as possible. At this clinic, a Stamm type jejunostomy is used, employing a No. 12 or No. 14 F. Pezzer catheter placed in the jejunum just beyond Treitz's ligament (6 to 10 inches). Through this the patient is fed the Scott-Ivy mixture, administered slowly and more or less continuously by means of a Murphy drip. The patient himself can regulate this, if there is too rapid accumulation at any one time. Supplementary vitamin therapy as well as aminoids are also given through the jejunostomy, as indicated. Additional parenteral therapy can also be used, of course, but with the intestinal avenue available less of a burden is imposed upon the peripheral venous bed, which can thereby be saved to meet whatever emergencies may arise during and after the major operative procedure.

Following the institution of the nutrient jejunostomy, every effort is directed at rehabilitating the patient's entire physical economy. He is gotten out of bed immediately and is urged to spend as much time as possible walking about. Frequent studies are made of his metabolic status. As guides in evaluating the patient's condition we use the following tests: complete blood count, hemoglobin and hematocrit; serum protein, albumin-globulin ratio, and total blood volume; urinalysis, blood urea nitrogen and carbon dioxide combining power; and the electrocardiogram, as an index of his myocardial status. As soon as deficits in these spheres have been relieved, rarely

a matter of more than ten days, the patient is considered to be ready for definitive surgery. Seventy-two hours preoperatively penicillin therapy (15,000 to 20,000 U. every three hours) parenterally and, unless contraindications exist, sulfadiazine by the enterostomy, are started. Finally, it is very desirable that the esophagus above the obstruction be as clean as possible and empty, even of saliva, when it is opened. This is accomplished by Wangensteen suction, applied for twenty-four to forty-eight hours preoperatively if complete obstruction is present. Where the obstruction is only partial, the Levin tube is passed the morning of operation, approximately two hours before the patient goes to the operating room.

OPERATIVE PROCEDURE

Cyclopropane-oxygen inhalation anesthesia by means of an intratracheal tube is used. When the patient is asleep, intravenous drips to permit the continuous and, if need be, rapid administration of blood, are placed in each internal saphenous vein. We never attempt such an operative procedure without having drawn and immediately accessible a minimum of 5 units (2500 cc.) of compatible whole blood. In addition, unless a blood bank is available, we require that three or four more known compatible donors be within easy call. We prefer the use of cannulas, tied in place, to needle venipunctures. As a further safety factor, each drip has interposed at the cannula a three-way stopcock, to permit periodic clearing of the cannula and the immediately adjacent vein. The patient is then placed on his right side, with both arms extended, and strapped in position on the table with two long strips of 3-inch adhesive tape, one across his hips and the other over the left shoulder. Sandbags in front and in back buttress him in this position.

Silk sutures are employed throughout the operative procedure, except as otherwise specifically indicated.

Following careful skin preparation and draping, the skin and panniculus are incised in a long sweeping curve. When the lesion is in the terminal esophagus or at the cardia, this incision is made only slightly off the horizontal, from a point just lateral to the spine to the anterior axillary line. When greater exposure within the thorax is desired because of a lesion higher in the esophagus, the incision is curved more sharply, posteriorly, to follow the paravertebral line as high as the level of the fourth rib. The skin edges are protected with towels fastened with Michel clips. Care is taken to secure the greatest possible hemostasis with the least possible blood loss. The muscles of the lateral and posterior chest wall are divided individually and hemostasis is secured by individual control of transected vessels, rather than by mass ligature. In the longer incision referred to above, partial division of the trapezius and rhomboid major permits easy

mobilization of the scapula, with subsequent free exposure of the entire thorax. We have found the optimum level for entry into the thorax to be through the bed of the resected eighth rib. Infrequently the seventh rib may be preferable. One-inch segments of the vertebral ends of the adjacent ribs above and below are also resected for mobilization. The anesthetist is given a word of warning to permit cushioning of the collapse of the lung and the pleura is incised throughout the entire length of the bed left by the resected rib. The incision is then opened widely with a mechanical retractor.

Any adhesions preventing collapse and retraction of the lung are divided and a rapid inspection of the mediastinum is carried out. The mediastinum is opened widely by incising the inferior pulmonary ligament and the pleura is reflected off the underlying esophagus. This structure is then freed from the adjacent pericardium and aorta and mobilized for 2 to 3 inches above the lesion. Care is taken to identify, so far as possible, all blood vessels, and to divide them between clamps or ligatures. Every effort is made to leave all immediately contiguous lymph nodes, and as much of the surrounding areolar tissue as possible, attached to the esophagus. Almost invariably it is necessary to include both vagi in this mobilization and in the subsequent resection. About the mobilized segment of esophagus, two or more tapes are passed to facilitate subsequent handling.

The diaphragm is now widely incised radially, from the hiatus laterally to the costal margin, and the gastroesophageal juncture is freely mobilized. Bleeding from divided diaphragmatic vessels is controlled with transfixion sutures in preference to more easily displaced ligatures. The matter of whether or not to interrupt diaphragmatic movement is not altogether settled. In the great majority of instances a low phrenic nerve avulsion is done before the diaphragm is opened. Occasionally, however, we have felt that the elderly patient's postoperative cardiorespiratory function will be better served with an active diaphragm. In that case diaphragmatic motion is controlled for the duration of the operation by injecting the phrenic nerve with 2 per cent procaine solution.

It is now possible to survey both visually and manually the entire upper abdomen as well as the thorax. Where the lesion arises in the cardia of the stomach the amount of that organ to be removed is determined, allowing a wide margin below the malignant growth. An estimate is made also of the amount of stomach which must be mobilized to bridge the gap resulting from the resection, and to provide enough slack, so that in the subsequent anastomosis there will be no tension whatever on the suture line, even if the diaphragm is permitted to move postoperatively. This is particularly important in lesions of the middle third of the esophagus. A small contracted stomach may preclude the possibility of a direct esophagogastrostomy, an

eventuality which must be determined before extensive alterations in the gastric circulation are instituted.

The feasibility of the proposed anastomosis having been demonstrated, the stomach is mobilized. Following the greater curvature and the posterior wall, the short gastric vessels and the left gastroepiploic vessels are divided between transfixion sutures. Thus the spleen is detached from the stomach and can be displaced into the abdomen, out of the way. This dissection can be continued down the gastrocolic ligament almost to the pylorus, to the point of anastomosis between the right and left gastroepiploic vessels. Or it can be limited to any desired fraction of this distance, depending upon the length of stomach needed. Returning to the cardiac area on the lesser curvature, the left gastric artery is divided between transfixion sutures and, by the procedure just outlined, the lesser curvature is similarly mobilized. At the same time the gastrohepatic ligament is largely excised together with all regional lymph nodes. The importance of removal of lymph nodes cannot be overemphasized. Excision of every accessible regional node is indispensable for cure of the patient.

The cancer-bearing portion of the canal is now excised, together with a wide margin of normal tissue on either side. If the tumor is gastric, the stomach is divided between Payr clamps well below the distal limits of the tumor. Where the tumor is well up in the esophagus, transection is carried out between long Kocher clamps at the esophagogastric juncture. In either instance the entire area is blocked out with moist pads, to minimize the risk of contamination. The inferior stump is closed over the clamp with a continuous inverting right angle suture of No. 0 or No. 1 chromic catgut on a swedged needle, reinforced by a row of Halstead mattress sutures of medium silk (No. 000). The proximal stump having been occluded either with a simple tie or by a suture, the clamp is removed, the end of the tube is occluded with rubber protective securely tied, and the tube is temporarily displaced upward out of the immediate operative field.

The mobilized stomach is now delivered into the thorax for a distance sufficient to meet the following requirements. In the first place the superior point of division of the esophagus, and consequently the level of anastomosis, must be well above the farthest extent of the tumor. Frequently, we have asked the pathologist for an immediate frozen section of the proximal end of the resected segment, to make certain that no tumor has been left intramurally in the esophageal stump. *Secondly, there must be absolutely no tension on the anastomotic suture line.* In fact, those portions of the esophagus and stomach immediately adjacent to the anastomosis should be quite slack. Finally, there must be a sufficient length of stomach in the thorax so that subsequent closure of the diaphragm will not drag on the anastomosis. These criteria having been met, the stomach is tem-

porarily anchored with interrupted sutures of medium silk to the periosteum of adjacent ribs. The anesthetist now applies positive suction to the indwelling Levin tube to make certain that the lumen of the esophagus is empty. The area is blocked out with fresh moist pads and the esophagogastric anastomosis is carried out by the following technic.

An area on the anterior surface of the stomach is chosen as the site of anastomosis and the esophagus is united to the stomach at the predetermined level by means of two guide sutures of medium silk placed at each lateral extremity of the esophagus. By this maneuver the length of the incision into the stomach can be made approximately equal to the diameter of the esophagus. The posterior half of the esophagus between the guide sutures is then united to the stomach by a layer of interrupted sutures of medium silk which penetrate the *submucosa* of both structures (Fig. 467, *1*). This is the posterior outer layer. The stomach is now incised as previously planned, the submucosal vessels being ligated before the mucosa is opened. The esophagus is now divided (Fig. 467, *2*). When the mucosa of the esophagus tends to retract, as not infrequently happens, two or three temporary sutures anchoring this layer to the submucosa are helpful in preventing such retraction. The free posterior lips of the incision in the stomach and of the esophageal stump are then united by a layer of interrupted sutures of silk passing through all coats of each organ, care being exercised to accomplish an accurate coaptation of the two mucosal edges (Fig. 467, *3*). This is the inner posterior layer. At this point the Levin tube is threaded into the stomach beyond the anastomosis. The anterior lips of the anastomosis are now approximated with a row of interrupted Lembert sutures passing through the entire wall of each organ—the inner anterior layer (Fig. 467, *4*)—and the anastomosis is completed with an outer anterior layer of interrupted sutures which include the submucosal coats (Fig. 467, *5*). As an alternative technic, we occasionally use for the entire inner, through-and-through suture line a continuous right angle suture of catgut locked at intervals to interrupted sutures of silk. When possible, a piece of omentum is brought up and tacked over the suture line to reinforce it. The temporary anchor sutures in the stomach are removed, and the anastomosis is allowed to seek its own level. The stomach is then securely anchored to the periosteum of adjacent ribs and intervertebral disks in such fashion as to provide slack about the anastomosis (Fig. 468). When possible, it is highly desirable to anchor the esophagus in similar fashion to adjacent intervertebral disks, in order to provide further insurance against tension on the suture line (Fig. 468).

The diaphragm is closed by attaching it to the gastric wall with numerous interrupted sutures (Fig. 468). These should be placed

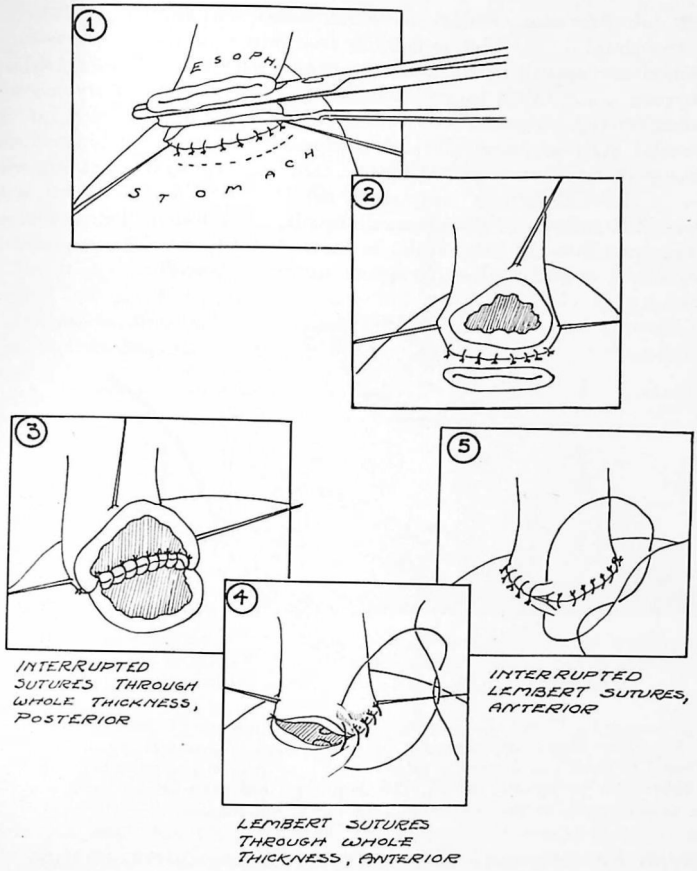

Fig. 467.—*1*, The esophagus has been resected between clamps, the proximal one of which has been left in place. A row of Lembert sutures of silk which penetrate the submucosa unite the stomach and the esophagus.

2, An incision has been made into the fundus of the stomach and the esophagus divided just proximal to the clamp.

3, Interrupted sutures of silk unite the stomach and the esophagus posteriorly. This is the second row of posterior sutures and it involves the whole thickness of the cut edges.

4, The first row of anterior sutures consists of Lembert sutures of silk and involve the whole thickness of the stomach and esophageal wall.

5, A row of Lembert sutures of silk complete the anastomosis. They involve the submucosa of both organs.

well down on the stomach to avoid subsequent drag on this organ by the diaphragm. The remaining free edges of the diaphragmatic incision are approximated with figure-of-8 sutures of double medium silk, care being taken to avoid constriction of the stomach by the new hiatus. Two Pezzer catheters (No. 16 F.) are threaded through intercostal stab wounds, one anteriorly and one posteriorly, and the chest wall incision is closed tightly. The ribs are approximated with four pericostal sutures of braided silk; the rib bed is closed with figure-of-8 sutures of double medium silk; the chest wall musculature is reapproximated anatomically in layers with figure-of-8 sutures; and the skin is closed with interrupted sutures of fine silk.

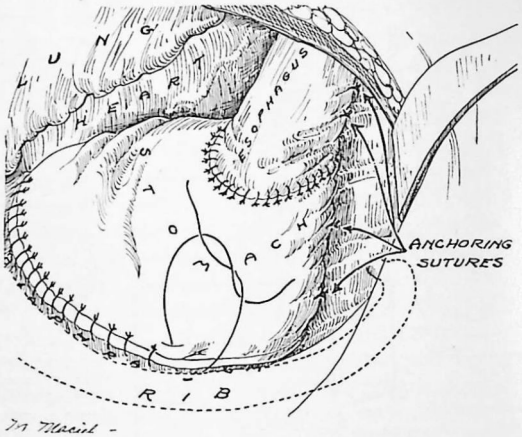

Fig. 468.—The anastomosis has been completed. The united organs have been allowed to retract to a level at which there is no tension and have been anchored at that point by sutures of silk. The diaphragm has been sutured well down on the stomach so as to avoid a drag on the line of anastomosis.

With the intercostal catheters open, the anesthetist reinflates the left lung under positive pressure, following which the catheters are clamped off and kept that way until the patient reaches his bed, where they are attached to floor bottles with an underwater seal. If the right parietal pleura has been inadvertently opened, as frequently happens, it is imperative that the resulting pneumothorax be evacuated, and the right lung completely re-expanded. For this purpose a right thoracentesis is done and the air aspirated while the anesthetist gently applies positive pressure. It is most important, under such circumstances, that the intratracheal tube should not be removed until the surgeon is satisfied that both lungs are fully expanded. Application of positive pressure without the intratracheal tube in place carries

the risk of inflating the stomach with resultant strain on the fresh anastomosis.

A considerable amount of experimental investigation was carried out on the technic of the esophagogastrostomy by Carter, Stevenson and Abbott[5] in 1941. These investigators performed esophagogastrostomies on fifty-two dogs and concluded that the above type of anastomosis was far superior to that in which the end of the esophagus was implanted into the stomach (Fig. 469), as had been advocated by Meyer,[6] Bircher,[7] Fischer[8] and Bengolea.[9] When the latter type of anastomosis was used, stricture resulted in every instance owing to the fact that the edges of the stump of the esophagus which protruded into the stomach healed together rather than sloughing away. This complication had occurred, not only in experimental animals but also in two instances in which the implant type of anastomosis had

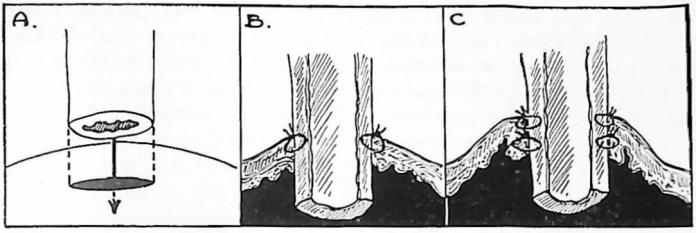

Fig. 469.—The implant type of anastomosis. The open end of the esophagus is introduced into the stomach. The first row of Lembert sutures of silk is shown in *B* and it has been inverted beneath a second row of similar sutures in *C*.

been performed in human cases.[10] Carter and his associates[5] also found that *the use of anchoring sutures in the stomach and in the esophagus in order to relieve tension on the suture line is a most important technical step in the performance of an esophagogastrostomy.* When no such sutures were used the instance of perforation at the line of anastomosis was 89 per cent, when the stomach alone was anchored the instance of perforation was 29 per cent, but when both stomach and esophagus were anchored it was 0 per cent.

POSTOPERATIVE CARE

Continuous suction (Wangensteen) without irrigation is applied to the gastric tube as soon as the patient returns to his room, and is maintained, barring contraindications, through the sixth postoperative day. Water or 5 per cent glucose in physiological saline solution is administered by the jejunostomy on the day following operation, and the Scott-Ivy mixture, augmented with aminoids and vitamins, is resumed on the second day postoperatively. Penicillin and

sulfadiazine are continued uninterruptedly postoperatively until the need for them is deemed past. Usually, one of the saphenous drips is left in place for twelve to twenty-four hours after operation in order that whole blood, plasma or electrolyte solution may be given as indicated.

Whether or not oxygen should be administered is determined for the individual patient by the surgeon and anesthetist jointly. The criteria used in making this decision are the presence or absence of cyanosis or pallor, ability to maintain a clear airway, the state of the blood pressure (including pulse pressure), and the quality, rate and rhythm of the pulse. Aberrations in any of the foregoing are indications for the use of oxygen. On the other hand, the use of supplementary oxygen may lead to a slowing in the rate and reduction in the depth of respiration sufficient to induce or aggravate the serious menace of atelectasis. In elderly patients in particular, atelectasis is a frequent and dangerous complication. Every precaution is taken to prevent it, to detect its development and to relieve it. The routine use of oxygen therapy is avoided. The patient is placed in mid-Fowler's position as soon as he has fully reacted from the operation and is turned from side to side hourly for the first forty-eight hours postoperatively. Even thereafter he is not allowed to remain in any one position for any extended period of time. He is urged to breathe deeply and to cough at frequent intervals, and occasionally inhalations of carbon dioxide-oxygen mixtures are used at intervals to stimulate deep breathing. Particularly in the immediate postoperative hours and as long thereafter as is necessary the trachea is aspirated at frequent intervals, transnasally, with mechanical suction. To facilitate the evacuation of tracheobronchial secretions we have found the repeated use of aromatic steam inhalations very helpful and, when indicated, bronchoscopy with direct aspiration of each bronchus is done.

Roentgenography on the evening of the day of operation, using a portable x-ray machine, is in our opinion a wise precaution. It is especially desirable in those instances in which the right pleural space has been opened. Any residual pneumothorax may be detected and promptly evacuated, and any accumulation of fluid is aspirated dry immediately upon detection. If, in the subsequent period, there is a tendency for fluid to recur on the right side, we believe it wise to institute a closed thoracostomy. Finally, while the optimal time at which to get the patient out of bed is still somewhat controversial, we prefer, subject to modification by the individual patient's recuperative powers, early ambulation (fifth to seventh day) whenever possible.

Due attention is paid to the patient's cardiovascular-renal status. We prefer to have at least one electrocardiographic tracing, periodic blood urea nitrogen determinations, and a daily urinalysis in the post-

operative period. Blood cell counts, hemoglobin determination and hematocrit readings are obtained every day during the first week postoperatively, and indicated therapy is promptly carried out.

On the seventh postoperative day the patient is given 1 ounce of water by mouth, hourly, with the gastric suction tube open. Chest pain, temperature and pulse rise, failure of the water to return through the gastric tube or the appearance of the water in the thoracostomy tubes are all strongly suggestive of a leak in the anastomosis. Should such unpleasant signs develop, the oral feedings are discontinued for three or four days. If, however, all is well at the end of twenty-four hours, the gastric tube is clamped off but left in place, and the hourly ounce of water by mouth continued. At the end of another twenty-four hours the tube is removed, and during the next week the patient is advanced as rapidly as possible through a gastrectomy diet. Simultaneously, the jejunostomy feedings are progressively discontinued and the jejunostomy tube removed by simply pulling it out. The wound heals spontaneously within three days to a week. Provided there is no drainage the thoracostomy tubes are removed on the ninth or tenth day. Before the patient leaves the hospital, we have found it instructive to have an x-ray visualization of the upper gastrointestinal tract with thin barium.

REPORT OF A CASE

The following is the case report of a patient recently seen, illustrating a specific application of the foregoing discussion.

CASE 45-9035 JH.—Mr. J. C., a patient of Dr. Nathan Kursban, was a 69 year old white farmer who was admitted to the hospital on December 19, 1945, because of inability to swallow even liquids. The patient's troubles with regurgitation of ingested food were of six to seven years' duration and had been ascribed to a diaphragmatic hiatus hernia for which he had refused to be operated upon. During the year preceding hospitalization, however, swallowing had grown progressively more difficult and on the day before admission to the hospital he was unable to swallow even water. The patient weighed 137 pounds, and was said by his family to have lost "a considerable amount of weight" in the preceding year.

Physical examination contributed little of significance. The patient carried his years well. There was evident recent weight loss of moderate degree. The lungs were moderately emphysematous but otherwise clear. The heart was not remarkable. There was no evidence of palpable metastases in the peripheral lymph nodes or in the liver. Blood pressure was 194/84, pulse 90 and regular. Temperature 99° F. Laboratory studies: hemoglobin 6.8 gm., red blood cells 4,200,000, white blood cells 6,800, differential normal but with marked hypochromia, anisocytosis and poikilocytosis of the red cells; serum protein 5.82 mg.; urinalysis not remarkable; blood urea nitrogen 14 mg.; electrocardiograms (2) failed to demonstrate any abnormality.

Roentgenographic visualization of the upper gastrointestinal tract with a barium meal was reported as follows: "There is a definite constriction (in the esophagus) about 2 inches long, just distal to the midpoint. The upper end is cone-shaped and the constricted portion fairly regular and smooth. The stomach and duodenum

are in normal position and are of normal size and shape except for some spasm and an apparently inconstant irregularity of the duodenal bulb." On December 22, 1945, esophagoscopy was performed under pontocaine topical anesthesia and at a distance of 13 inches from the incisor teeth an obstruction was encountered in the form of a fungating, ulcerated, necrotic, bleeding mass, from which sections were removed for biopsy. These were reported by the pathologist as epidermoid carcinoma of the esophagus. On December 26, 1945, a nutrient jejunostomy was established. Examination of the liver and upper abdomen failed to reveal any evidence of metastases in this vicinity.

After adequate preparation the patient was explored transthoracically on January 5, 1946, and the obstructing lesion identified. There was no evidence of lymphatic involvement within the thorax. The patient had the previously described hiatus hernia, together with a congenitally short esophagus, so that the stomach extended into the chest for a distance of about 2 inches. The aforementioned constricting mass in the esophagus lay about 1 inch above the esophagogastric juncture, thus placing it roughly 2 inches below the inferior border of the aortic arch. The phrenic nerve was anesthetized with 3 cc. of 2 per cent procaine, immobilizing the diaphragm which was then opened widely. A survey of the upper abdomen confirmed the findings at the time the jejunostomy was established. Utilizing the technic described heretofore, the stomach was mobilized and the gastrohepatic ligament excised. The cancer-bearing portion of the esophagus was resected and an esophagogastrostomy carried out just below the arch of the aorta.

Postoperatively the patient did exceedingly well. He had a rectal temperature of 103° F. for two days postoperatively, following which it dropped to 100° to 101° F., with a commensurate pulse. On the ninth postoperative day the patient was given water by mouth, 1 ounce hourly, but after the second ounce of water he experienced a pain radiating across his left chest followed shortly by a chill and a temperature rise to 104° F. Oral feedings were discontinued immediately. There was considerable question as to the cause of this episode. Among other things due consideration was given to the fact that the patient had been receiving penicillin for nine days. This was discontinued and his temperature gradually subsided to normal. Water by mouth was again started on the fifteenth postoperative day and was continued without untoward incident. The nasal tube was removed on the seventeeth day and oral feedings advanced while jejunostomy feedings were gradually discontinued. The patient was gotten out of bed on the seventeenth postoperative day and the jejunostomy tube was removed on the twenty-third postoperative day. He was discharged on the twenty-fifth postoperative day. Visualization of the reconstructed esophagus with a barium meal just prior to discharge revealed a completely patent esophagogastrostomy.

The patient has been seen repeatedly since discharge, and on the last occasion prior to this report, which was four months postoperatively, was doing very well. He had gained 20 pounds in weight, was eating everything without difficulty, and had regained his strength sufficiently to drive his own car for a distance of 50 miles from his home to the clinic.

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THE SURGICAL TREATMENT OF BLEEDING PEPTIC ULCER

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THE surgical treatment of bleeding peptic ulcer is far from standardized, and marked differences of opinion exist as to the best method of treating this complication. In general, it is agreed by surgeons that a patient with an ulcer which has caused severe, recurrent hemorrhage should be treated by operation in an interval after bleeding has ceased and the patient has recovered from the effects of loss of blood. This is particularly indicated when other symptoms of ulcer are present, such as pain or vomiting. Ideally, the operation in such cases consists of excision of the ulcer with partial gastrectomy.[6] While such a procedure does not remove permanently all possibility of future bleeding, it does reduce both the likelihood of its occurrence and its seriousness if it does occur. That operation should be performed in such cases is indicated by the well established fact that the mortality from bleeding ulcer increases with repeated hemorrhages and with the age of the patient.

Regarding surgical intervention during the bleeding episode there is considerable disagreement. In spite of reduction in mortality in recent years as a result of improvement in conservative or nonoperative treatment, it is well known that some patients still bleed to death from their ulcers and the question naturally arises as to whether some of these deaths could not have been prevented by an operation consisting of ligation of the vessel or vessels or resection of the ulcer during the episode of bleeding. It has been clearly established that this can be done in some cases in which the surgeon has been willing to operate on an almost exsanguinated patient. It seems almost equally obvious that, if this method were used in a large percentage of all cases with bleeding, a fair number of the patients would succumb to the operative procedure. As a matter of fact, it is generally stated that the mortality rate is higher with operative than with nonoperative treatment. It must be recalled, however, that the statistics quoted in support of such a statement usually will not stand critical analysis, for they often represent the operative mortality of patients who have failed to respond to nonoperative treatment and are

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operated upon as a last resort. They cannot in fairness be compared with the whole group of nonoperated patients. It is interesting to note that those who most vigorously oppose operative treatment are often those who have given it inadequate trial.

If it were possible to predict with any degree of certainty at the beginning of an episode of bleeding which patients would cease bleeding and recover, and which would bleed until death ensued, it would then be possible to operate only on the latter group, early in the course of bleeding, with the confident expectation that in some of them the bleeding could be stopped and the life of the patient saved. Unfortunately it is not possible at the present time to be sure what the outcome of an episode of bleeding will be, and therefore it becomes necessary to arrive at the best estimate possible on the basis of certain information plus past experience with other cases.

DIAGNOSIS

When one speaks of bleeding from ulcer, there is generally implied a hemorrhage of some magnitude, sufficient to cause rather striking clinical symptoms. These symptoms and signs vary somewhat depending on the amount and rapidity of blood loss, but in general consist of a feeling of weakness, dizziness or faintness, with rapid, weak pulse and often other signs of shock. There may be nausea with vomiting of bright red blood, or blood-tinged fluid, the amount of which is usually overestimated by the patient or the patient's family. Often, also, there is urgency of defecation which occurs at about the same time as the vomiting. Not infrequently the patient may actually faint during or following the attack of bleeding. The stools may be tarry for a period of days thereafter, while in very rare instances recognizable red blood may pass in the stools during the bleeding episode. Symptoms such as those just described, occurring in a patient with known gastric or duodenal ulcer, are sufficient to justify the assumption that the bleeding is coming from the ulcer. In a general hospital practice, however, in which patients present themselves with such signs of internal hemorrhage but without any record or history of their preceding physical status, the question of the origin or site of the bleeding may present a major diagnostic problem. Often the patient is too ill for careful history taking or complete and thorough examination.

The most frequent cause of serious bleeding into the upper gastroenteric tract which may be confused with bleeding peptic ulcer is undoubtedly rupture of esophageal varices which are secondary to cirrhosis of the liver or portal hypertension. Other common causes are diffuse gastritis with oozing from the mucosa, bleeding carcinoma or benign tumor, hemorrhagic disease, and aneurysm eroding into the esophagus or duodenum.

When a patient is seen with vomiting of blood and the signs and symptoms of bleeding into the upper gastroenteric tract such as have just been described, but about whom no previous history is available, these possible causes should be considered and an attempt made to establish the true diagnosis. One might try first to elicit a history from the patient or his family of the known presence of an ulcer, or a story suggestive of ulcer. If this is negative, the next attempt probably would be to look for evidence of cirrhosis of the liver such as mild jaundice, spider angiomas, enlarged liver and spleen, dilated abdominal veins and the like. In addition to routine blood studies, determinations of the prothrombin time and blood urea nitrogen should be made. If the patient is in shock, a transfusion of whole blood should be given slowly. Further studies may then be indicated. These might include fluoroscopy to determine the presence of an aortic aneurysm, an attempt to demonstrate esophageal varices by the Valsalva technic, and study of the stomach and duodenum by the Hampton technic.[1] Although one does not elect to make these studies with a very ill patient, one should not hesitate if the need for differential diagnosis seems to be sufficiently important. We have never seen harm come from a carefully performed examination of this sort, while on several occasions bleeding has ceased after barium study, and for this reason we do not regard the examination as hazardous. Many times an ulcer which has only been suspected, has been demonstrated by barium study, though at times incorrect information has been reported. Failure of correct findings is inherent in the procedure, which is limited in its application, but if these limitations are appreciated it may at times prove very helpful. The most frequent sources of error have been reporting the presence of duodenal ulcer when one did not exist, and failure to demonstrate a gastric ulcer which was subsequently proved to be present.

CRITERIA FOR OPERATION

If ulcer is shown to be present as a result of these studies, or if it is known to be present as a result of previous knowledge of the patient, it is my belief that the question of prompt operation should now be considered. The decision for or against operation needs to be carefully judged in each individual case. If the bleeding is moderate, and if it apparently ceases promptly, the patient is watched and treated by nonoperative measures. However, if the bleeding is massive, if it apparently continues, or recurs shortly after having once stopped, and particularly if the patient is in the older age group (i.e., 60 years of age or older) operation should be performed after adequate blood transfusion.

Before considering in detail the criteria we use for determining whether operation should be performed, it would be well to review

some of the important pathologic aspects of bleeding ulcer. Perhaps the most frequent site for bleeding ulcer is the posterior wall of the first portion of the duodenum, the ulcer having eroded one of the branches of the pancreaticoduodenal artery. If the gross specimen is examined, there is usually found a segment of artery exposed with an opening in its side which is partly or completely plugged with a clot of blood (Fig. 470). The artery has a sclerotic wall and is held firmly in the scar tissue in the base of the ulcer. At times the artery, especially if it be small, is completely divided and the two ends can be seen, each blocked at least in part by blood clot. Whether the artery is completely or incompletely divided, it is still impossible for retraction to occur because of the fixation of the vessel or vessels in scar tissue, so that one of nature's most efficient mechanisms for stopping bleeding from an open artery cannot function; that is, retraction of

Fig. 470.—Ulcer of stomach with erosion in side of artery plugged with clot. Autopsy specimen.

the artery with contraction of the open end. The only way for bleeding to cease is for the blood pressure to drop and the opening in the artery to be plugged by clot. Recurrence of bleeding may develop when the clot is digested or liquefied. The ulcer may of course lie in the stomach or in the superior or anterior wall of the duodenum. In my experience, ulcer of the stomach which bleeds will frequently prove to be a carcinomatous ulcer. Ulcers on the anterior wall of the duodenum seldom are the site of fatal bleeding. A number of patients on whom I have operated during a free interval after two or more previous massive hemorrhages have had an ulcer or scar of an ulcer in this location, often almost completely healed at the time of operation. Unfortunately one cannot tell from the roentgenologic appearance of a duodenal ulcer whether it is on the anterior or posterior wall, so that the fact that ulcer of the anterior wall is less likely to

lead to fatal hemorrhage than one on the posterior wall is of little practical value.

In deciding upon the plan of management of a patient with bleeding ulcer, it is important to have methods of evaluating the amount of bleeding and whether it is continuing or has recurred once it has stopped. The clinical signs of concealed hemorrhage, such as shock, pallor, sweating, and weak, rapid pulse, may be all that is needed to make a diagnosis. The blood pressure should be taken at regular intervals and charted, as a sudden drop may signal recurrent hemorrhage. Blood counts, hemoglobin and hematocrit determinations should be obtained and repeated, as they may give indications not

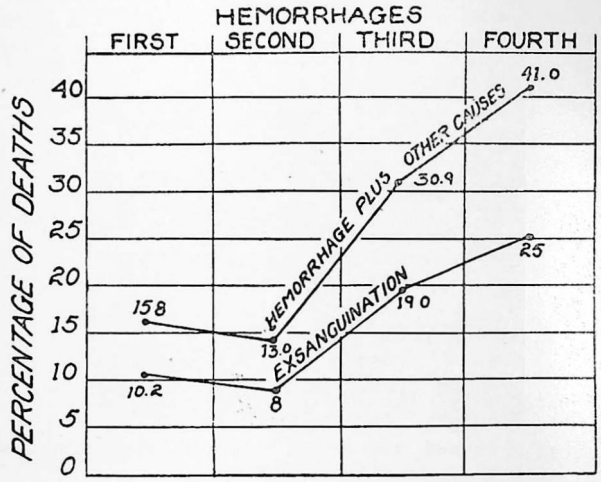

Fig. 471.—Chart showing known number of gross hemorrhages and mortality rate (after Goldman).

only of the extent of the bleeding but of the need of blood transfusion. One important method of estimating the amount of blood loss and also of continuation or recurrence of bleeding is to determine the *blood urea nitrogen.* Schiff[2] has shown that the digestion of blood in the gastrointestinal tract leads to elevation of the blood urea nitrogen proportional to the amount of blood. It is possible therefore by making determinations every other day to get an estimate not only of the amount of blood loss but also of continued or recurrent bleeding, since the blood urea nitrogen remains elevated for only twenty-four to thirty-six hours from one episode of bleeding. It is desirable to obtain blood for the blood urea nitrogen determination as soon as the patient reaches the hospital and every other day thereafter.

It has been demonstrated conclusively that the age of the patient and the recurrence of bleeding are important considerations in evaluating the danger of fatal hemorrhage. Patients under 45 years of age rarely bleed to death, while patients over 60 show a higher incidence of fatal hemorrhage. It is presumed that sclerosis of the arteries accompanying increased age is an important factor. In Goldman's[3] series of 349 cases the average age of the patients who died was 54 years. Allen and Benedict[4] found in 138 cases that the average age of those patients who died was 56.4 years, and of those who recovered 41.8 years, a differential of 15 years. In this connection they point out that the age of the patient seems to be more important than the duration of symptoms. Death from the first hemorrhage is quite rare, but with each succeeding hemorrhage the danger of a fatal outcome rises. Goldman, for example, found a sharp rise in mortality in his series with repeated hemorrhages, especially in those with two severe hemorrhages, as is shown in a reproduction of his chart (Fig. 471).

PLAN OF MANAGEMENT

In the management of patients with massive bleeding from ulcer, the following plan is recommended. The patient is put to bed, given nothing by mouth, if he is vomiting, otherwise sips of water or cracked ice. The blood pressure is taken, as is blood for count, prothrombin time and blood urea nitrogen determinations, hematocrit, and blood typing. If the blood pressure is below 100 systolic a blood transfusion is given promptly. An evaluation of the cause of bleeding is made as quickly as possible, by history, review of previous findings if these are available, and by physical examination. Conservative treatment is continued if the bleeding ceases and the general condition remains good. This consists of rest in bed, and a Meulengracht diet. Further laboratory studies, x-rays and other examinations are made as indicated. The most urgent indication for early operation is failure of bleeding to cease, or its recurrence if it has temporarily ceased. Often a patient will apparently do well, only to start bleeding again after a lapse of several hours to half a day. With such recurrent bleeding, operation is considered or actually carried out unless in the meantime satisfactory evidence is obtained that the bleeding is due to some cause other than ulcer. A tube is passed into the stomach, blood transfusion is carried out continuously and the patient is taken to the operating room.

Usually patients who bleed can be placed into one of several groups as follows:

1. Patients with known chronic gastric or duodenal ulcer who bleed seriously while under treatment. I believe that patients in this group should be operated upon promptly, either during or immediately following the hemorrhage.

2. Patients with duodenal ulcer who have previously been operated upon, and who now experience serious hemorrhage several years later. In most instances the bleeding will be from a gastrojejunal ulcer. Unless bleeding continues unchecked, conservative treatment would seem to be the method of choice in this group, as the operation is likely to be complicated and it is unlikely that it could be performed quickly or safely. However, if bleeding persists, even in this group operation may be necessary.

3. Patients who are admitted without any information available as to previous ulcer, and in whom the source of bleeding is not known. Here caution is necessary and studies to determine the source of bleeding should be instituted. If chronic penetrating ulcer can be demonstrated, I believe prompt operation is indicated.

4. Patients with bleeding in addition to some other complication such as perforation or obstruction should be operated upon promptly. The mortality in this group is high, but some patients can be saved by operation.

5. Repeated severe hemorrhages recurring in any of the above groups may make operation advisable, unless a definite diagnosis can be made that the bleeding comes from some condition other than ulcer. Failure to prove the existence of ulcer is not a contraindication to operation. The danger to life with repeated hemorrhage is greater than the risk of exploratory laparotomy.

The type of operative procedure will vary with the individual case, though excision of the ulcer with partial gastrectomy is the method of choice, if the condition of the patient permits a procedure of this magnitude. With gastric ulcer, ligation of the vessels around the ulcer, from outside the stomach, may be sufficient. I have used this method successfully in two critically ill patients. With duodenal ulcer, ligations outside the bowel wall alone are insufficient, because of the intricate anastomoses and the inability to reach the vessels entering posteriorly from the pancreas. Successful control of hemorrhage in such cases may be obtained by opening the anterior wall of the duodenum and placing a deep suture of catgut through the ulcer bed around the bleeding point, followed by closure of the duodenum or resection. Bleeding from diverticula and from benign or malignant tumors usually requires resection of these lesions. In duodenal ulcer, in which exposure is exceedingly difficult or hazardous, an operation of the Devine exclusion type has been suggested, but I have had no personal experience with this method and cannot recommend it.

In general the method of management I have used is as follows: The patient is brought to the operating room with a transfusion of blood running. A tube is placed in the stomach so that fresh bleeding can be detected by suction on the tube. Cyclopropane and oxygen with or without ether by intratracheal tube is the anesthetic of choice.

An upper transverse abdominal incision is made. Inspection and palpation will usually show the location and nature of the lesion. If it is in the stomach, and there is no fresh bleeding as evidenced by blood from the tube in the stomach, a gastrectomy according to the usual technic can be carried out (Fig. 472). If the lesion is in the duodenum it is usually wise to open the duodenum and make sure that there is no active bleeding. If there is, it can usually be controlled by pressure on the bleeding point with a sponge on a clamp, by direct pressure with the finger, or by passing a deep suture. In most instances after the bleeding has been stopped, with the transfusion running, the condition of the patient improves and resection

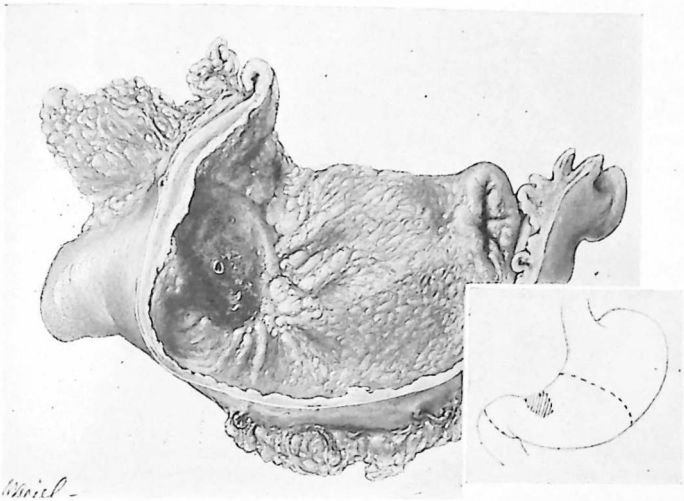

Fig. 472.—Drawing of specimen after resection. Gastric ulcer with eroded vessel.

can be carried out, the patient leaving the operating room even after several hours of operation in better condition than when he arrived. On the other hand, if the patient is not doing well, or is not improving, the duodenum is closed as soon as the bleeding is controlled and the operation is terminated as quickly as possible.

If resection is done, the base of the ulcer may have to be left in situ as a granulating wound, the duodenum being removed distal as well as proximal to it (Fig. 473). Closure of the duodenal stump may be rather difficult in such cases. If the posterior wall can be mobilized the usual closure can be used. The method I prefer is to clamp the bowel with a Kocher clamp, divide it with the cautery and obtain inversion of the crushed end with a continuous right angle

suture of No. 00 chromic catgut in two layers. If the posterior wall cannot be mobilized, this may be impossible. In such instances the anterior wall should be freed as much as possible, after which a right angle continuous suture can be placed, using the scarred fibrotic pancreas for the posterior line. This usually leads to incomplete inversion and needs a row of mattress sutures of silk between the anterior duodenal wall and the scarred, fibrous pancreas to secure adequate closure. It is important that a few carefully placed sutures be used, rather than many poorly placed ones, as a multiplicity of sutures may impair the circulation and lead to leakage. After closure of the duo-

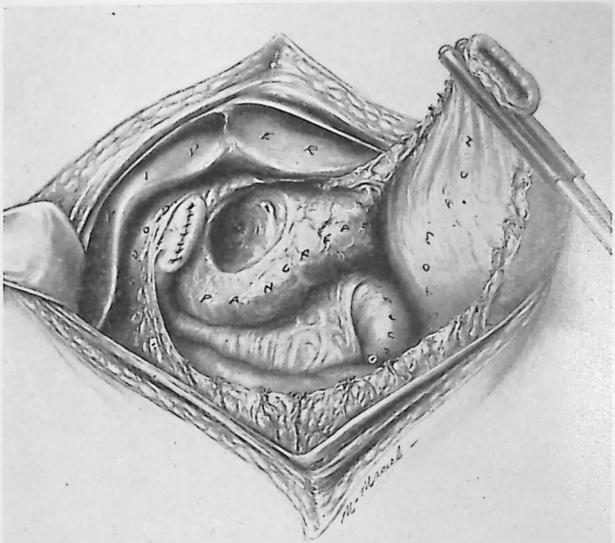

Fig. 473.—Bleeding duodenal ulcer. Partial gastrectomy leaving base of ulcer on pancreas.

denal stump, resection of the stomach can be carried out in the usual fashion. If it has been necessary to leave the base of the ulcer in situ, several soft cigarette drains are placed down to it and the abdomen is closed with through-and-through wire sutures.[5]

If the lesion is in the stomach and bleeding is continuing, one may either ligate the vessels on the outside of the stomach or open the stomach and ligate the bleeding point from within and then proceed with resection. I have had no experience with the latter method, but doubt that with it it would be very easy to accomplish satisfactory control of the bleeding.

In case laparotomy is done when neither ulcer nor tumor is present, the surgeon may be in doubt as to how to proceed. The first thing to do is to feel for any abnormalities. If none are found, the bowel should be carefully inspected to determine the highest level at which blood can be seen in the lumen through the wall as evidenced by a purplish-blue appearance. If this is not helpful in locating the lesion, the stomach may be opened to see if there is blood in its lumen and to inspect and palpate its mucosa as well as that of the first portion of the duodenum. There may be found diffuse oozing from the gastric mucosa, evidence of an acute gastritis. In such an instance closure of the stomach and abdomen should probably be done although some surgeons have recommended partial gastrectomy for this condition. In most instances in which nothing abnormal can be felt from outside the stomach or duodenum, it is unlikely that much valuable additional information will be obtained from opening the stomach. On two such occasions I have closed the abdomen without exploratory incision into the stomach. Both patients ceased bleeding. One remained well but the other subsequently had another hemorrhage and died. At autopsy the site of bleeding could not be demonstrated.

CASE REPORTS

Brief histories of a few cases of bleeding which I have seen during the past five years will serve to emphasize some of the points.

CASE I.—A white woman, 62 years of age, was admitted to the hospital for roentgenologic study of presumed ulcer of the duodenum. The x-ray examination showed a deep chronic ulcer of the duodenum. Twelve hours later she suddenly had a massive gastric hemorrhage. She was seen by a surgeon in consultation and, since the bleeding had stopped, he recommended transfusion and watching. About twenty hours later she began bleeding again. I was asked to see her at this time but found her pulseless when I reached the hospital. She died twenty minutes later. Postmortem examination showed a chronic duodenal ulcer penetrating into the head of the pancreas, with erosion of the pancreaticoduodenal artery.

CASE II.—A white man, 65 years of age, was admitted to the hospital for pain in the abdomen and vomiting. X-ray showed gastric retention and ulcer of the duodenum. He was treated by Sippy diet with gastric drainage twice daily. Because of only moderate improvement, operation was decided upon and was scheduled for the following week. Three days before the date set for operation he suddenly had a massive hemorrhage. Fainting and shock developed. A transfusion was given. About four hours later he bled again and it was thought that he probably would bleed to death. However, the bleeding ceased again and operation was done several hours later as an emergency procedure. He was a large man, weighing nearly 200 pounds, and exposure was difficult. A huge ulcer crater was found in the head of the pancreas. There was apparently no bleeding when the operation was started. The anterior wall of the duodenum was incised and the lumen was found to be filled with blood clot. As this clot was pulled out there was a sudden gush of fresh blood from the ulcer. The bleeding was stopped by pressure, first with the finger, then with a ring forceps. While the forceps was

held in place, two deep sutures of No. 0 chromic catgut were placed in the pancreas, one above and the other below the bleeding point. When these were tied, the bleeding was controlled. Resection was then done. The duodenal stump was difficult to close but was fairly well secured. Drains were placed to the base of the ulcer which was left in situ and the abdominal wound was closed with silver wire.

The patient developed a little duodenal leakage, and a pancreatic fistula, both of which healed spontaneously. He left the hospital apparently well about one month later.

CASE III.—A white woman, 68 years of age, was admitted to the hospital because of repeated gastric hemorrhage. She was under treatment for duodenal ulcer. She had had two operations about twenty-five years before, the exact nature of which was not certain, but one was said to have been a pyloroplasty for duodenal ulcer. Her last x-ray had been made about six months before and showed deformity of the duodenum. Because of continued bleeding she was operated upon as soon as shock was controlled by transfusion. A firm lesion was found in the prepyloric region together with the scar of a healed duodenal ulcer. The gastric lesion was thought to be a carcinomatous ulcer and resection was done. As the dissection was carried upwards on the stomach, a patent gastroenterostomy stoma was found. The stomach was amputated just distal to the stoma and the cut end closed.

Unfortunately the patient developed severe gastric bleeding about twenty-four hours after operation, and bled almost continuously for twenty-four hours. Bleeding then ceased, but she developed pneumonia and urinary suppression and died two days later. Postmortem examination showed organizing blood clot all along the turned-in end of the stomach and this was undoubtedly the source of the postoperative bleeding. The excised specimen showed adenocarcinoma. This case was a technical failure due to improper hemostasis of the cut end of the stomach.

CASE IV.—A white man, 57 years of age, was admitted to the hospital with massive hematemesis. He was in severe shock. Transfusion was given and his condition improved. History and general physical examination were not characteristic of any particular lesion. A series of severe hematemeses occurred during the next few days. Barium studies of the esophagus, stomach and duodenum were made. Fluoroscopic examination of the chest showed some widening of the aortic shadow. There was apparently a little distortion or spasm of the esophagus. Nothing abnormal was seen in the stomach or duodenum. In spite of repeated massive hemorrhages there was no elevation of the blood urea nitrogen.

Because of the recurrent severe bleeding, exploratory laparotomy was done by the resident surgeon. No ulcer, tumor or other abnormality was seen or felt. The stomach was opened and found to contain only a little blood-tinged fluid. The abdomen was closed. About thirty hours later the patient had a very severe hematemesis and died in shock shortly thereafter. Autopsy showed a small aneurysm of the thoracic aorta, which had perforated into the esophagus. Very little blood was found in the stomach or intestine. Apparently most of the blood had been vomited up and this fact accounted for the failure of the blood urea nitrogen to rise. This probably should have led to the conclusion that the bleeding was cephalad to the stomach. It is important to note that that the exploratory laparotomy apparently did not contribute to the fatal outcome.

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THE TREATMENT OF PENETRATING WOUNDS OF THE ABDOMEN IN CIVILIAN PRACTICE

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PENETRATING wounds of the abdomen have always been associated with a very high mortality in both military and civilian surgical practice. In the wars prior to the Second World War, including the Civil, Spanish American, Boer and Russo-Japanese Wars, the published mortality rates in collected series varied between 60 and 90 per cent, and in World War I it was 50 to 80 per cent.[1–7] In the early part of World War II it remained high, being approximately 50 per cent in Gordon-Taylor's series[8] and 47.5 per cent in Ogilvie's.[9] The reports collected from civilian practice between 1899 and 1945 show a similar high mortality varying between 30 and 80.5 per cent.[10–22]

It must be remembered that the usual treatment of these cases during the Boer and previous wars, and even during the early part of the first World War, consisted of nonoperative management with starvation and large doses of morphine, and the majority of casualties who were operated upon died. However, reports from civilian surgeons during this same period indicated that early operation was a more desirable form of treatment and this was substantiated by military surgeons during the later part of the first World War, who concluded that the nonoperative treatment was a failure.

The high mortality associated with such wounds has been caused primarily by severe shock, hemorrhage and peritonitis. Associated multiple wounds of the thorax, genitourinary tract, spinal column or head, or cutaneous burns have added to the perplexity of the problem.

GENERAL CONSIDERATIONS

Although penetrating wounds of the abdomen have a low incidence in most parts of the country, according to life insurance statistics, they are encountered frequently as emergencies in large charity hospitals. In the Cincinnati General Hospital there have been 161 cases between January 1942 and May 1946, an average of three cases per month. The abdominal cavity usually is penetrated by wounds through the anterior, lateral or posterior walls, but penetration may also occur

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through the thorax, neck, perineum, buttocks, sacral area and even the thighs. The wounds may vary from small puncture wounds produced by a hatpin or icepick to extensive lacerations permitting intestinal evisceration. The causes of penetrating wounds of the abdomen vary somewhat in civilian and military practice. In civilian surgery they are usually produced by knife, icepick, low velocity pistol or rifle, and shotgun, whereas in war they are caused by high velocity rifle and machine guns, fragments of high explosive shells, grenades, bombs and bayonets. Damage to the intra-abdominal viscera varies with the velocity, size, shape and nature of the weapon, the small bowel being damaged most frequently and the solid organs, colon and stomach less frequently. Patients with lacerations of the great vessels including the aorta, vena cava and iliac or renal arteries seldom reach the civilian surgeon unless unusual opportunities are available for rapid transportation to nearby emergency hospitals.

Shock is commonly seen in penetrating wounds of the abdomen and its severity is determined primarily by the degree of hemorrhage as well as by the type of the weapon, by the location and extent of the wound, and by the multiplicity of injuries.

Hemorrhage may be of any degree from minimal to massive with early death, and the bleeding may occur in the free peritoneal cavity or in the retroperitoneal space as a hematoma. It is usually the result of perforation of one of the larger vessels of the abdomen or of laceration of a solid viscus such as the liver, spleen or kidney. In our experience it is rarely caused by damage to the vessels in the anterior abdominal wall such as the deep epigastric artery.

Infection is particularly prone to complicate this type of injury in the form of peritonitis, residual abscesses, putrefactive empyema, retroperitoneal cellulitis or wound infection. It is the result of gross contamination by escaping gastrointestinal contents and rarely by material such as soil or dirty clothing carried into the wound from without. The severity of infection may vary with the segment of the gastrointestinal tract injured, the amount and character of the food digested before injury, the virulence of the bacterial flora, and the resistance of the patient.

The fully distended stomach after meals or drinking is particularly vulnerable to upper abdominal or lower left thoracic wounds. Small gastric wounds, especially those located near the lesser curvature, may be followed by little spilling, whereas larger ones, particularly those near the greater curvature, may permit almost complete emptying of the stomach. Poor oral hygiene, swallowed nasal secretions, and low gastric acidity favor high bacterial contamination of the peritoneal cavity by escaping gastric contents. The effusion of contents from the lower ileum is particularly serious because of its liquid nature and the character and abundance of its bacterial flora. The contents of the

colon are normally solid or semisolid and diffuse contamination is less likely to occur from penetration of the colon. Nevertheless, the resultant infection is serious.

The infection developing after penetrating wounds of the abdomen is almost always polymicrobic, being caused by several or many different types of bacteria.[23] The ascription of the average case of peritonitis to the unaided activity of Bacillus coli or other single strains seems to be without sufficient justification, and the synergistic or cumulative action of the various infecting bacteria seems to be a more plausible cause. It must be remembered that the normal peritoneum possesses considerable natural powers of resistance to infection, but if repeated or constant soiling occurs, such as that produced by an unrepaired perforation of the gastrointestinal tract or a leaking anastomosis, it is unable to withstand bacterial attack and a severe, usually fatal, peritonitis is the result.

The retroperitoneal tissues on the other hand seem to have very little resistance to bacterial contamination in the presence of injury. A severe form of retroperitoneal cellulitis may complicate penetrating wounds of the abdomen if adequate drainage of the retroperitoneal spaces is not carried out. It is characterized by a spreading, often crepitant cellulitis of the retroperitoneal areolar tissues with the production of considerable gray necrotic slough, and profound toxemia.[24] The condition is often referred to as "anaerobic cellulitis" and is likewise caused by the synergistic action of the group of aerobic and anaerobic bacteria resident in the intestinal tract at the time of injury.

Infection of the abdominal operative wound may also be caused by the same group of bacteria. Its occurrence and severity are minimized by sharp dissection, protection of the wound edges with gauze during the operative procedure, gentle handling of tissues, closure by through-and-through silver wire sutures, and adequate chemotherapy.

A severe mixed infection of the pleural cavity may complicate combined penetrating wounds of the chest and abdomen with perforation of the esophagus, stomach or intestine.[24] It is characterized by a progressive effusion of thin, bloody, purulent fluid often with a foul odor within the pleural cavity and signs of profound toxemia with elevated temperature, pulse and respiratory rates and a fall in the blood pressure which usually begins between the first and third days after operation.

The successful management of penetrating wounds of the abdomen consists essentially of early, surgical repair of the injuries by exploratory operation as soon as the patient's condition will permit. As in all wounds of violence, the primary purpose of surgical treatment is to save life by the alleviation of shock, arrest of hemorrhage, and the prevention or control of infection. The secondary purpose is to restore the function and appearance of the wounded parts in so far as possible.

To accomplish these objectives, adequate preoperative preparation, early and thorough operative repair, and vigilant postoperative care are necessary.

PREOPERATIVE PREPARATION

Treatment of Shock.—A sterile dressing is applied as soon as possible to all open wounds and immediate measures are taken to recognize and alleviate existing or impending shock. The effectiveness of active treatment consisting of the use of morphine, oxygen, shock position, and the intravenous injection of fluids is largely determined by the promptness with which it is instituted. Physiologic saline or glucose solutions and plasma are used until whole blood has been made available by the blood bank. In our opinion, whole blood is far superior to plasma or any other solution in the treatment of shock associated with penetrating wounds of the abdomen. This therapy is continued throughout the operative and immediate postoperative periods. Stimulants or other liquids by mouth are not given.

If the shock is due to the effects of trauma other than hemorrhage, and if the treatment is started early, active therapy is usually successful in restoring the measurements of blood pressure, pulse and body temperature to normal within three quarters to one hour.

Control of Hemorrhage.—In general every severely shocked patient with an abdominal wound should receive transfusions of whole blood, and if little or no response occurs to the injection of 2 units of blood within one hour or less, it must be assumed for practical purposes that severe hemorrhage is a major cause of the shock. Under such circumstances two and occasionally three continuous intravenous injections of whole blood are used simultaneously in an effort to supply blood at a faster rate than that at which it is lost. In this connection it should be remembered that it is wise to make at least one of the intravenous injections through the veins of the arm whenever there is a possibility of penetration of the abdominal vena cava. In this way it is usually possible to overcome the manifestations of shock sufficiently, even in severe wounds involving the major abdominal veins and some of the larger abdominal arteries, to permit anesthesia and rapid abdominal exploration for arrest of the hemorrhage and definitive operative repair. Any hemorrhage that occurs from the wound in the abdominal wall is usually controlled easily by the application of a sterile dressing applied with moderate compression.

Diagnosis of Extent of Injuries.—After treatment for shock and hemorrhage has been started, a rapid and thorough examination is necessary to determine whether the wound has penetrated or perforated the abdominal cavity and whether there are any associated injuries of the chest, head or extremities. If a wound which perforates a hollow viscus is thought to be nonpenetrating, the mistake is usually disastrous. In most instances, however, the diagnosis offers

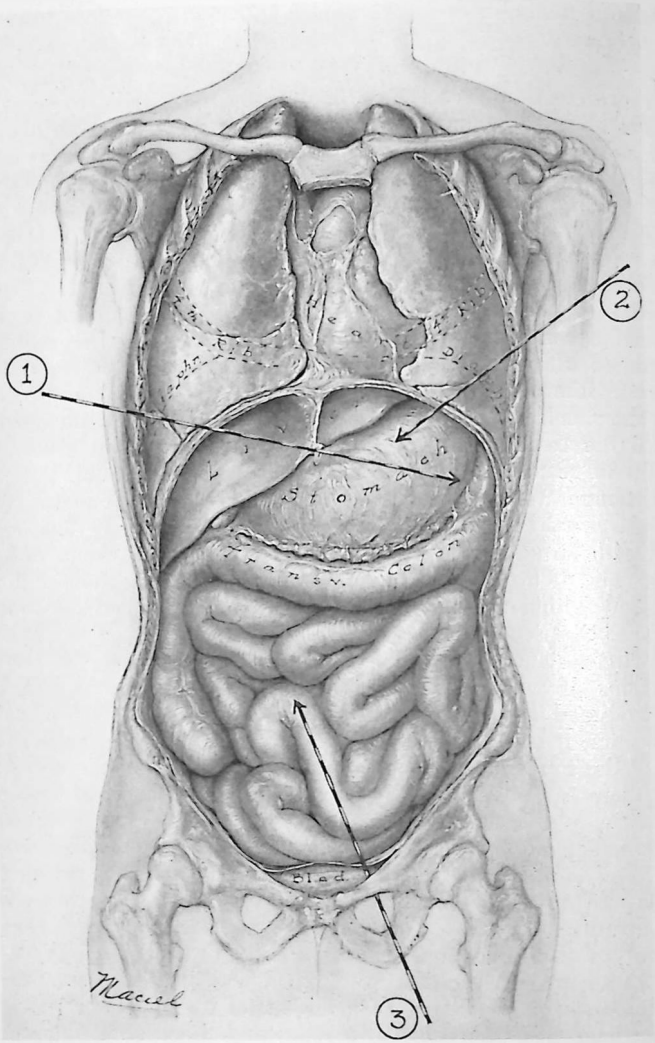

Fig. 474.—Semidiagrammatic and reconstructive drawing showing the anterior and lateral relations of thoracic cage to the diaphragm, pleural sacs, peritoneal cavity, and viscera. Note the vulnerability of upper abdominal viscera to penetrating injuries which first traverse the pleural sac and particularly to those which enter the chest below the fourth rib anteriorly.

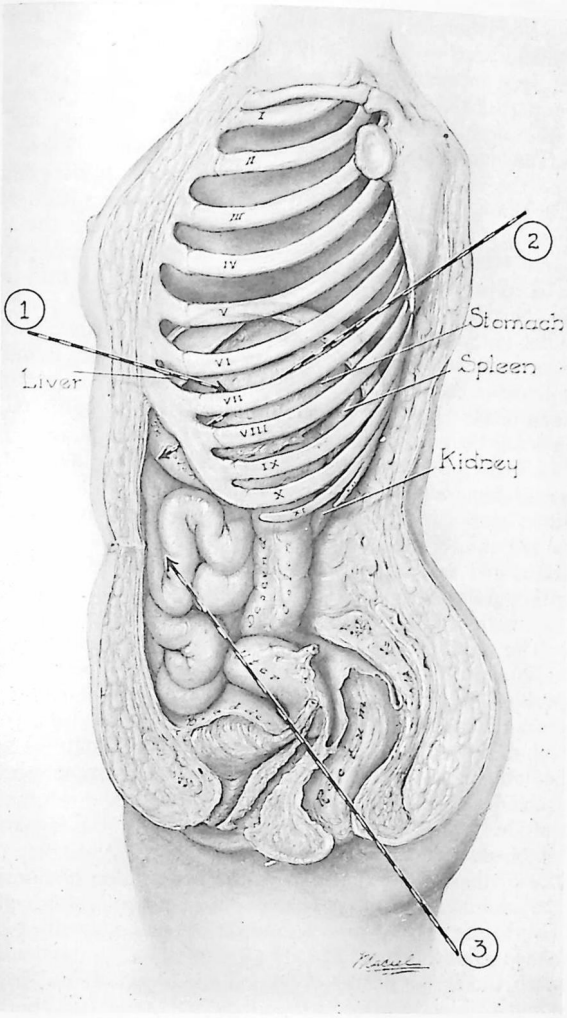

Fig. 475.—Semidiagrammatic left sagittal drawing through the left dome of the diaphragm which illustrates the relationship of the thoracic cage to the upper peritoneal and lower pleural cavities and which explains the frequency of combined penetration of both cavities in wounds involving the lateral and posterior aspects of the thorax and particularly those below the sixth rib posteriorly.

little difficulty since a study of the history, the wound, the physical signs, and the laboratory data will usually indicate its penetrating nature. Difficulty arises particularly in tangential or oblique wounds. It must be kept in mind that it is possible for wounds originating in almost any part of the body to involve the abdominal cavity and those between the nipple line and upper thighs frequently do. Single wounds of the lower posterior and lateral aspects of the chest, particularly on the left side below the level of the sixth rib, should be regarded as thoraco-abdominal until proved otherwise (Figs. 474 and 475). Puncture wounds of the anterior chest wall below the level of the fourth rib may also penetrate both the pleural and peritoneal cavities. A careful study of the points of entrance and exit helps to determine the pathway of the weapon and presence of penetration. If the bullet entered the skin obliquely, an area of abrasion is evident on the proximal side of the wound and one of undermining in the subcutaneous tissue is on the distal. When there is no wound of exit, an area of tenderness or the bullet often may be palpated immediately beneath the skin at the end of the tract.

When only the abdominal wall has been injured, shock, localized tenderness and guarding may be found, but they will subside or at most remain stationary if the injury is purely parietal. If signs of peritoneal irritation develop, such as decreased respiratory movements of the abdominal wall, diffuse tenderness, rigidity, rebound tenderness, a rising pulse rate, increasing leukocytosis, and tenderness on rectal examination, the perforating nature of the injury becomes apparent. The diminution or absence of audible peristalsis on auscultation is also a very valuable diagnostic sign. The demonstration of a pneumoperitoneum by percussion of diminished liver dullness and roentgen examination signifies perforation of a hollow viscus. Occasionally injuries confined to the chest, particularly those associated with a hemothorax or fractured ribs, may present upper abdominal tenderness and rigidity, but the absence of the other signs of peritoneal irritation help in the differential diagnosis. If the signs are not conclusive of penetration it may become necessary to explore the wound, but if there is any doubt as to the penetration or nonpenetration of the abdominal cavity, laparotomy and exploration offer less over-all risk to the patient than conservative management.

A specimen of urine should always be obtained immediately after admission to the hospital and examined for blood. If no urine or a small amount of bloody urine is found on catheterization, perforation of the bladder has occurred.

Chemotherapy.—Chemotherapy is indicated after any abdominal injury in which the peritoneal cavity has been soiled. We believe that the systemic administration of 3 gm. of sodium sulfadiazine preoperatively by intravenous injection is of definite value. Early in our

studies sulfanilamide was instilled into the peritoneal cavity and operative wound at the completion of the operation, but we have abandoned this practice in favor of the preoperative systemic administration of sulfadiazine. Our *in vitro* studies indicate that sulfadiazine is preferable to penicillin in the mixed gram-negative and gram-positive flora of intestinal organisms, and our clinical experience seems to bear this out. More recently systemic sulfadiazine and penicillin have been used concurrently.

EARLY OPERATIVE TREATMENT

It is imperative that the patient with a penetrating wound of the abdomen be operated upon as soon as his general condition will permit. Early operation within six hours of the time of injury is desirable and will result in a lower incidence of peritonitis. Throughout the operative procedure the transfusion of blood is continued as a safety measure. The treatment of other wounds which often accompany the main abdominal one requires judgment, but in general they assume secondary importance and are treated expectantly for the time being.

Anesthesia.—Operation is usually performed under inhalation gas and ether or cyclopropane anesthesia. Intubation is desirable particularly in upper abdominal injuries, and inhalation anesthesia under positive pressure may be required in associated thoracic wounds. Local and spinal anesthesia have not been practical at the Cincinnati General Hospital because so many of the patients with penetrating wounds of the abdomen are intoxicated and unruly.

Skin Preparation.—Preparation of the abdominal wall is carried out usually after the induction of anesthesia. If any viscera protrude through the penetrating wound, they are gently but thoroughly irrigated with a solution of physiologic sodium chloride and covered with sterile gauze. The abdominal skin up to the edge of the wound is then washed thoroughly with soap and water, painted with a skin disinfectant, and prepared for incision with sterile drapes.

Incision.—If the wound of entrance or exit is large, it is usually débrided and extended in a transverse or vertical direction for exploration. If the wound is small, it is usually disregarded and a separate vertical left or right rectus incision is made. In any event, a sufficiently large incision should be made to permit maximum exposure. The incision is made on the right side in most instances, which gives ample exposure for exploration of the entire contents of the abdominal cavity. In many of the thoraco-abdominal wounds the exposure has been limited and the technical procedure difficult through abdominal incisions. Military experience in the past war has demonstrated clearly the superiority of the thoracic approach for many of the high penetrating wounds of the chest and abdomen, particularly those involving the left upper quadrant.

Arrest of Hemorrhage.—When the abdomen is opened the immediate consideration is the arrest of hemorrhage which may have been increased by the induction of anesthesia and by the release of pressure. The removal of clots and liquid blood by mechanical suction aids in the recognition of the bleeding points. The blind application of clamps in a pool of blood may be disastrous and the surgeon unaccustomed to emergency surgery may become confused and lose valuable time at this point. Hemorrhage from many bleeding vessels may be temporarily controlled by digital compression. In the upper abdomen, compression of the portal vein, hepatic artery, or coeliac axis between the thumb and a finger inserted through the foramen of Winslow may help greatly in the control of bleeding.

Damage to the spleen is usually treated by splenectomy since attempts at repair are usually futile, wasting both time and blood. In the case of lacerations of the liver, persistent bleeding may be controlled by suture of the laceration, or in rare instances by packing. However, packing with gauze should be avoided whenever possible since it may be followed by infection and secondary hemorrhage. The use of gelatin sponge promises to aid in the control of this type of hemorrhage. Detached and devitalized portions of liver should be removed and a drain placed down to the wound to permit the escape of bile.

After the arrest of major hemorrhage, a delay of several or more minutes while the transfusion of blood is being continued may be followed by a prompt rise in blood pressure and general improvement of the patient's condition.

Suture of Perforations of Diaphragm.—The necessity for early recognition and closure by suture of all perforations of the diaphragm cannot be overemphasized. It minimizes pleural contamination and the danger of developing severe pleural infections, massive pneumothorax, or herniation of the abdominal contents. A sucking wound of the thorax may be produced as soon as the abdominal cavity is opened, and such wounds should be repaired immediately followed by aspiration of air and contaminated blood from the pleural cavity. If a perforation of the diaphragm is not sutured, a serious and often fatal putrid empyema may develop postoperatively.

Location and Repair of Injuries.—In order to locate every wound, it is necessary to examine thoroughly and systematically all of the abdominal contents. Demonstration of the points of entrance and exit through the peritoneum suggests the possible viscera damaged by the injury. Every section of the gastrointestinal tract must be demonstrated and carefully inspected for perforation. To do this, it is necessary to "run" the bowel and inspect the tract from the lower portion of the esophagus to the rectum replacing the loops of intestine immediately after inspection. In general the points of gastrointestinal per-

foration are easily recognized by the exposure and eversion of the punctured mucosa, the visible escape of gas and fluid, the dark brown or black discoloration of the adjacent tissues, the presence of food or feces in the peritoneal cavity or the presence of crepitation in retroperitoneal hematomas about the colon. If one perforation into the free peritoneal cavity is missed, the outcome is almost invariably fatal. The penetrating wounds most often overlooked are tangential ones located at the junction of the mesentery with the small intestine, those along the retroperitoneal surface of the transverse colon, rectum, pelvic portion of the colon or duodenum, and those of the posterior

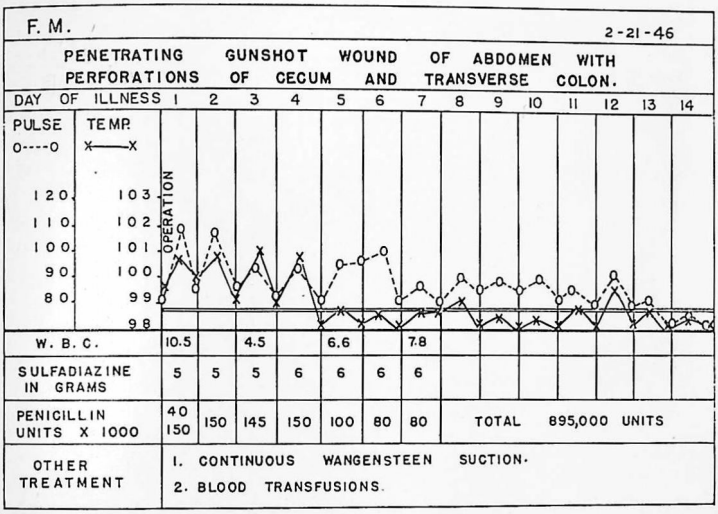

Fig. 476.—Chart showing the clinical course of a patient with penetrating gunshot wound of the transverse and ascending colon who was treated by early closure of the perforations without exteriorization of the colon.

aspect of the stomach. In both the large and small intestine, hematomas in the mesentery may hide perforations in the mesenteric border.

All perforation of the gastrointestinal tract must be closed and most of them can be repaired by inverting Lembert or mattress sutures of fine black silk rather than by resection. When resection is necessary in more extensive wounds, primary anastomosis is preferred to exteriorization in civilian practice and it is usually done by the closed end-to-end method over Kocher or Stone clamps using fine black silk for suture material. At the Cincinnati General Hospital, injuries of the large bowel have also been treated with good results in the same way

as those of the small bowel without attempt to exteriorize them (Fig. 476).

Wounds of the rectum should be repaired whenever possible and thoroughly drained. A proximal colostomy should never be omitted in wounds of the rectum, however trivial they may appear to be. A left inguinal colostomy is usually desirable, but when it is evident that mobilization of the rectum will be required for any subsequent repair, a transverse colostomy is advisable to facilitate this.

A careful inspection must be made for injuries of the other retroperitoneal structures which may be concealed by a hematoma. If

Fig. 477.—Illustrating the appearance of the wound closed ten days previously with through-and-through silver wire sutures. The contaminated retroperitoneal tissues had been drained through the right flank wound and two "cigarette" drains have just been removed. Note the absence of infection in the operative wound.

necessary, the kidneys and their pedicles may be exposed transabdominally through an incision in the peritoneum lateral to the ascending or descending colon followed by the reflection of the bowel and its mesentery medially. Small wounds of the kidney may be sutured but wounds of the kidney with active hemorrhage or severe fragmentation are best treated by nephrectomy after making sure that a second good kidney is present.

Perforations of the bladder should be sutured in layers followed by cystostomy or insertion of a retention catheter. Wounds of the ureter must be detected and repaired, preferably over ureteral catheters.

Before closure, particles of feces, shotgun wadding, pieces of food, detached portions of viscera, accessible projectiles, bits of clothing,

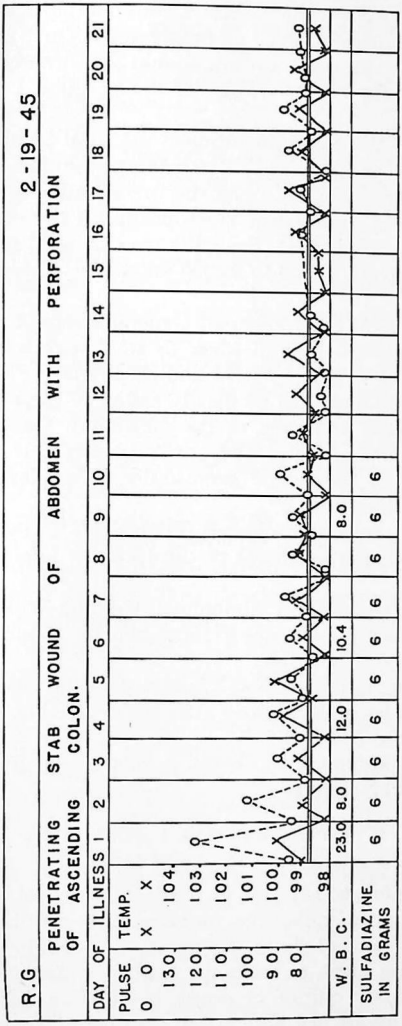

Fig. 478.—Chart illustrating the clinical course of a patient with a penetrating wound of the abdomen and perforation of the ascending colon under treatment by systemic sulfadiazine in addition to early operative closure of the perforation. (Solid line, temperature; broken line, pulse.)

fragments of bone, sponges used for exposure or hemostasis, and liquid or clotted blood are removed from the peritoneal cavity. Bul-

lets not readily accessible are not removed. Lavage is not done. The use of postoperative drainage is a matter of judgment and depends upon a number of factors. In most cases, drainage of the peritoneal cavity is considered useless unless there is considerable damage to structures such as the pancreas, liver or biliary tract. On the other hand, contaminated retroperitoneal tissues should be drained through a stab wound in the flank after closure of the peritoneal wound (Fig. 477).

Chemotherapy.—We have discontinued the local instillation of sulfanilamide into the peritoneal cavity for the prevention or control of infection and prefer to depend upon the preoperative and postoperative administration of sulfadiazine systemically for the control or prevention of infection (Fig. 478). Penicillin may be used in conjunction with sulfadiazine giving 15,000 to 20,000 units every three hours (Fig. 476).

Wound Closure.—At the Cincinnati General Hospital the wound is closed with through-and-through silver or steel wire sutures according to the method described by Reid and Zinninger.[25, 26] This method of closure (Fig. 477) seems to be ideally suited to these cases, and it has been used almost routinely at the Cincinnati General Hospital during the past thirteen years. The advantages of this method are:

1. Rapid closure of the wound even under difficulties arising from unsatisfactory anesthesia.
2. Secure closure which is affected relatively little by infection or slough of the fascia; the incidence of disruption is minimal with this method.
3. Closure of contaminated abdominal wounds without burying suture material which predisposes to more benign wound healing and reduces the liability of infection.
4. Easy reopening of the incision by untwisting the wires if a second operation becomes necessary shortly after the original one for delayed hemorrhage or obstruction.
5. Incidence of postoperative ventral hernia is not greater than in more formal types of closure.

POSTOPERATIVE CARE

After operation, the patient is returned to his bed and placed in semi-Fowler's position which aids in the localization of intra-abdominal infection. General supportive measures are continued immediately after operation, and fluids by mouth are withheld. Adequate parenteral fluids are given to maintain positive water and electrolyte balance and a urinary output in excess of 1000 cc. per day. Blood and plasma transfusions are also given postoperatively as indicated.

Continuous gastric suction is maintained by Wangensteen's method until active peristalsis returns and gastric retention ceases. The de-

compression afforded by the immediate use of gastric suction tends to place the bowel at rest and to prevent gastric and intestinal distention resulting from postoperative ileus. Repeated auscultations of the abdomen usually show a return of peristaltic sounds on the second postoperative day. If there is any question of the adequacy of peristalsis, it may be tested by aspirating for gastric residual after the patient has been allowed to drink one ounce of water every one-half hour for five or six hours with the tube clamped off. If the residual is less than two ounces, it may be safely assumed that peristalsis is adequate and fluids by mouth may be started. If more than three ounces, it is usually wiser to leave the tube in another day and repeat the test.

Chemotherapy by the systemic administration of 3 gm. of sulfadiazine subcutaneously every twelve hours is continued until it can be given by mouth in doses of 1 gm. every four hours, being carefully controlled by the usual means for early detection of toxicity. The blood levels are measured daily or every other day and the dose is adjusted to maintain a blood level of 6 to 10 mg. per cent. It is our impression that the intelligent use of sulfonamides has been largely responsible for the elimination of peritonitis as a major cause of death in penetrating wounds of the abdomen. Penicillin may also be given parenterally in conjunction with sulfadiazine, injecting 15,000 to 20,000 units every three hours intramuscularly.

Vigilance is necessary to detect the presence of various complications which are prone to occur during the postoperative period and which must be treated as they develop. The most common ones in our experience include pulmonary atelectasis, pneumonia, pleural empyema, wound infection, intra-abdominal abscess, peritonitis, hemothorax, delirium tremens, intestinal obstruction, retroperitoneal cellulitis and thrombophlebitis. Dehiscence did not occur in any of the wounds closed by the method described and wound infections were decreased in frequency and severity.

An analysis of 161 consecutive cases of penetrating wounds of the abdomen or chest and abdomen in which the patients were admitted to the Receiving Ward of the Cincinnati General Hospital between January 1942 and May 1946 is of interest. Three of these patients were moribund on admission and died within forty-five minutes in the receiving ward as a result of severe hemorrhage. Two others died on the operating table also as the result of exsanguinating hemorrhage. In the remaining 156, there were eighteen deaths, giving a mortality rate of 11.5 per cent for those cases which survived long enough to be operated upon. For all cases admitted including those in which death occurred within ten minutes after the patient's arrival at the hospital, the over-all mortality rate was 14.2 per cent.

There were thirty-four thoraco-abdominal wounds in this series

with nine deaths, or a mortality rate of 26.4 per cent which emphasizes again the severity of this type of injury and suggests the possibility that the thoracic approach might be used to greater advantage.

The causes of death and their incidence in this series are shown in Table 1. Hemorrhage with severe shock was responsible for 30.4 per cent of the deaths, and pneumonia and acute putrefactive empyema were the next most important causes. In later cases it has been possible to control the putrefactive empyema by routinely closing all perforations of the diaphragm at the time of operation, by early diagnosis, and by drainage either by repeated aspirations or preferably by thoracotomy used in conjunction with the local injection of penicillin and the systemic administration of sulfadiazine and penicillin.

TABLE 1.—COMPARISON OF THE INCIDENCE OF THE CAUSES OF DEATH IN PENETRATING WOUNDS OF THE ABDOMEN BEFORE AND AFTER CHEMOTHERAPY

104 Cases Admitted between January 1938 and January 1942		161 Cases Admitted between January 1942 and May 1946	
Cause of Death	No. Cases	Cause of Death	No. Cases
Peritonitis	9 (31.0%)	Hemorrhage	7 (30.4%)
Hemorrhage	7 (24.1%)	Pneumonia	4 (17.4%)
Shock	6 (21.3%)	Putrefactive empyema	4 (17.4%)
Pneumonia	5 (17.2%)	Peritonitis	2 (8.7%)
Uremia	1 (3.4%)	Meningitis	2 (8.7%)
Retroperitoneal cellulitis	1 (3.4%)	Uremia	1 (4.3%)
		Undetermined	1 (4.3%)

If the diagnosis is confused with postoperative pneumonia and drainage is not instituted, the infection progresses rapidly and soon produces a severe state of toxemia. Figure 479 shows the charted course of a penetrating wound of the abdomen which developed a fatal putrefactive empyema. In this case the perforation of the diaphragm had not been sutured, the diagnosis was delayed, drainage by thoracotomy was too late, and chemotherapy with penicillin was not given.

Significantly, peritonitis was a contributing cause of death in only two instances, and these were due to a perforation of the duodenum which was overlooked in one case, and to a leaking suture line of the duodenum in the other. Thus, peritonitis was largely eliminated as a cause of death, apparently by the use of adequate chemotherapy with systemic sulfadiazine or penicillin and sulfadiazine used in conjunction with early operative repair of all perforations.

In contrast, a study of 104 cases with penetrating wounds of the abdomen treated without chemotherapy in the four years preceding

January 1942 at the Cincinnati General Hospital showed that the mortality rate was 27.9 per cent. Significantly, generalized peritonitis was responsible for 31 per cent of the deaths (Table 1). A comparison of the incidence of the causes of death in the two series indicates that several changes have occurred since the advent of chemotherapy.

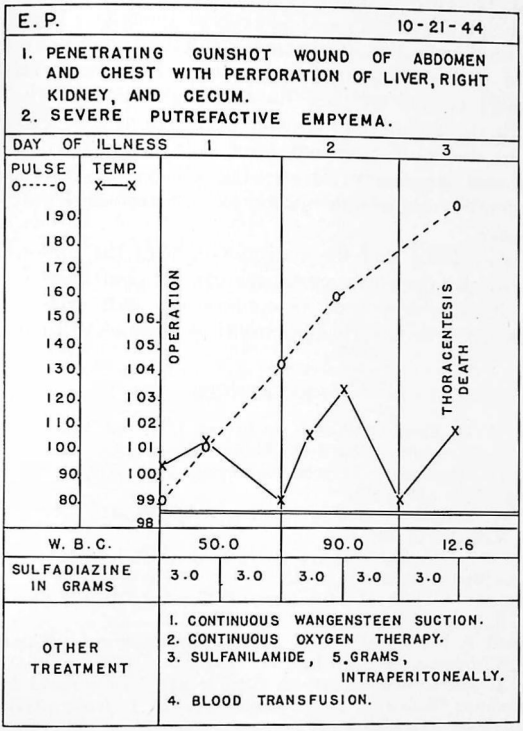

Fig. 479.—Acute putrefactive empyema with profound toxemia developing in a penetrating thoraco-abdominal wound which resulted in death. In this case the puncture wound of the diaphragm had not been closed, the diagnosis was delayed, and treatment including drainage was started too late.

In the four years prior to that time peritonitis accounted for 31 per cent of the deaths, hemorrhage 24.1 per cent, severe shock 21.3 per cent, and pneumonia 17.2 per cent. Since 1942 the incidence of hemorrhage and pneumonia as causes of death has remained essentially the same, being 30.4 per cent and 17.4 per cent respectively, but that of peritonitis and severe shock has been significantly reduced.

SUMMARY

Although massive hemorrhage from injuries to the major vessels of the abdomen and lower chest, particularly the aorta and vena cava, remains a serious cause of death, the mortality rate in penetrating wounds of the abdomen has been significantly reduced for a number of reasons. The early and liberal use of whole blood and blood substitutes has helped to overcome the effects of shock and hemorrhage and has permitted operation under more suitable conditions in a larger number of patients. Laparotomy performed on better risk patients permits more careful and less hurried exploration of the peritoneal cavity with the result that visceral perforations are seldom missed. Damage to the gastrointestinal tract, solid viscera, diaphragm and retroperitoneal structures can be investigated and adequately repaired, thereby minimizing peritoneal, pleural and retroperitoneal contamination.

There is evidence that the contamination of the abdominal cavity remaining under these circumstances can be controlled by adequate systemic chemotherapy used in conjunction with early surgery and that sepsis has been greatly minimized as a cause of death.

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THE MANAGEMENT OF MEGACOLON (HIRSCHSPRUNG'S DISEASE)

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MEGACOLON is a rare disorder of the large bowel which has resulted in hypertrophy and dilatation of the affected parts of the colon. Clinically it is characterized by abdominal distention and obstipation. From the therapeutic standpoint it is important to differentiate between the idiopathic variety of megacolon and other similar conditions in which the hypertrophy or dilatation of the colon is secondary to some congenital or acquired obstruction to the fecal stream in the distal portions of the intestinal tract.

The clinical condition of megacolon was first described by Fredrick Ruysch[1] in the seventeenth century and more than a score of authors had recorded similar cases in the scientific literature before Harold Hirschsprung[2] published his classical account of the syndrome in 1888. He popularized the condition and added considerably to our knowledge of certain types of megacolon so we have come to refer to the congenital or idiopathic variety of megacolon as "Hirschsprung's disease." His original definition was "a condition of congenital high-grade dilatation of the colon with thickening of all its tunics, especially the tunica muscularis, with retention of large quantities of fecal matter."

The idiopathic form of megacolon is from three to four times more frequently observed in boys than in girls, and the congenital origin of the disturbance has been shown by the demonstration of the characteristic changes in the colon of an unborn fetus of seven months' gestation.

A few decades ago most of the infants with megacolon died before they reached the age of five years and those children with the less severe varieties of the disturbance rarely reached adult life. Complications such as bronchopneumonia, myocardial failure, volvulus of the colon with perforation of the wall and generalized peritonitis are still the most common causes of death during early life in patients with megacolon. In recent years, however, the important advances which have been made in the supportive treatment by the pediatrician, the improved dietary, medical and surgical therapy and the

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better understanding of the pathologic physiology of the disturbance have all played a part in the improvement of the prognosis of this type of megacolon.

THEORIES ON GENESIS OF MEGACOLON

Defective Muscular Tone of Bowel.—One of the earliest theories relative to the etiology of megacolon was that a segment of the colon was paralyzed or possessed defective muscular tone. Spasm of the anal sphincter muscles with secondary dilatation and hypertrophy of the colon proximal to the rectum was described by Fenwick.[3] However, more interest was centered about disturbances of the visceromotor mechanism of the colon and Hurst[4] suggested that megacolon was due to failure of the sphincter muscles of the anal region to relax when the normal colonic peristalsis reached the rectum.

There are considerable experimental and clinical data to support the theory that megacolon results from this type of failure of coordination which leads to dysfunction of the neuromuscular apparatus of the colon and rectum. In patients with megacolon the affected part is not paralyzed in spite of the fact that it is greatly dilated. Vigorous and even painful peristaltic movements of the colon are regularly observed when the wall of the colon is thickened. When these patients develop intestinal obstruction we find the usual clinical signs and symptoms of mechanical obstruction; yet at operation or at autopsy there may be no demonstrable kinking or twisting of the colon. It is thought that the colon must be contracting against a closed sphincter muscle which fails to relax or it is contracting against some valvular type of obstructing mechanism. Clinicians have reported considerable improvement after manual dilatation of the anal sphincter muscles and after the systematic use of rubber bougies to bring about dilatation of the anal canal and the rectum.

Increased Plastic Tone of Bowel.—Wade and Royal[5] suggested that megacolon was the result of increased postural or plastic tone of the bowel which is mediated through the action of the sympathetic nervous system just as it is in regard to striated or skeletal muscles. This theory has since been shown to be incorrect, nevertheless it was responsible for opening the vast field of surgery of the sympathetic nervous system in the management of megacolon. Even though their theory of action of the operation is probably incorrect, the end results following properly performed sympathetic denervation of the colon in selected cases of megacolon are surprisingly good and should always receive careful consideration in planning out the management of patients with megacolon.

Sympathetic-Parasympathetic Imbalance in Bowel.—Two etiologic hypotheses are possible in this neurogenic theory of the origin of megacolon. Firstly, the excessive sympathetic activity (afferent impulses) may give rise to loss of tone of the wall of the bowel with secondary distention of the affected portion of the bowel, or, secondly, the diminished tonus of the parasympathetic innervation of the colon and its associated inefficient relaxation of the anal sphincter muscles may disturb the physiologic equilibrium and thus give rise to dilatation of the colon. Overactivity of the sympathetic nerves to the colon is difficult to demonstrate clinically and diminished tonus of the parasympathetic nerves can be demonstrated clinically only by the use of cholinergic drugs.

The lack of coordination between the proximal and distal portions of the colon seems to be the most probable cause of congenital megacolon. In order to understand this mechanism we must familiarize ourselves with the extrinsic as well as the intrinsic innervation of the colon. Peristalsis is a coordinated neuromuscular activity which is dependent upon mechanical and chemical stimuli arising from food being carried along the intestine but acting through the extrinsic nerves and upon the intrinsic nervous plexuses of the bowel. The upper lumbar nerves bring

in the sympathetic impulses while the lower sacral nerves carry the parasympathetic impulses to the distal portion of the colon. The first and second lumbar segments of the spinal cord give exit to those sympathetic nerves which pass through the lumbar sympathetic ganglionated trunks and the lumbar splanchnic nerves into the inferior mesenteric and hypogastric plexuses and then on to the colon. These sympathetic fibers are also intimately associated with the circular muscle fibers of the rectum.

Stimulation of the sympathetic nerves will inhibit colonic peristalsis and tighten the internal sphincter muscle of the anal region. Stimulation of the superior hypogastric plexus (presacral nerve of Latarjet[6]) of sympathetic nerves gives rise to pelvic pain in addition to constriction of the internal sphincter muscle. Stimulation of the parasympathetic fibers from the sacral outflow or irritation of the ganglion of Frankenhäuser in the pelvis will greatly increase peristalsis and cause relaxation of the sphincter muscles of the anal region.

PATHOLOGICO-PHYSIOLOGIC CONSIDERATIONS

The surgical interruption of the sympathetic nerves to the distal portion of the colon results in a release of rectosigmoidal inhibition and is often followed by evacuation of the lower part of the colon as the sphincter muscles of the anal canal become relaxed. Overdistention of the colon must be combated by all available means for there are many unfavorable effects which may result from prolonged, maximal distention of the bowel. Wangensteen[7] has described many of these untoward effects in his monograph on intestinal obstructions. He pointed out that the gaseous content of the bowel after obstruction of the sigmoid colon contains only a small amount of oxygen and carbon dioxide and an overwhelming amount of nitrogen. When the intracolonic pressure rises there is a marked diminution in the blood flow to the walls of the bowel. Under such circumstances the colonic pressure may rise from 12 to 52 cm. of water. This, according to Wangensteen, exerts a pressure of 735 cm. of water against each cubic centimeter of surface of the cecum and 340 cm. of water pressure against the wall of the descending colon. This difference in pressure within the colon accounts for the frequency of perforation of the cecum in late or neglected cases of obstruction of the large bowel.

Increased intracolonic pressure also influences the absorption from the bowel. The absorption of dyes or bacteria by the lymphatic vessels is greatly enhanced in all cases of chronic intestinal obstruction and the absorption of materials into the veins or by the peritoneal surfaces is also modified when the bowel is greatly distended. Most of the patients with megacolon who come to operation show enlarged lymph nodes in the mesentery and usually show enlarged lymph channels on the surface of the bowel and in the mesentery. Such lymphangiectasis was considered by Finney[8] as a cause for megacolon.

Physiologic research directed toward the identification of the chemical substances which the autonomic nervous system utilizes to activate the tissues led to the production of the cholinergic drugs. Loewi

showed that the activity of the intestine is increased by its contained choline derivatives. Choline is changed into acetylcholine and acts as a peristaltic hormone which generally increases the intestinal activity. In 1921 Loewi[9] demonstrated the relationship between acetylcholine and its parasympathetic stimulative action. Dale[10] later showed that acetylcholine is released at all parasympathetic nerve endings on stimulation of these nerves, consequently it serves as a potent chemical mediator in transmitting the excitatory effect from the nerve endings to the reacting cells. The administration of acetylcholine increases the function of the parasympathetic nerves and stimulates peristalsis in the colon.

Klingman[11] found that atropine sulfate gave satisfactory response despite the unpleasant toxic effects, so he concluded that the parasympathetic nervous system played an important role in the production of the disturbed neuromuscular function in patients with megacolon.

How a drug which supposedly acts exclusively as a paralyzer of the parasympathetic nerves can actually become effective in establishing better bowel function in megacolon is difficult to explain. Klingman is of the opinion that, with overaction of the parasympathetic nerves, the retention of feces in the colon results from an inability of the longitudinal muscle fibers to expel the feces without help from the circular fibers of the colon. In neurogenic megacolon these circular fibers of the colon are too completely relaxed. In such a case the parasympathetic paralysant would reduce the inhibitory effect so one should expect some action from the circular muscle fibers.

Still another explanation for the action of a parasympathetic paralysant was given by Loewi when he showed that a drug like atropine inhibits the action of the parasympathetic nerves not by paralyzing, as had been previously supposed, but by stopping or preventing the action of acetylcholine in or near the reacting cells. He also pointed out that when a complete balance exists between cholinergic and adrenergic substances, atropine acts as a synergist to the adrenergic factor by removing the cholinergic factors. Myerson's experiments support this theory.[12] In particular reference to the gastrointestinal tract, the tonus of the rectosigmoidal apparatus may be diminished by adrenergic action following the administration of a parasympathetic paralysant.

Another explanation of this action comes from the effect that the parasympathetic paralysant may have when it acts as an inhibiting factor to the liberation of acetylcholine in the tissues. Aside from being liberated in very small quantities, ordinarily at the termination of the parasympathetic nerves, acetylcholine is also present in small quantities at the termination of the sympathetic fibers at the junction of the preganglionic and postganglionic fibers. A drug which reduces

the liberation of acetylcholine at this junction might sufficiently reduce the overactivity of the sympathetic nerves to bring about a better balance between the two elements of the innervation of the colon.

In some respects the use of a parasympathetic paralysant is almost paradoxical and one is forced to accept it on the grounds that it is effective in spite of the fact that the mechanism by which it acts is still unexplained. Whatever the explanation might be, clinical experience has demonstrated that the drugs which act exclusively as paralyzing agents to the parasympathetic nerves are beneficial in establishing better emptying of the bowel in certain cases of megacolon.

Atropine should be the drug of choice to inhibit the liberation of acetylcholine but its highly toxic effects contraindicate its regular clinical use. Syntropan (Roche) was found to have an effect similar to atropine on the parasympathetic nerve endings of reacting cells. It controls the tonus of the bowel without interfering with the peristaltic activity. The toxic dose is about twice that of atropine, and the administration is not accompanied by the disagreeable effects upon the heart and circulation, the pupils or the glandular secretions. Its effect on the colon is also much greater than that of atropine and it has no atropine-like action on the small intestines. The effective dose of syntropan is also much more readily reached without the appearance of any toxic signs or symptoms.

DIAGNOSIS OF MEGACOLON

The diagnosis of megacolon, except in very early infancy, is relatively easy and can be made on the basis of the following three cardinal findings: (1) obstinate constipation, (2) marked enlargement of the abdomen, and (3) visible peristalsis on inspection of the abdomen.

The clinical history shows that these patients rarely have spontaneous bowel movements and they may even go weeks or months without proper evacuation of the colon. Examination of the stools usually reveals large amounts of indigestible foods which had been ingested weeks before. Some patients develop periods of diarrhea as a result of the irritation from impacted feces in the lower portion of the colon.

The young children with megacolon are usually small and frail and fail to gain weight properly. Their general state of nutrition is poor because of the anorexia and the toxemia which result from the long-standing fecal stasis. The victims of this malady usually show marked muscular weakness, and complain of headaches and weakness generally. The skeletal muscles are soft and flabby. There is marked retardation in the development of secondary sexual characteristics in those who reach the age of puberty.

The abdomen may assume tremendous proportions and the enlargement is usually in the portion of the abdomen above the umbilicus.

There is usually marked flaring of the costal margins and the diaphragms may be pushed up into the chest and encroach upon the intrathoracic organs (Fig. 480). The skin of the abdomen is usually thin and shiny and on percussion the abdomen is usually tympanitic in spite of the fact that large masses of fecal material can be palpated along the course of the colon (Fig. 481). As a rule, there is no free fluid in the peritoneal cavity in the early cases but in the advanced forms of megacolon definite evidence of ascites is usually present. Deep peristaltic waves are often visible over the abdomen and gurgling sounds may be heard either with or without the stethoscope.

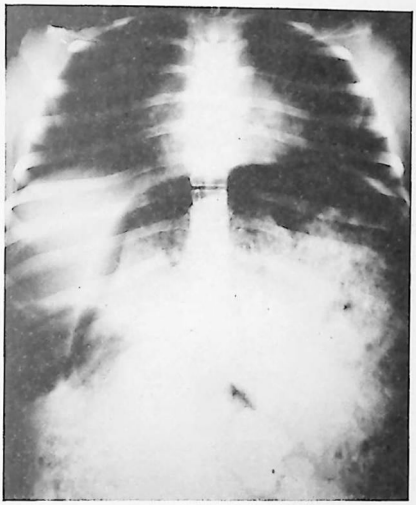

Fig. 480.—Roentgenogram showing severe congenital megacolon. Note flaring of the costal margins and compression of the liver, heart and lungs from the enlarged colon and elevated diaphragms.

Most of the patients with megacolon have an elongated or redundant sigmoid colon and a loop of the sigmoid colon may extend up under the right lobe of the liver (Fig. 482). Sudden complications may occur in the form of ulceration of the wall of the colon or perforation of the colon due to volvulus of the long sigmoid loop. Such complications may result in death rapidly unless the complication is promptly recognized and properly treated.

In infants the diagnosis may be extremely difficult. The abdomen is enlarged and visible peristaltic waves over the abdomen may give the clue to the nature of the intestinal disturbance. Diarrhea may alternate with constipation or the diarrhea may predominate for the

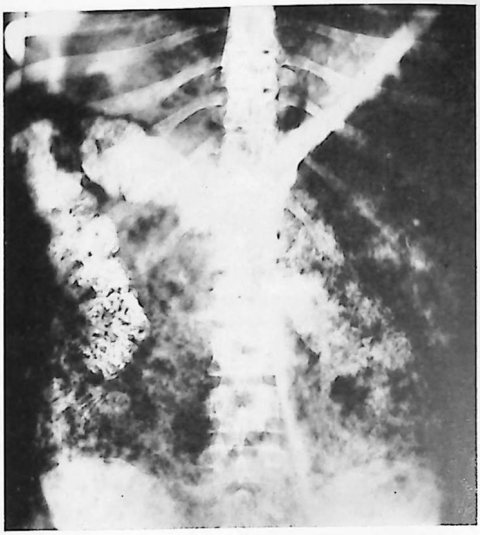

Fig. 481.—Roentgenogram of young girl with megacolon involving descending colon and sigmoid. Note ascending and transverse colon are about normal size. Large masses of fecal material and barium in the distal part of the colon.

Fig. 482.—Barium enema showing elongated and enlarged sigmoid colon which extends along the right side of the abdomen and pushes the liver upward and outward.

first few weeks of life. Persistent vomiting during the first few weeks of life is not uncommon. When an infant presents these signs and symptoms one should suspect congenital megacolon but careful differential diagnosis must be made to rule out congenital duodenal obstruction, celiac disease, tuberculous peritonitis and rickets. Mechanical obstruction in the rectum must be ruled out by digital or proctoscopic examination. If the child's condition will permit, the colon should be thoroughly cleansed and a thin suspension of barium should be instilled slowly through the rectal tube so the size and shape of the lower portion of the colon can be determined accurately on the

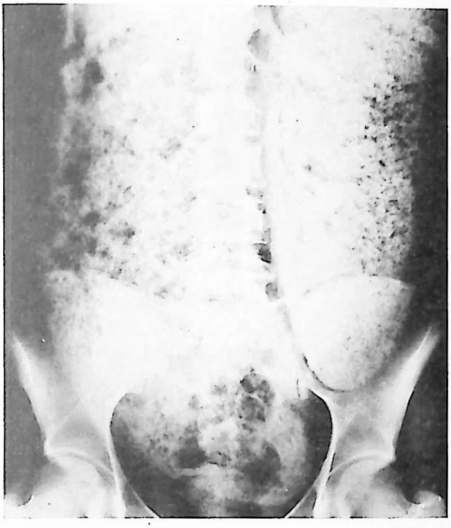

Fig. 483.—Roentgenogram showing barium mixed with fecal matter three weeks after small amount of barium was given by mouth.

roentgenograms. Contrast enemas using a small amount of air in the colon frequently help in the roentgenologic interpretations. If the colon is very large it is very important to evacuate all of the barium from the colon by mechanical or medicinal means, otherwise serious fecal impaction may result.

In older children and in adults the palpation of the abdomen gives the impression of a doughy consistency of the intra-abdominal contents, and frequently masses of varying sizes can be seen and felt along the course of the descending colon and the sigmoid colon (Fig. 483). The masses may vary in consistency from that of thick dough to that of hard putty. These masses are readily recognizable as fecal-

iths since pressure over the mass with the finger usually leaves an indentation in the mass. The masses may be found in any part of the abdomen.

It must be remembered that congenital megacolon may exist in the adult patient and remain as a latent or asymptomatic disturbance for many years (Fig. 484). In such patients the muscular dysfunction is compensated for and spontaneous bowel movements are frequently possible. These patients rely mostly on enemas of various types for regular evacuation of the lower portion of the colon. In spite of the

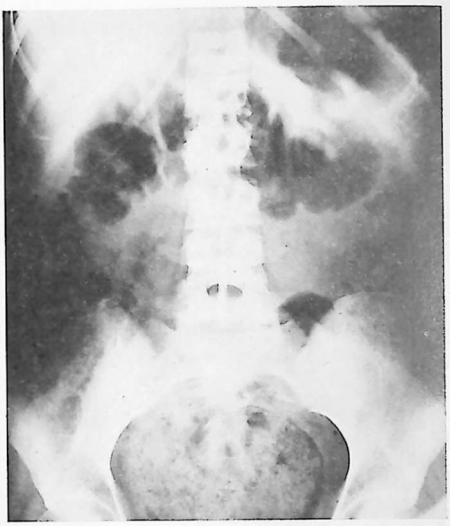

Fig. 484.—Roentgenogram showing the latent or asymptomatic megacolon with primary involvement of the sigmoid colon in an adult.

apparent satisfactory functioning of the colon the anatomic or pathologic changes may be very extensive and the serious complications of volvulus, perforation, peritonitis or massive fecal impaction may take place at any time.

PATHOLOGICAL CHANGES IN MEGACOLON

Analysis of the gross pathological changes in the colon of patients with congenital megacolon reveals that about 33 per cent of them have involvement of the sigmoid colon alone. Bartle[13] is of the opinion that the sigmoid colon is invariably involved but always in conjunction with other adjacent portions of the large bowel. Analysis of the cases which have been observed at the Mayo Clinic shows that 42.3

per cent had involvement of the rectum and 11.5 per cent had involvement of the cecum. The parts of the colon proximal to the hepatic flexure were involved in 26.9 per cent of their cases. In all of our cases of congenital megacolon there was involvement of the sigmoid colon and the portions of the large bowel immediately adjacent and proximal to the sigmoid colon.

In the congenital variety of megacolon the wall of the affected portions of the colon is greatly thickened and presents the physical characteristics of thick, wet leather (Fig. 491). The blood vessels on the surface are enlarged and the lumen of the bowel is usually ten to twenty times enlarged. The taenia and the haustra are absent and the epiploic appendices and the mesentery are thickened and elongated. Many large lymph nodes are embedded in the thickened mesentery. The sigmoid colon is usually elongated and because of its elongated mesentery it may present several extra loops. This is of particular importance because it predisposes to volvulus and secondary perforation of the colon.

Adamson and Aird[14] found that the nerves of the colon were enlarged but this increase in size was due to fibrous tissue rather than to any numerical increase in nerve fibers. The increase in the size of the nerves is only part of the general increase in connective tissue throughout the mesocolon.

The involved parts of the colon show signs of chronic inflammatory changes such as hypertrophy, fissures, ulcerations and even an ulcerative type of colitis with perforation of the colonic wall. Chronic lymphatic stasis was usually present with some cystic degeneration in the lymph nodes. The ganglion cells and fibers in the plexuses of Auerbach have been found to be smaller and many of the ganglia were imperfectly formed.

THE TREATMENT OF MEGACOLON

General Measures

After the diagnosis of megacolon has been established the patient should be hospitalized for further evaluation and study of the type of abnormal function of the bowel. When these patients are brought into the hospital the distal part of the colon is usually packed with feces and often large fecal concretions are found which cause subacute colonic obstruction with marked gaseous distention of the entire colon.

This fecal matter must be carefully removed by using repeated cleansing enemas of warm, soapy water together with the oral administration of mineral oil and if necessary the instillation of mineral oil into the colon by means of a rectal tube.

As the first step in the management of megacolon a careful rectal

examination with the gloved finger must be done to make certain that there are no congenital strictures in the rectum. If, however, such strictures are present they must be treated by regular dilatation with the finger or with soft rubber bougies before any other form of treatment is instituted. These strictures are usually situated 1 or 2 cm. from the anus so the child's mother or the nurse can be taught to carry out the manual dilatation regularly. Occasionally these strictures are firm and unyielding and must be treated surgically in order to overcome the obstruction.

Rectal dilatation has been systematically employed by Hurst who advises the use of soft rubber bougies of increasing size to induce better relaxation of the internal sphincter muscles. Such mechanical dilatation of the anal canal and the rectum may be of real value and should always be part of a well planned medical regimen. Adolescent children and young adults have reported many weeks of relief following a single manual dilatation of the sphincter muscles and evacuation of the contents of the lower portion of the colon. Such forceful dilatation of the rectum should always be carried out under general or spinal anesthesia. Overstretching of the sphincter muscles usually leads to a short period of fecal incontinence.

A great variety of medical and surgical methods of treatment have been advocated in the management of congenital megacolon. It is our firm belief that every patient with megacolon must first be carefully studied by the pediatrician or by the internist and all available conservative methods of management should be given a fair trial before any surgical intervention is contemplated. It is a well established fact that children under four years of age do not tolerate surgical operations well and we believe they should not be exposed to the hazards of extensive surgical operations unless perforation of the colon or volvulus makes such an operation imperative.

It is sometimes extremely difficult to decide whether conservative management should be continued or whether some surgical procedure should be advocated. The age of the patient and the extent of the involvement of the colon usually serve as valuable guides for therapy since young children should always have the benefit of prolonged medical treatment and those children over five years of age with extensive involvement of the colon should have the benefit of properly planned and executed surgical treatment. The sudden development of some serious complication like intestinal obstruction, volvulus or perforation makes surgical intervention necessary regardless of the general condition of the patient. The surgeon must then rely upon supportive measures to help tide the patient over the critical phase after operation.

Obviously there are many children who are suffering from chronic constipation and present roentgenologic evidence of some anatomic

anomaly of the colon such as an undescended cecum, a mobile cecum or a redundant loop of the sigmoid colon. Our experience has proved that this type of condition can usually be adequately cared for by special training and conservative measures alone.

Medical Measures

As a remedial agent the use of acetylcholine is limited because it is rapidly hydrolyzed to less active substances by certain esterases in the blood stream. Oral administration of this drug is not effective and the results from the parenteral administration are inconstant unless the dosage is so large that the peristaltic action is overshadowed by the undesirable toxic manifestations of the drug. Although it is physiologically potent, its instability and its frequent alarming toxic effects after parenteral use have discouraged its use in the medical management of megacolon.

In the early part of 1935 the chemical compound of *acetylbetamethylcholine* (mecholin and mecholyl) became available and the problem of the medical management of megacolon began to change. This chemical substance was synthesized by Major and Cline[15] and chemically it is a derivative of acetylcholine. It has the advantageous pharmacological properties of acetylcholine but it is much more stable in the tissues. When given orally it produces definite and continuous stimulation of the parasympathetic nerves usually without untoward toxic manifestations. It slows the heart action, lowers the systemic blood pressure, dilates the peripheral blood vessels, stimulates the sweat glands to greater activity, increases the tone of the intestines and stimulates peristalsis. It may constrict the bronchioles and incite an asthmatic attack and in large doses it may produce abdominal pain and vomiting. The ill effects of this drug can be abolished immediately by the subcutaneous injection of as little as $\frac{1}{400}$ grain of atropine sulfate.

Experience has shown that the optimum times for the administration of acetylbetamethylcholine bromide are (1) thirty to sixty minutes *after* breakfast, (2) in the midafternoon, or (3) at any juncture to parallel and enhance an observed daily intestinal rhythm.[16] If the drug is given *before* breakfast we have found that the patients usually develop the toxic manifestations of nausea, vomiting and abdominal pain. This drug should be administered for a period of from five to ten days if we expect the autonomic imbalance to be corrected with the establishment of the new reflexes which are necessary to regulate intestinal function.

An *average initial dose* of acetylbetamethylcholine bromide for patients with megacolon is 0.1 gm., increased if necessary to 0.2 gm. within two or three days. Then after several more days with this daily dose if the bowel function is still not well established an additional

dose of 0.1 or 0.2 gm. in midafternoon may be prescribed. As the drug becomes effective in bringing about more normal function of the bowel the daily enemas are discontinued but the oral administration of the mineral oil is continued because of its lubricating action in the colon.

In some patients 0.2 gm. given each morning and in midafternoon is required to initiate bowel movements. If this quantity of the drug produces diarrhea the dose should be reduced to 0.1 gm. the next time the drug is given. When the patient becomes stabilized on a dose of the drug which produces one or two stools daily we usually release him from the hospital with instructions to take 0.2 gm. of acetyl-betamethylcholine bromide each morning about thirty minutes *after* breakfast and 1 or 2 tablespoonfuls of mineral oil each evening and report back to the doctor in two weeks. An occasional enema should be used if the patient becomes constipated or is troubled with gaseous distention of the colon.

Prostigmine bromide has been used as an augmenter of the acetyl-betamethylcholine bromide. Prostigmine prevents the destruction of acetylcholine by the esterases in the blood. In moderate doses prostigmine bromide is a safe drug to use and it does not disturb the blood pressure or the heart action.

Klingman[11] expressed the opinion that *syntropan* (Roche) is of value in the management of certain cases of megacolon because it is a parasympathetic paralysant and has an action similar to atropine in inhibiting the liberation of acetylcholine. He reported satisfactory clinical improvement following the use of syntropan on five patients with megacolon. Klingman[11] and Law[16] are not entirely in agreement concerning the basis for drug therapy in patients with megacolon since some of the benefits which Law ascribes to the use of drugs might also be explained on the basis of the excellent supplementary medical treatment which his patients received in conjunction with the drug therapy.

We are convinced that the medical management of megacolon must be employed vigorously to minimize the distention of the colon and prevent nutritional changes in children at least up to the age of five years. We also believe that medical management should be continued after that age especially when the child continues to grow normally and continues to have satisfactory evacuations of the bowel. Medical management must always receive its proper attention as an active preoperative measure as soon as it is recognized that the disturbance of colonic function cannot be completely controlled by the general and medical measures alone. Unfortunately the surgeon frequently loses sight of this important fact and the patients come to operation improperly prepared for such an extensive surgical procedure.

Surgical Measures

The surgical measures which are of value in the management of megacolon can be divided roughly into the *emergency procedures* and the *elective procedures.* The emergency procedures are to be used only as an heroic attempt to save a life after some acute surgical catastrophe such as volvulus, complete intestinal obstruction, gangrene of the obstructed loop of bowel or peritonitis from perforation of the colon has taken place. The minimal amount of surgical manipulation necessary to accomplish the immediate task is all that should be done in those patients with megacolon who may require immediate or emergency surgical intervention.

At the top of the list of elective procedures we have the various kinds of sympathectomy. When medical treatment and sympathectomy both fail to bring about relief in patients with megacolon then we must consider the other elective procedures, such as partial or segmental colectomy or even total colectomy. When patients are being prepared for colectomy the elective operations of cecostomy and tangential colostomy should be considered to permit better cleansing of the rest of the colon and for the safer execution of obstructive resection of the colon during and after partial colectomy.

Sympathetic Denervation of Colon.—Before the advent of sympathectomy in the management of megacolon there was only a slight difference between the mortality rates following medical and surgical measures. Pässler[17] reviewed the literature and collected 117 cases of megacolon which had been subjected to sympathectomy. Complete relief was reported in thirty-eight of the cases and improvement was observed in sixty-four cases. There was failure to obtain benefit in twelve patients and three died. In our own series of nineteen patients with congenital megacolon showing an age distribution of two months to twenty years, we have subjected fourteen to the operation of sympathetic denervation of the colon. Only one of these patients failed to obtain satisfactory function of the bowel following the sympathectomy and many months of intensive medical management. This patient will be reported upon more in detail in the paragraphs devoted to colectomy.

The operation of sympathectomy is an empirical method of treatment. There are various minor differences in the operations which have been described yet all of them are directed toward the interruption of the sympathetic nerves to the affected portion of the colon. It must be emphasized that patients who have been subjected to sympathectomy must be observed carefully for a long time after the operation because it is not uncommon to have fecal impaction or even volvulus take place many weeks after the operation.

Sympathectomy will not produce satisfactory results in cases in which the muscle power of the colon has been lost. We have observed

that there is a gradual diminution in the size of the colon as measured by roentgenologic studies for several years following the sympathectomy. We have no new information about the changes which take place in the thick, heavy wall of the involved portion of the colon after sympathectomy, for none of our patients have had to be reoperated upon and none has come to autopsy. One young man whom we have followed for nearly fourteen years after sympathectomy still shows some thickening of the colon but he has continued to have normal function of the colon despite the fact that he had never had a spontaneous bowel movement during the first nineteen years of his life prior to the sympathectomy.

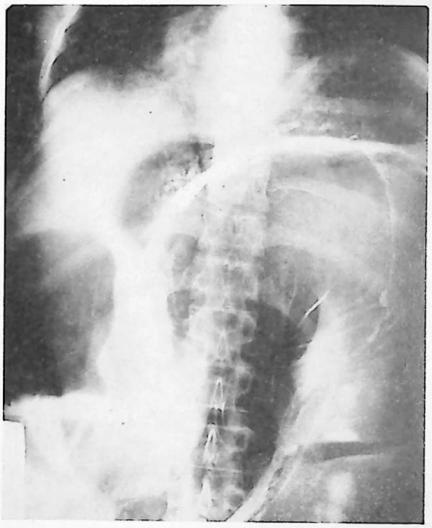

Fig. 485.—Roentgenogram showing marked dilatation of the transverse colon in a man 53 years of age. The wall of the colon was thin and atonic.

White and Smithwick[18] mention some important observations which throw additional light on the effect of sympathectomy upon the *normal* colon. They determined the intracolonic pressure relationship before and after bilateral lumbar ganglionectomy, and combined ganglionectomy and splanchnicectomy which were performed for the cure of Raynaud's syndrome and malignant hypertension. They were unable to show any alterations in the basic tone of the bowel, the peristaltic activity or the sensory acuity of the bowel following such complete sympathectomies. These observations, however, have never been made on patients with congenital megacolon.

Wade[19] observed that patients who showed hypertrophy of the

colon and visible peristalsis did well following sympathectomy. When hypertrophy of the colon was absent, the improvement which followed the sympathectomy was minimal and in those patients in whom the disturbance of the colon had progressed to the stage of marked dilatation with thin, weak musculature of the colon, the results following sympathectomy were completely unsatisfactory. These patients were in constant danger of great gaseous distention of the bowel and kinking of the sigmoid loop. They required regular enemas to bring about evacuation of the bowel. One such patient came under our observation and because the bowel was greatly distended and thin

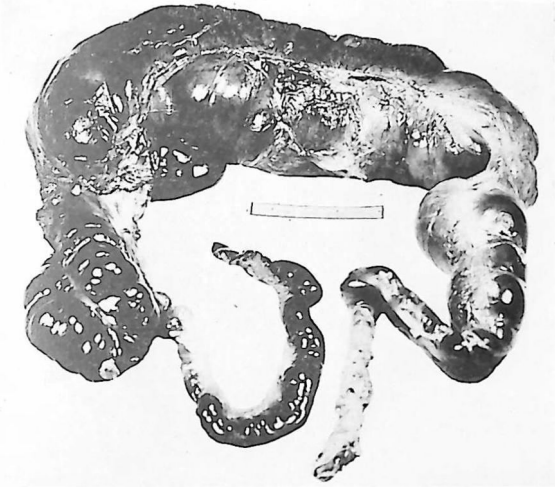

Fig. 486—Photograph of entire colon and terminal ileum removed at autopsy from a patient with enormous dilatation of the right half of the colon and secondary volvulus with gangrene of ascending colon. The rule in the center is 6 inches long.

walled we were certain that sympathectomy would give no improvement (Fig. 485). Arrangements were made for him to enter the hospital and be prepared for the resection of the colon and an ileorectostomy. Without our knowledge and while he was at home he developed acute intestinal obstruction from volvulus of the ascending colon with gangrene of the cecum. When he was brought to the hospital he was moribund and autopsy showed the tremendous dilatation of the entire right two thirds of the colon with volvulus involving the ascending colon and cecum with gangrene of the bowel. The photograph shows the specimen after it had been untwisted (Fig. 486).

Technical Considerations.—The operation of lumbar sympathectomy was first performed in the treatment of megacolon by Wade and Royal[5] in 1927. Their operation consisted of ramisection of the left lumbar sympathetic ganglia. Since that time several modifications of their original operation have been described in the medical literature. Rankin and Learmonth[20] advocated the resection of the superior hypo-

Fig. 487.—Drawing showing anatomic relation of various portions of the abdominal sympathetic nervous system.

gastric plexus (presacral nerve of Latarjet) together with the removal of the inferior mesenteric plexus of sympathetic nerves (Fig. 487). Judd and Adson[21] reported good results in the treatment of megacolon from bilateral lumbar sympathetic ganglionectomy. More recently, however, they suggested the resection of the lumbar splanchnic nerves together with the upper lumbar sympathetic ganglia for the more severe varieties of megacolon.

All of the operations upon the lumbar sympathetic nerves also interrupt important sympathetic fibers to other organs beside the distal portion of the colon. Resection of the superior hypogastric plexus interrupts the motor fibers to the seminal vesicles and the prostate gland and abolishes the ejaculation of semen which produces sterility in the male. When the second and third lumbar sympathetic ganglia are removed the power of ejaculation of semen is not disturbed but vasomotor paralysis of both lower extremities takes place so the skin of the legs and feet becomes hot and dry. This vasomotor paralysis in the extremities causes no discomfort or disadvantages.

Telford and Stopford[22] have suggested the resection of the preaortic plexus of sympathetic nerves in order to avoid sterility in the male and at the same time not interfere with the vasomotor control of the lower extremities. This at first appeared to be the operation of choice but because of the uncertainty of the anatomical distribution of these sympathetic fibers these authors finally decided that bilateral lumbar sympathetic ganglionectomy would give more uniform denervation of the colon in patients with megacolon.

Scott and Morton[23] made an important contribution to this field when they suggested the use of spinal anesthesia as a means of inhibiting the sympathetic impulses to the colon to bring about evacuation of the colon in patients with megacolon. This test aids in the selection of suitable cases for sympathectomy.

After the muscle tone of the colon has once been lost through overdistention from feces or gas, the operation of sympathetic denervation of the part will not give satisfactory results. It is important, therefore, to prevent such overdistention of the colon in order to preserve the tone of the bowel in all patients with megacolon who might subsequently be treated by sympathectomy.

We believe that the operation of abdominal sympathectomy should be performed by the *transperitoneal route* since that approach also affords an excellent opportunity for the surgeon to examine the entire colon and to determine accurately the extent of the pathological changes in its wall. By this route both lumbar sympathetic trunks and their ganglia can be removed at the same operation. Other important sympathetic nerves which course along the preaortic area and into the inferior mesenteric plexus can also be interrupted at this operation if the severity of the megacolon demands such an extensive interference with the sympathetic innervation of the colon.

The *retroperitoneal approach* to the lumbar sympathetic ganglia and trunks possesses no real advantage in the management of megacolon and has the great disadvantages that two separate operations are necessary to completely denervate the colon and the surgeon never gets a chance to determine the extent of the pathological changes by direct examination of the bowel.

Since 1932 we have performed the operation of abdominal sympathectomy by using the transperitoneal route and in the more advanced varieties of megacolon we have removed most of the preaortic plexus of sympathetic nerves together with the inferior mesenteric plexus and its ganglia, the superior hypogastric plexus and both lumbar sympathetic trunks with the second and third lumbar sympathetic ganglia (Fig. 488).

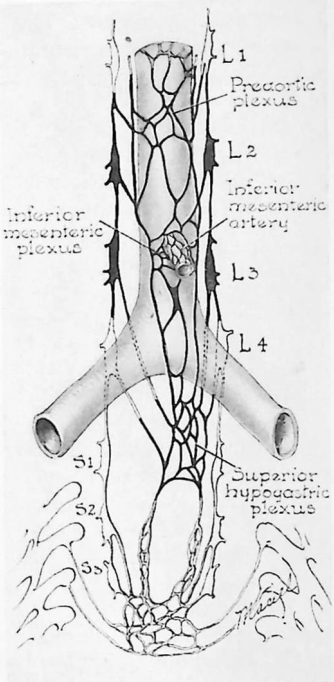

Fig. 488.—Schematic drawing showing the portions of the sympathetic nervous system from which the innervation of the colon is derived. Portions shown in black should be removed for complete denervation of the colon in the treatment of congenital megacolon.

The operation of sympathectomy does not always restore the involved bowel immediately to normal functional activity. It is sometimes necessary to enlist the aid of daily enemas, mineral oil and even mild laxatives for several weeks before the habit of spontaneous evacuation of the bowel is established. Sympathectomy does not always solve the therapeutic problem in patients with megacolon and even intractable relapses have been reported. Some of these patients

have died from acute intestinal obstruction secondary to extreme distention of the colon or interference with the blood supply to the colon by volvulus.

Resection of the Colon (Colectomy).—There is still considerable difference of opinion about the most effective surgical measure in the treatment of megacolon. Yeazell and Bell[24] have reported good results from resection of the colon in six cases of Hirschsprung's disease. More recently Grimson, Vandegrift and Dratz[25] condemned the more conservative methods of treatment and expressed the opinion that when resection of the colon was indicated it should start with the cecum and continue distally through the proximal divisions of the colon to the sigmoid region if necessary in order to have the liquid contents of the ileum empty into the remaining and preferably rather short segment of the terminal colon. They also believe that sympathectomy interrupts the pathways of visceral pain so completely that the early warning of impaction, pressure necrosis or volvulus is abolished in these patients.

Accurate observations concerning therapeutic results are difficult to make because of the limited number of patients which any one observer has the privilege of studying as well as the difficulties which are encountered in trying to follow these patients for long periods of time.

With due regard for sympathectomy we also believe that partial colectomy is indicated in the segmental type of megacolon when only a small portion of the colon is involved in the hypertrophy and dilatation and the adjoining segments of the colon are relatively normal. The mortality in this type of operation is much lower than when extensive resection of the colon is necessary. The disturbing feature about the operation of segmental resection of the colon is not the immediate mortality but the fact that progressive dilatation of the segment of the colon proximal to the portion which had been resected frequently takes place. Hurst[4] states that he has observed the dilatation of the bowel to extend into the ileum after the entire colon had been removed. Usually, however, the resection of segments of the colon gives excellent end results and removes the danger of volvulus which develops all too frequently after sympathectomy.

Patients with megacolon who have not been benefited by the combination of good medical management and sympathectomy should be subjected to partial or total colectomy if they can no longer be benefited by the less drastic measures. Persistent obstipation with fecal impactions and all the accompanying troubles is sufficient to justify the most radical of surgical procedures if there is the slightest chance of giving the patient some relief.

We also believe that the type of megacolon which is due to low-grade mechanical obstruction of many months or years standing, when

surgical removal of the obstructing lesion still fails to bring benefit to the thin walled and overdistended colon, should be given relief by colectomy. Volvulus with gangrene of the enlarged and dilated colon frequently presents itself as a serious complication in this type of megacolon (Fig. 486).

In addition to these three groups we believe that subtotal colectomy should be carried out in those patients with megacolon who show no contraction of the bowel or evacuation of feces following spinal anesthesia and for whom intensive drug therapy fails to reduce the size of the involved colon or reestablishes the peristaltic activity.

Subtotal colectomy is not indicated in infants with megacolon unless they present complications which make resection of part of the colon necessary to remove gangrenous areas. Even under such circumstances it is much safer to exteriorize the damaged portion of the colon and then perform the resection of the colon in stages at some later date.

In a review of the literature Carey was able to study ninety-five cases in which subtotal colectomy was performed for megacolon. The mortality rate for these cases was 27 per cent.

Dixon[26] reported that, in his experience, in patients who have had great dilatation of the colon for many years there are always permanent changes in the wall of the bowel and subtotal colectomy is the only surgical procedure which will give satisfactory improvement.

Barrington-Ward[27] reported five cases in which total colectomy was done and an ileocolostomy or ileorectostomy was performed to reestablish the continuity of the bowel. In the 102 cases of megacolon treated by partial colectomy and reported by Ask-Upmark,[28] the benefits were observed immediately and the author thought they would be permanent.

The one patient in our series, a girl 20 years of age, who failed to show improvement after intensive medical treatment and sympathectomy was subjected to resection of the sigmoid colon (Fig. 489). After the sigmoid colon was removed from the rectum by the use of Payr clamps in an aseptic manner, the distal end of the sigmoid colon was freed by dividing the mesentery so the enormously dilated and hypertrophied bowel could be emptied of the fecal content by placing the distal end over the side of the operating table and removing the Payr clamp. This was excluded from the field of operation and the entire contents of the colon were milked out. The fecal matter had the consistency of putty and in all 42 pounds of feces and colon were removed without causing any untoward reaction in the patient during the entire operation. A Devine type of colostomy was made so that the distal end of the descending colon and the upper end of the rectum could be brought together in such a way that the fecal stream will later be reestablished by crushing the spur between the two

portions of the bowel (Fig. 490). We prefer to allow several months to elapse before the continuity of the colon is reestablished in order

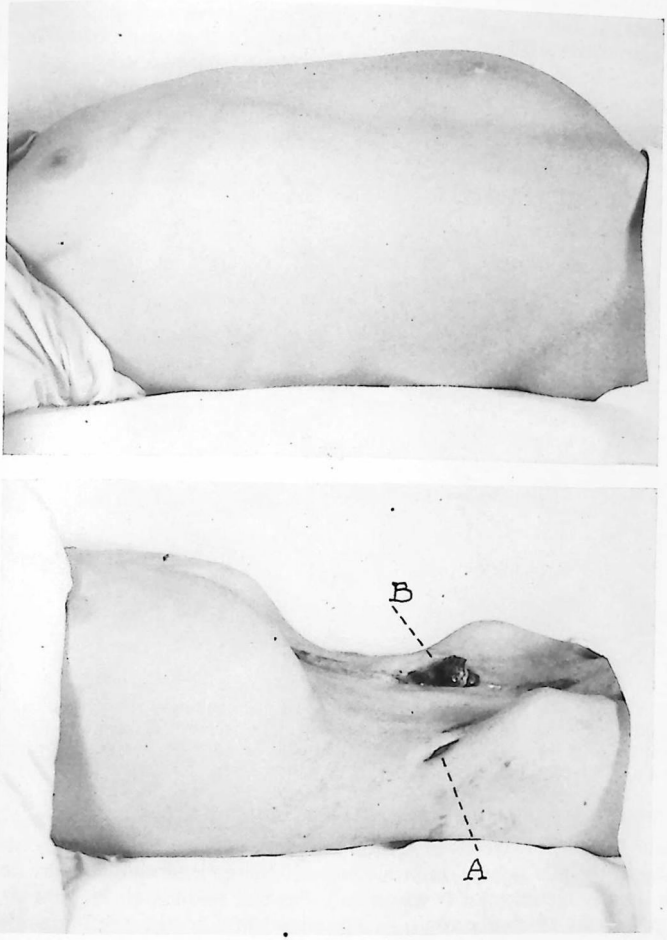

Fig. 489.—Photographs of a young woman with congenital megacolon. Pictures taken before and ten days after partial colectomy (see Fig. 490). *A*, Site of cecostomy. *B*, Site of Devine colostomy.

to give adequate time for the medical and drug therapy to completely restore the function of the remaining portion of the colon. At this

time, two months after operation, the colon is functioning normally and the portion visible at the colostomy opening is of normal size and activity. The patient has gained 21 pounds in weight and is normally active.

The removal of a greatly dilated and thickened portion of the colon (Fig. 491) is a somewhat different surgical procedure from the resection of a diseased portion of an otherwise normal colon. It is our opinion that all of the involved colon should be resected by a one stage aseptic procedure and when possible a temporary double-barrel

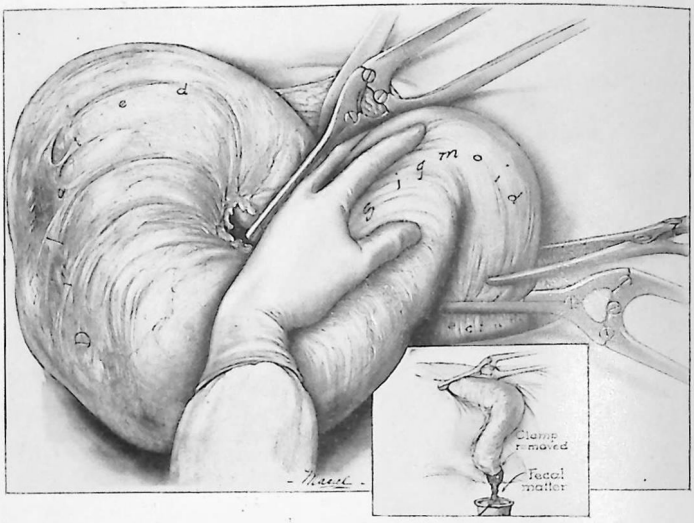

Fig. 490.—Drawing showing the resection of the enlarged sigmoid colon. Note method of emptying entire large bowel of large quantities of putty-like fecal material without contamination of the field of operation. Wounds healed promptly without infection.

colostomy should be constructed. This colostomy can be closed any time from a few weeks to several months but not until the patient has shown definite general improvement. If the caliber of the entire colon is greatly increased it is wisest to remove it entirely or at least to the upper part of the rectum. The proximal end of the rectum and the distal end of the terminal portion of the ileum are brought to the outside of the abdomen and the final anastomosis should be made as a second stage procedure at some later date. The procedure described above gives us hope of saving portions of the colon which may be showing only secondary changes that may be reversible. Certainly with the modern drug therapy it should be possible to restore normal

function to parts of the colon which previously were thought to be involved in the process of megacolon.

It has been found that a liberal left rectus incision is a satisfactory type of abdominal opening to have, for it affords adequate exposure of the splenic flexure of the colon which occasionally is very difficult to mobilize adequately. The mesentery of the sigmoid colon and the descending colon is usually elongated and this adds greatly to the ease with which an enlarged colon can be mobilized and even brought out onto the abdomen to facilitate the resection. The anal sphincter

Fig. 491.—Photograph of the portion of the sigmoid colon removed at operation. Note the leather-like, thickened wall and the dilated blood vessels on the surface.

muscles should be forcefully dilated at the completion of the colectomy and again when the colostomy is closed.

Because of the poor healing qualities of the enlarged bowel due to long-standing distention and lymphatic stasis in the tissues, the single stage resection of a part of the colon in megacolon and an immediate anastomosis between the proximal and distal segments of the bowel is fraught with danger of serious complications. We do not recommend this one-stage procedure in the management of the more advanced types of megacolon.

In the interval between the resection of the portion of the colon and the closure of the colostomy and after the immediate postoperative period, the patients are allowed a high protein, high vitamin and low residue diet. They may wear a colostomy bag or simply take a cleansing enema through the proximal loop of the colostomy each morning and then just wear a pad of soft material over the colostomy opening. They are taught to carry out irrigations of the lower loop of the colostomy at regular intervals.

SUMMARY

Because of the incomplete and sometimes apparently conflicting evidence we are not justified in making any exact statements concerning the pathologico-physiologic mechanisms which are at work in the production of congenital megacolon. Experimental evidence, the effect of surgical interruption of the sympathetic nerves to the colon and the action of cholinergic drugs certainly tend to support the neurogenic theory of megacolon as a functional imbalance of the autonomic nervous system which innervates the colon. Since there is no exact test for overactivity of the sympathetic elements of the autonomic nervous system, the final decision about when to do a sympathectomy to reduce the hyperactivity of the sympathetic nerves must be empirical. Sympathectomy should not be done in the very young children and the results in patients with great dilatation of the colon and weak musculature are very discouraging. Sympathectomy does not miraculously restore function of the bowel in all patients with megacolon, and adequate parasympathetic tone and strong colonic musculature are absolutely necessary for normal peristalsis and evacuation of the bowel. Patients with vigorous visible peristalsis and hypertrophy of the wall of the colon usually respond best to the operation of sympathectomy.

The administration of some cholinergic drug, which should be the remedial agent for diminished tone of the parasympathetic nerves, is the only known functional test for tonus of the bowel, but its use is also empirical. The proper and prolonged use of acetylbetamethylcholine bromide has proved valuable in the management of megacolon and might be a valuable adjuvant in the management of those patients with megacolon who have not received complete or lasting relief from sympathectomy.

When the operation of sympathectomy is performed it is important to remove sufficient fibers from the sympathetic nervous system to produce complete denervation of the involved portion of the colon.

In advanced types of megacolon and in certain types of acquired dilatation of the colon it may be expedient to remove the involved portion of the colon and later restore the continuity of the bowel. This operation of colectomy is especially valuable in the management

of those types of megacolon which have failed to respond to intensive medical and drug therapy or sympathectomy.

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TECHNIC OF ANASTOMOSIS OF THE COLON FOLLOWING RESECTION

PAUL I. HOXWORTH, M.D., PH.D., F.A.C.S.*

IN the surgical removal of cancer of the colon there is common agreement among surgeons as to the fundamental objectives desired. Attempt is always made to transect bowel at points wide of the primary growth, to remove an extensive area of the regional mesentery and its contained lymphatic structures, and to preserve blood supply to the remaining segments of colon. Beyond these points of agreement there are differences in practice both in the technics using during the resection and in methods used for restoring the continuity of bowel.

At the time of operation the surgeon may elect to reestablish continuity of the intestine immediately or he may choose a method requiring delayed anastomosis, such as a modification of the so-called Mikulicz procedure or obstructive resection. At the Cincinnati General Hospital it has been the practice to follow resection with immediate anastomosis, by either an open or closed method, in all except occasional cases.[1] In order to do this it is necessary to establish suitable conditions for the avoidance of sepsis and for primary healing by use of careful preoperative, operative and postoperative measures. Suitable conditions will be defined in terms of clinical criteria throughout this paper. If these conditions cannot be met with respect to the individual case, it is safer to resort to exteriorization and delayed anastomosis. If they can be realized, primary anastomosis becomes a safe method and usually permits a wider resection of the mesentery. Also it shortens the period of hospitalization for patients and obviates the necessity for secondary operative procedures. The latter two considerations are largely economic and they are of importance only if safety is established.

CONSIDERATIONS IN THE PREPARATION OF THE PATIENT FOR RESECTION

Once the diagnosis of carcinoma of the colon is made and the lesion is localized by sigmoidoscopy or roentgenology, the presence of constipation or obstipation, abdominal distention and x-ray evidence of retention of gas, fecal material or barium indicate obstruction. In this

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clinic any degree of chronic or acute obstruction due to lesions distal to the hepatic flexure is relieved by antecedent proximal colostomy. Neither distended thin nor edematous thickened intestinal wall lends itself to safe anastomosis. Of equal importance is the fact that systemic disturbances secondary to obstruction militate against recovery. These may be disturbances in chemistry, nutrition and water balance, and in mechanical interference with the respiration due to abdominal distention. Tangential cecostomy is preferred in cases of simple obstruction because it provides adequate decompression, it is safely and easily performed under local anesthesia in one stage, and in most instances closes spontaneously. If operative closure is required it is a relatively simple procedure. If associated local inflammation is present complete diversion of the fecal content as well as decompression is essential. Fever, leukocytosis, tenderness, palpable fixation and fistulous tract formation are signs of inflammation. When these are present in connection with lesions at or distal to the splenic flexure a modification of the Devine colostomy performed on the right or left half of the transverse colon is used. The technic for this and the method for later closure are as described by Ochsner, DeBakey and Rothschild.[2]

Obstruction secondary to lesions in the cecum and ascending colon is encountered rarely. This is due to the fungating quality of the growths with less tendency to scirrhous contracture, the larger lumen of the bowel, and the fluid consistency of its contents. If obstruction is present here it often denotes incurability by resection either because of local extension of the tumor or of widespread metastases. Signs of associated local inflammation are also frequently present. Often the relief of obstruction in the right colon may be accomplished by use of the Miller-Abbott tube or continuous gastric suction and frequent small enemas. Unless distinct progress is made in two or three days, decompression is then best obtained by performing an ileotransverse colostomy through a short transverse incision. In our hands simple anti-peristaltic side-to-side anastomosis has often proved valuable. If the general condition of the patient and local condition of the bowel justify the procedure, the ileum may be divided and the end turned in before the anastomosis is made.

In the absence of obstruction we do not hesitate to perform resection with immediate anastomosis without decompression. The preoperative management of these cases and of those in which obstruction has been relieved are about the same. In the supportive management anemia is treated by adequate transfusion of whole blood, and a diet high in carbohydrates, protein and calories, and low in residue is given. If the oral intake is not adequate, solutions of amino acids, glucose and saline are used intravenously. Daily minimum requirements of vitamin B are satisfied.

In addition to the supportive management every attempt is made to cleanse the bowel as thoroughly as possible. Collections of gas, stool and barium at the time of resection interfere with exactness in technic and increase opportunities for soiling of the peritoneum. A cleansing enema of saline or tap water is given by rectum and through the colostomy each day. Succinylsulfathiazole is given orally each six hours for five days before operation. The dosage is calculated at the rate of 0.25 gm. per kilogram of body weight for twenty-four hours. On the day before operation an x-ray examination is made for the presence of gas, stool and barium in the colon. At this time the patient is placed on a liquid diet, and continuous gastric suction is begun on the evening before or the morning of operation.

On the day of operation the skin is shaved widely and prepared by gentle washing for five minutes with gauze saturated in 1:100 aqueous solution of cetylpyridinium chloride (ceepryn chloride). Towels and drapes are applied with regard to the planned location of the incision. All lesions of the colon except those lying very low in the sigmoid are approached through a transverse incision, often extending into the flank as described by Hoag.[3] We are convinced that the transverse incision affords better exposure than a vertical one, less retraction is required, wound disruption is encountered less often, there is less postoperative pain and splinting of respiration, and healing occurs with a finer scar. The wound is isolated from the skin by fixing the under sides of towels to skin edges with Michel clips. Careful attention is paid to hemostasis and the subcutaneous and muscular layers are protected from trauma and from the field of resection with moist laparotomy packs.

PROCEDURE FOR LESIONS IN THE CECUM, ASCENDING COLON AND HEPATIC FLEXURE

Upon opening the peritoneum, first the liver and then the regional lymphatic area are palpated for metastases. (If remote metastases are present palliative resection may be done. Many of these patients remain in relative comfort for months.) The primary growth is examined with care, since rough handling may result in perforation and soiling. If there is evidence of an active inflammatory process extending beyond the bowel wall, with or without abscess, ileocolostomy is done without resection.

If this complication is not present, the cecum, ascending colon and hepatic flexure are mobilized by incising the avascular lateral mesenteric reflection. The bowel is rotated mesially and the ureter and spermatic or ovarian vessels are identified from their origin down to the brim of the pelvis and spared. The retroperitoneal fat and lymphatic-bearing tissue are removed using a gentle wiping process with gauze alternating with sharp dissection, and carried mesially with

the bowel and its mesentery to the points of origin of the right colic and ileocecal arteries. At the upper end of the field the descending portion of the duodenum is identified and the beginning of the transverse mesocolic reflection is divided at its attachment to the duodenum and to the anterior surface of the head of the pancreas. The dissection below is carried proximal to the cecum to include the mesentery of about 12 cm. of the terminal ileum, incising only the serosa. The entire mobilized segment is then elevated and its blood supply visualized. The points for division of the transverse colon above and the ileum below are selected and the mesial reflection of mesentery is incised with a scalpel from these points to an apex at the points of origin of the right colic and ileocecal arteries. The vessels are isolated, divided between clamps and transfixed with No. 000 silk. At the points selected for division of the transverse colon and the ileum the serosa is carefully cleansed of fat and mesenteric tissue by a gentle wiping process with a single layer of gauze over the finger. Small perforating vessels are clamped as they are encountered close to the serosa, divided with a scalpel and ligated with fine No. 0000 silk. This is done for a sufficient distance to permit the placing of clamps and for an additional margin of serosa to allow later inversion or anastomosis without interposition of fat, long segments of vessels or large ligatures. Pairs of Kocher clamps are applied in a position to shorten the antimesenteric borders of the viable segments. The bowel is then divided with cautery at each site and the specimen is removed.

At this point either a side-to-side anastomosis similar to the method of the Halsted entero-enterostomy[4] or an end-to-side anastomosis somewhat according to the technic described by Rankin[5] is employed. If the side-to-side method is used, simple closure of the ends of the ileum and transverse colon is made over the clamps with a single row of Halsted mattress sutures of No. 000 silk. These are laid in place to include the submucosa, drawn up to accomplish inversion as the clamp is withdrawn, and tied. The closure is then reinforced by placing a Lembert mattress suture between each two Halsted mattress sutures using No. 0000 silk. Another method often used is that of an inverting right angle (Cushing) suture of No. 0 chromic catgut over the Kocher clamp. This suture, after the clamp is removed and inversion is complete, is continued back as a second row and tied. We prefer either of these methods to that of ligating the bowel and inverting the ligated stump because they avoid cavities closed at each end with ligatures.

After both ends of the bowel are closed, the terminal ileum is held parallel to the longitudinal band of the transverse colon, and the side-to-side anastomosis is done near the ends in order to leave as little blind stump as possible. The field is carefully walled off with gauze packs. Traction sutures of silk are placed at each end of the proposed

anastomosis, and a posterior continuous suture of No. 000 silk is placed (Fig. 492, *1*). Halsted mattress sutures of No. 000 silk are then laid anteriorly (Fig. 492, *2*). These are next pulled aside, half to each end (Fig. 492, *3*). Before opening the bowel a temporary occlusion is produced to prevent gross soiling. Rubber-shod clamps, or soft lead bars (5 by 3 mm. in cross section and covered with soft rubber tubing)

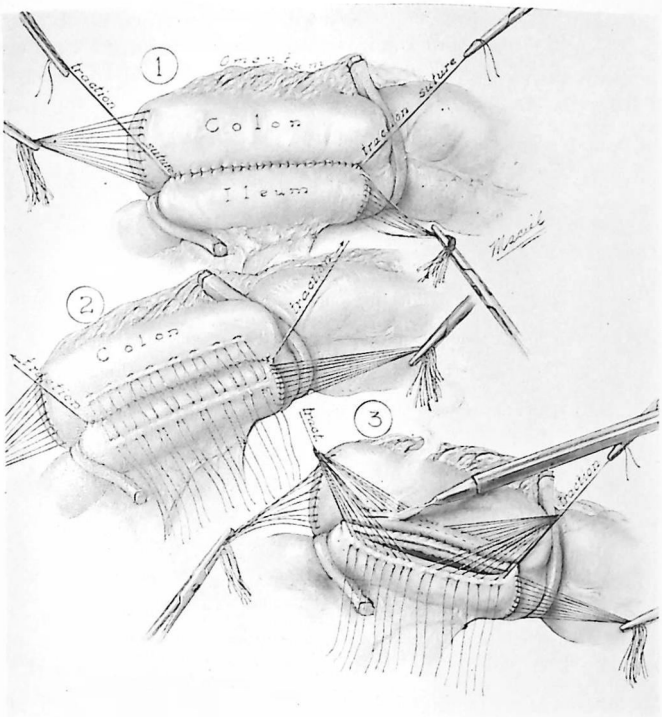

Fig. 492.—Steps in side-to-side ileocolostomy. *1*. Posterior continuous sutures of silk between two traction sutures. *2*, Anterior row of Halsted mattress sutures placed. *3*, Mattress sutures pulled aside; incisions made in bowel and vessels clamped and tied with catgut or coagulated.

bent like a hairpin can be placed across the bowel. One is used across the ileum and one across the colon. At the site of the anastomosis itself no clamps are used. The bowel is held up by the assistant lifting the traction sutures, and there is ordinarily no escape of intestinal contents. The bowel is opened with a knife and scissors or with high frequency cautery, and bleeding points are clamped and

tied with No. 000 chromic catgut or they are coagulated (Fig. 492, 3). The posterior suture line is reinforced with a continuous lock stitch of No. 0 or 00 chromic catgut which goes through the entire thickness of both walls (Fig. 493, *4*). The ends of the anterior row of mattress sutures are pulled up, the traction sutures are cut or pulled aside and, when the mattress sutures are drawn up to approximate the bowel and tied, the anterior lip of the anastomosis is closed (Fig. 493, 5). A Lembert suture of No. 0000 silk is placed between each two mattress sutures. The angles of the anastomosis are reinforced with mattress sutures of No. 000 silk and the occluding rubber-shod clamps or lead bar clips are removed. After removal of the protecting gauze

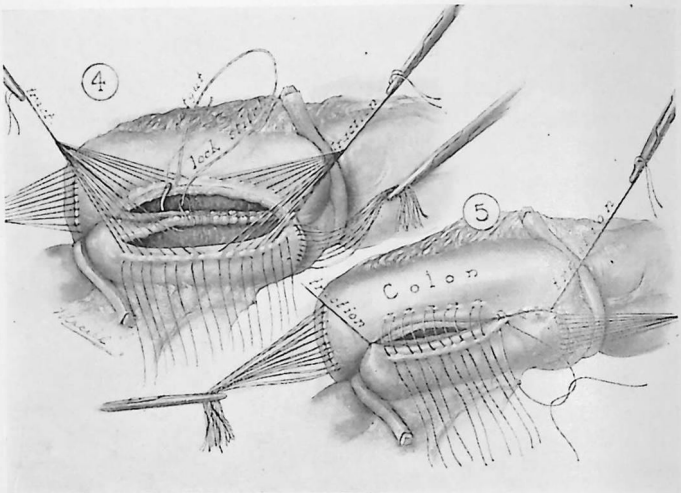

Fig. 493.—Steps in side-to-side ileocolostomy (*continued*). *4*, Posterior lock stitch of catgut through all layers of bowel. 5, Mattress sutures pulled up and tied.

packs the gloves are changed before continuing the operation. The overlapping folds of the mesentery are sutured together to close the defect, care being taken not to injure the blood supply. We have abandoned the use of a sulfonamide in the peritoneal cavity, relying upon systemic administration by the intravenous or subcutaneous routes only in occasional cases where soiling has occurred.

If the end-to-side method of ileocolostomy is used the cut end of only the colon is closed and a site is selected for the anastomosis. A portion is tented up by grasping it with two Allis clamps. A Kocher clamp is placed across this area longitudinally and the protruding portion, which is made to correspond in size with the diameter of the ileum, is excised with the cautery (Fig. 494, 2). The stump of the

ileum, which is held in a Kocher clamp, is then approximated to the defect in the colon and the anastomosis is begun. Using an atraumatic needle, a posterior running suture of No. 0 chromic catgut is placed with a tie at the beginning and a lock at the end, leaving both ends long in order to tie them later at each end of the anterior suture (Fig. 494, 3). The clamps are then rotated inward and a continuous right angle (Cushing) suture is placed anteriorly with no tie at either extremity (Fig. 495, 4). The clamps are withdrawn as the assistant makes traction on one end of the suture to begin the inversion. The

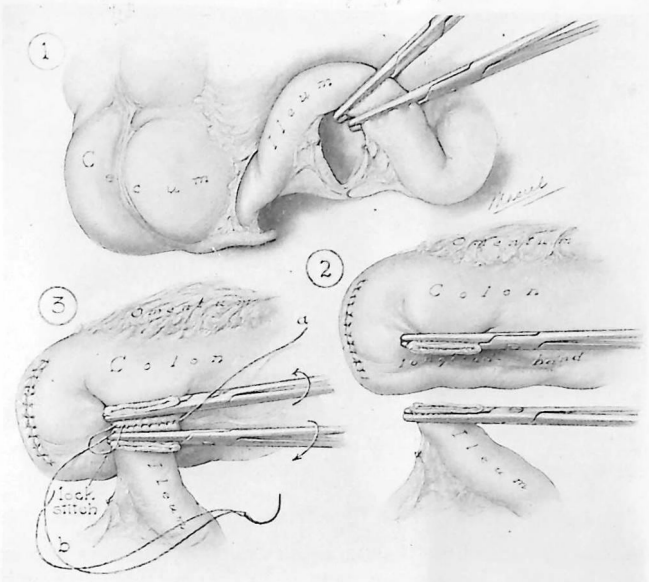

Fig. 494.—Steps in end-to-side ileocolostomy. *1*, Division of terminal ileum. 2, Kocher clamp on side of colon. 3, Posterior continuous suture of catgut.

operator completes the inversion by making traction on the other end of the anterior suture. Agglutination of the crushed ends of the bowel is depended upon to maintain closure until the inversion is accomplished. Corresponding ends of the anterior and posterior sutures are then tied (Fig. 495, 5). The long end of the posterior suture is continued around anteriorly and tied, forming a second anterior suture line (Fig. 495, *6*). The continuity of the lumen is established by invaginating the walls of the ileum and colon with the thumb and forefinger. The anastomosis is reinforced posteriorly and at the angles with

Lembert sutures of No. 0000 silk. A portion of omentum is anchored loosely over the anastomosis with silk. The same attention is directed to the mesentery as described in the open type of anastomosis.

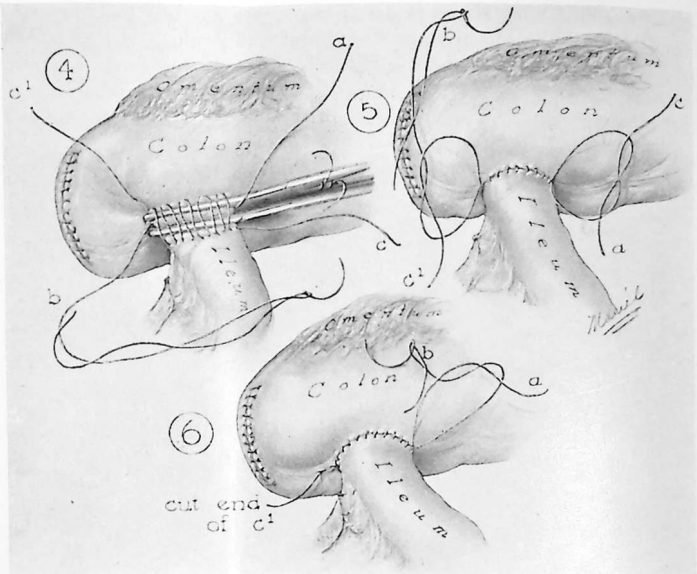

Fig. 495.—Steps in end-to-side ileocolostomy (*continued*). *4*, Anterior right angle (Cushing) suture of catgut over clamps. *5*, Anterior suture pulled up after clamps are removed. *6*, Posterior suture continued as second anterior layer.

PROCEDURE FOR LESIONS DISTAL TO THE HEPATIC FLEXURE

For lesions beyond the hepatic flexure an end-to-end aseptic anastomosis is usually done, but in some cases circumstances encountered at the time of resection prevent the operator from proceeding with end-to-end anastomosis. Great disparity in the size of the bowel proximal and distal to the lesion may be present, requiring a side-to-side anastomosis in the manner described above for resections of the right colon. This may be true despite preliminary decompression and frequent irrigation. After careful exploration of the abdomen to determine the extent of metastases, adhesions adjacent to the lesion are divided by sharp dissection in order to elevate the bowel to the full length of its mesentery. The points for division of the bowel and its mesentery are then selected wide of the lesion, testing the proposed sites for division carefully to determine that they can be approximated without tension. The lateral and mesial reflections of mesentery are

divided from these points to an apex at the base of the mesentery. This is done with the same respect for blood supply and the vessels are ligated individually as described under the procedure for resections of the right colon. Extreme care is taken to remove the appendices epiploicae and other fat tabs from the bowel at the proposed site of anastomosis. Stone clamps are applied diagonally so that the antimesenteric border is somewhat shorter than the mesenteric. A Kocher clamp is placed on the segment to be removed next to each Stone clamp and the bowel is divided between clamps with cautery (Fig. 496, *1*). The cut ends of the bowel held in Stone clamps are

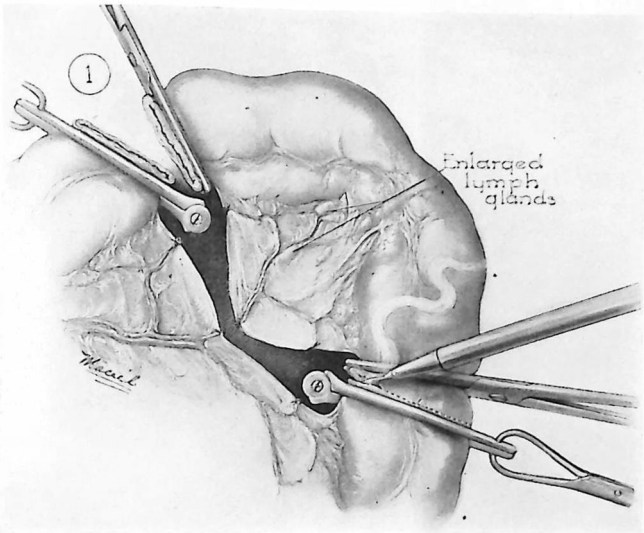

Fig. 496.—Steps in end-to-end aseptic intestinal anastomosis. *1*, Division of bowel with cautery between Kocher and Stone clamps.

then brought into apposition. A single row of Halsted mattress sutures of No. 000 silk is laid on one side, just far enough from the clamps so that they can be pulled up and tied (Fig. 497, 2). A row of mattress sutures is laid on the opposite side of the bowel and a rubber-shod clamp or lead bar is placed across the proximal loop (Fig. 497, *3*). The Stone clamps are removed. The second row of mattress sutures is then pulled up and these are tied, completing the inversion (Fig. 497, *4*). A Lembert suture of No. 0000 silk is placed between each two Halsted sutures (Fig. 497, 5). Serosal approximation at the mesenteric border is the most difficult and must be obtained by precision

in placing the sutures. After completing the suture, continuity is established and the adequacy of the stoma is determined by invaginating the bowel on either side with the thumb and forefinger. The cut edges of the mesentery are approximated carefully to leave no defect or raw surfaces (Fig. 497, 5).

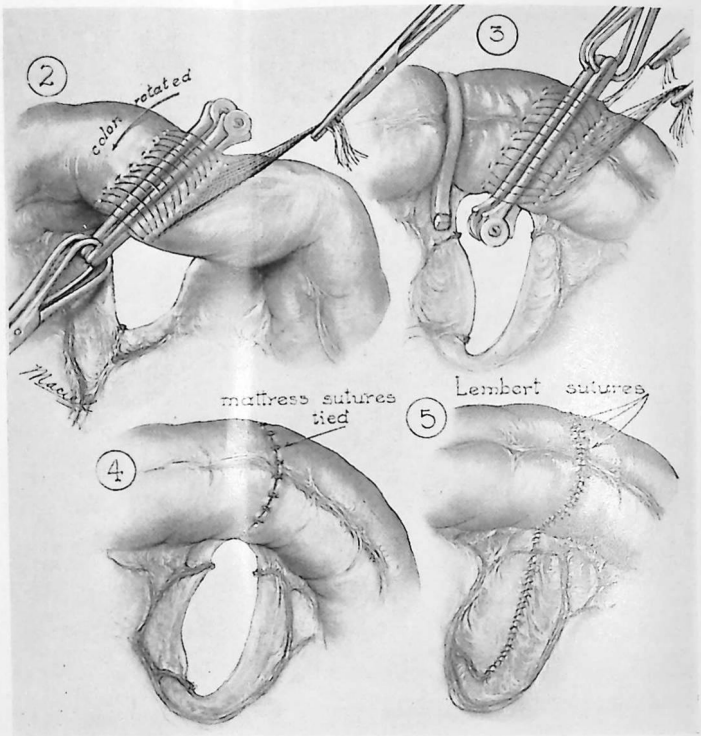

Fig. 497.—Steps in end-to-end aseptic anastomosis (*continued*). 2, Clamps rotated and first row of Halsted mattress sutures of silk placed. 3, First row of sutures tied and opposite row of mattress sutures placed. 4, Stone clamps removed and second row of mattress sutures tied. 5, Completed anastomosis.

CLOSURE OF THE WOUND

The exact method of closure of the wound has differed with individual operators. As a rule, the peritoneum is closed with continuous No. 0 or No. 1 chromic catgut. The wound is thoroughly but gently irrigated with saline solution, the muscle and fascia closed with interrupted figure-of-8 sutures of doubled No. 000 black silk or of No. 1

chromic catgut, and the skin with interrupted No. 0000 silk. In cases in which soiling has occurred the closure is usually made with 21 gauge silver wire stay sutures. These are placed through all layers of the abdominal wall, no suture material being used in the line of the incision.

POSTOPERATIVE CARE

The postoperative care is important, but usually not difficult. The operation is ordinarily not accompanied by much loss of blood or by shock. Intravenous injection of glucose and saline solution is given during operation and whole blood is substituted if indicated. Continuous gastric expression is usually maintained until the morning after the operation. The patient is placed in a position of comfort when recovered from the anesthesia and is turned from side to side at two hour intervals. Morphine is given as necessary to avoid pain and restlessness. Deep breathing exercises are encouraged and hyperventilation with carbon dioxide is effected at regular two and four hour intervals respectively throughout the first postoperative day. If a colostomy is present, water by mouth is started on the day after operation and a diet low in residue is given as soon as tolerated. If no colostomy has been provided small amounts of water only are given for the first forty-eight to seventy-two hours. The urinary output is maintained at a level of above 1000 cc. for each twenty-four hour period by parenteral hydration with glucose and saline solution if oral intake is not adequate. Daily requirements of vitamins B and C are satisfied.

COMMENT

Even though careful preliminary preparation designed to permit safe immediate anastomosis is employed, one is occasionally confronted with circumstances that force him to abandon primary anastomosis in favor of a Mikulicz or an obstructive type of resection. For example, the colon proximal to the lesion may be filled with inspissated stool despite antecedent colostomy and days of attempts to cleanse the bowel by irrigation. Another example of such a circumstance is the presence of an abscess secondary to perforation at the site of the lesion. Also the general condition of the patient after mobilization of the lesion may contraindicate further abdominal manipulation, and require an exteriorization procedure with obstructive resection. It must be admitted that methods of immediate anastomosis following resection for carcinoma of the colon are not suitable for anyone unwilling to pay exact attention to details of careful preoperative, operative and postoperative management. Disregard may lead to complications, chiefly those of leaking of the suture line with peritonitis and intestinal obstruction.

Principles to be regarded in obtaining the best possible results may be enumerated:

1. Preliminary correction of anemia and of disturbances in chemistry, nutrition and hydration.
2. Relief of obstruction and attempts at thorough cleansing of the intestine before removal of the lesion.
3. Use of the abdominal transverse incision.
4. Careful attention, during resection of the mesentery, to preservation of blood supply to the segments of bowel at and adjacent to the proposed site of anastomosis.
5. Gentleness in the dissection and handling of the bowel and its mesentery.
6. Adequate mobilization of the segments to be anastomosed in order to prevent tension at the line of suture.
7. Precision in placing of sutures after careful preparation of the bowel to receive them. Inverting mattress sutures should catch the submucosa but not penetrate the mucosa, and should be tied just tight enough to hold serosal surfaces in apposition but must not strangulate the tissue. Inversion of too much of a diaphragm is to be avoided.
8. Accuracy in approximating the edges of the mesentery and in reperitonealizing denuded areas.
9. Isolation of the field of resection and exclusion of contaminated gauze, instruments, towels and gloves from the field before reperitonealization and closure of the wound.
10. The use of continuous gastric expression until obstruction is relieved, and for the immediate preoperative and postoperative period.
11. The provision of adequate hydration and nutrition and the prevention of atelectasis after operation.

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SYMPOSIUM ON GENITOURINARY SURGERY

THE MANAGEMENT OF BLADDER TUMORS

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WITH the introduction of the various operating cystoscopes, electrosurgical units, radium, deep roentgen ray therapy and improvements in surgical technic, tremendous strides have been made in the therapy of tumors of the bladder. In order to discuss the management of these tumors properly a brief consideration of their incidence, etiology, pathology and symptomatology is desirable.

INCIDENCE

In 1937, 3.2 per cent of deaths from cancer in the United States were due to carcinoma of the bladder.[1] There was no reduction five years later when the same percentage was reported. Tumors of the bladder are seen four times more frequently in males than in females.[2] Most of these are encountered in patients between the ages of 30 and 70, the majority being between 50 and 60 years old. The lower grades are more common in the earlier age group whereas the infiltrative, high grade malignancies are seen more often in older people.

ETIOLOGY

Little is yet known concerning the etiology of bladder tumors. Although there is no doubt that mechanical or chemical irritation plays some part, it is nevertheless well known that bladder calculi are rarely associated with tumors. Yet many urologists believe that chronic cystitis either with or without stones is a factor in the etiology of these neoplasms. It has definitely been shown that the incidence of bladder tumors is greater in aniline dye workers and that the irritation caused by the presence of the ova of Bilharzia in the bladder is a recognized causative agent. Since the majority of bladder tumors are located on or near the trigone, the area most subject to inflammation, it is conceivable that chronic irritation plays some role.

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PATHOLOGY

Most bladder tumors involve the trigone, neck or lateral walls of the bladder. The posterior wall, vault and anterior wall are less frequently involved. Practically all tumors encountered in clinical practice are of epithelial origin. Rarely are mesodermal tumors seen. These rarer growths can occur as *sarcomas, myomas* or *fibromas.*

The simplest form of epithelial tumor is the *papilloma,* which appears as a slender, delicate, almost transparent papillary growth supported by a long pedicle projecting from the mucosa of the bladder. Although often referred to as a "benign papilloma," these tumors are, nevertheless, considered as of actual or potential grade I malignancy. The *papillary carcinoma* may not differ materially in appearance from the papilloma but it is more likely to be firmer in consistency and it develops on a shorter and more sessile base. These tumors are much more likely to be single than the simple papilloma and they undergo sloughing more rapidly. In contradistinction to the papillary tumor the more malignant *infiltrating carcinoma* begins as a small, discrete ulcer which rapidly invades the bladder wall and eventually infiltrates a large segment of the bladder.

We find Broders' classification with respect to relative malignancy a convenient method of grouping bladder tumors, in addition to the impression obtained from observation of their gross appearance. Our experience has been that the clinical course of at least 90 per cent of bladder tumors can be accurately predicted from their Broders' grading when correctly reported. This is of great value in planning treatment in each individual case. On the other hand, it will be readily admitted that a small percentage of bladder tumors will not behave clinically as might be expected from their grading. Some feel that this is due to the presence of two or more tumors intimately associated with each other and of different degrees of malignancy. Thus, a low grade tumor might mask one of much greater malignancy in which case the patient's unfavorable course after treatment would be due to the underlying tumor of greater malignancy. There are also some who believe that if there is recurrence of a bladder tumor following fulguration or removal of the tumor, this is actually not a recurrence of the original tumor but a new one and therefore capable of being of much greater or lesser malignancy than the original. Nevertheless, since this percentage of atypical cases is small, we consider it well worth while to rely upon the microscopic grading of the tumor in planning treatment and in arriving at a prognosis.

Metastasis beyond the bladder wall itself occurs chiefly in high grade malignancy. The extension follows the regional lymphatic vessels from the base and lateral walls of the bladder throughout the pelvis and lower abdominal nodes. Rarely will the lesion metastasize to remote organs such as the brain, lungs or liver but this occasionally

occurs. Bladder tumors can be malignant by position as well as by their microscopic characteristics and if the location of a tumor or multiple tumors involves the ureteric orifices, upper urinary tract obstruction with renal failure may result. This can occur even after repeated fulguration of the tumor, as the scar tissue following treatment will itself produce ureteric obstruction. Likewise, invasion of the bladder wall in the region of the ureteric orifices may also produce constriction and upper urinary tract obstruction. Therefore, not infrequently patients with bladder tumors die of uremia before metastasis has become of clinical importance.

SYMPTOMATOLOGY

The cardinal symptom of bladder tumors is *painless hematuria,* usually intermittent in character and frequently profuse. The bleeding may be persistent or fleeting, that is, the patient may have blood in the urine once and then not again for several months or even longer. Whenever tumors are allowed to grow to such size as to encroach materially upon the lumen of the bladder, *frequency* will result from the reduced bladder capacity. This will also be true in cases in which infiltrating tumors cause contraction of the bladder with resultant reduction in capacity. Tumors of long standing will cause secondary infection of the bladder with resultant *dysuria.* Obstruction to urination or retention of urine will rarely occur when tumors are situated near the vesico-urethral junction. Symptoms due to metastasis or upper urinary tract obstruction rarely appear prior to the more obvious and localizing symptoms of hematuria or dysuria. Localized symptoms are usually absent in abdominal and pelvic metastatic lesions unless the perineural lymphatics are involved. Occasionally, invasion of bone structures in this area will cause pain.

DIAGNOSIS

Any patient giving a past or present history of hematuria should have the benefit of a complete urologic study. A careful *history* and complete *physical examination* are most important. A catheterized specimen of the *urine* from the female patient and the second of a two glass specimen from the male patient are obtained for microscopic study. The absence of red blood cells on microscopic examination in such cases should not deter further examination. The total kidney function should be determined in all cases. We use the *phenolsulfonphthalein function test* routinely except in the presence of gross hematuria. We consider satisfactory a reading of 50 per cent or more in an hour and ten minutes after the intravenous injection of 1 cc. of phenolsulfonphthalein. We feel that this is evidence of at least complete compensation of kidney function whether or not finer degrees of change in renal function might be demonstrated by other more

sensitive tests. The *prostate gland* in the male is then carefully palpated for possible evidence of malignancy and its secretion examined microscopically for infection.

Cystoscopy is then performed and the entire bladder wall as well as the proximal portion of the urethra is carefully studied for evidence of tumor. If bleeding is difficult to control at the time of cystoscopy or if bladder spasm makes it impossible for the patient to cooperate sufficiently to allow careful study of the bladder wall in the office, the cystoscopic examination is done again in the hospital under spinal or general anesthesia. A careful, unhurried examination with good vision and good relaxation of the bladder is most essential in diagnosis. It is easy to overlook a small or ulcerative tumor in the patient with constant bladder spasm during the examination or if bleeding prevents a clear field of vision. After the tumor has been identified and its size and infiltrative qualities carefully estimated, biopsy specimens are taken from several areas for microscopic study. Treatment of the tumor is postponed until this information has been obtained.

A number of nonmalignant lesions of the bladder can confuse the cystoscopist who suspects a tumor. Chief among these is bullous edema, which frequently appears similar to the relatively benign papillary forms of bladder tumor. Complete distention of the bladder with water while cystoscopy is being performed will often "iron out" this edema and reveal its true nature. At other times it is necessary to take a specimen for biopsy in order to differentiate one from the other. Other confusing lesions include cystitis cystica, tuberculous ulceration of the bladder, alkaline incrusted cystitis, leukoplakia, vesical calculi covered with exudate and firmly attached to the bladder wall or inflammatory reactions resulting from radiation therapy previously administered in the female pelvis. Extension into the bladder base from carcinoma of the cervix or rectum can occur because of the intimate lymphatic connection between these organs. In such instances the tumor may have actually broken through with ulceration and this is easily recognizable or it may have produced only some elevation of the bladder mucosa with congestion and edema but no ulceration. In the latter instance biopsy of the superficial layers of the bladder wall will not reveal the presence of a tumor even though it is actually present deep in the muscular layer of the bladder wall. Endometriosis can occur in the bladder and produce hematuria usually following a pattern parallel to the menstrual cycle, and when seen will be purplish and grapelike in appearance. Such lesions may be accurately identified by biopsy and locally removed followed later by oophorectomy. If diverticula of the bladder are encountered, it is always well to remember that a tumor may occur deep in a diverticulum beyond the field of vision of the cystoscopist. In such in-

stances cystograms may or may not be of aid in identifying the lesion but if blood is seen coming from a diverticular orifice, this diverticulum should eventually be removed with a presumptive diagnosis of tumor. In routine cases of bladder tumor cystograms are of further aid in revealing the presence of infiltration of the bladder wall with resulting distortion and reduction of capacity, thereby giving some indication as to the extent of the tumor as well as its degree of malignancy.

Rectal palpation of the bladder base above the prostate in the male and *vaginal examination* in the female will give evidence of the presence or absence of infiltration of the base. *Bimanual examination* of the bladder, preferably under anesthesia, with one finger in the rectum or vagina and the other hand pressing suprapubically will frequently give palpable evidence of an infiltrated bladder and also yield information as to the relative degree of fixation of the bladder which has already occurred. This information is of great value when partial or complete cystectomy is contemplated and may indicate in advance those cases which are operable.

Excretory urograms are made in every case in order to rule out possible primary malignancy in the upper urinary tract as well as to establish the presence or absence of obstruction on either side as the result of the tumor. If partial resection of the bladder is contemplated with the possible sacrifice of one kidney by ligating its ureter due to its location in the involved area, it becomes of vital importance to establish the presence of a normal kidney on the opposite side. Likewise, if uretero-intestinal transplantation followed by cystectomy is contemplated, it is essential to establish the presence of normal ureters because ureters dilated by chronic obstruction from a tumor at the ureterovesical junction do not lend themselves well to intestinal implantation.

TREATMENT

Essentially, the treatment of all tumors of the bladder is their removal. The method by which this is accomplished depends upon many factors. Chief among these is the grade of malignancy of the tumor. Of great importance also are its size and location and the age and general condition of the patient. Also, as pointed out before, if radical operation is contemplated, it is always necessary to rule out, by bimanual palpation if possible, prohibitive fixation of the bladder by extension of the tumor beyond the bladder wall.

Transurethral or Suprapubic Fulguration and Resection; Radium.—Grade I papillary tumors are best treated, as a rule, by simple *transurethral fulguration.* It is our practice to use the Stern-McCarthy resectoscope for this purpose. This instrument allows the rapid cutting away of the great mass of the tumor or tumors followed by thorough

fulguration of the base. Since these tumors will not have infiltrated the bladder wall beyond the mucosa, fulguration need not be deep. Occasionally, such a tumor may have grown to such a size as to make it impractical to remove it transurethrally. This is also the case if the tumors are so great in number as to stud large areas of the bladder. *Suprapubic fulguration* of the open bladder is a more efficient and desirable method of handling these cases. Since these grade I tumors are notoriously recurrent in nature, we make it a fixed rule to inspect these bladders in the office by cystoscopy every three months after the original tumor has been removed. Small recurrences seen here and there in the bladder, not necessarily at the site of the original tumor, can usually be fulgurated in the office with any satisfactory electrosurgical unit without the use of an anesthetic.

The grade II papillary carcinomas are likewise treated by transurethral resection and fulguration, but we frequently supplement this with the application of radium. Radon seeds represent the most convenient means of applying radium. After resection these are implanted into the base of the tumor with an injector through an operating cystoscope. A sufficient number of seeds is ordered in each individual case to cover the entire base of the tumor. The radon seeds are calculated to deliver 1.25 millicuries at the time of implantation and are spaced approximately 1 cm. apart.

Partial or Segmental Resection of the Bladder.—For the more infiltrative, higher grade malignancies (grades III and IV) we consider open *radical operation* necessary when possible. Although simple transurethral fulguration of such a tumor followed by irradiation, either with radium or deep roentgen rays, will occasionally bring about a spectacular result in such tumors, it is felt that the margin of safety is too small and that the tumor itself as well as a generous portion of the remaining bladder wall, if not all of it, should be removed if possible. Here, the age and general health of the patient are of prime importance. Partial or complete resection of the bladder is a rather arduous procedure which has to be carefully balanced against the normal life expectancy of the patient and the status of his general health. It is likewise of great importance to establish normal kidney function in cases in which radical operation is being considered. Should it be possible to demonstrate clinically that the tumor has extended beyond the bladder or that it had invaded the urethra, then more conservative procedures would seem to be indicated. Here again, transurethral resection of the tumor followed by irradiation therapy seems the most desirable treatment.

In favorable cases, however, wide excision is preferable. If the tumor is located on the vault and is easily accessible, partial resection of the bladder without disturbing the trigone or ureters is indicated. The usual low midline incision is made under spinal or general anes-

thesia, the muscles and fascia divided, the bladder insufflated so as to make it more accessible and the peritoneal fold reflected upward off the bladder. Should the tumor be found to have invaded the peritoneum where it is attached to the bladder, this portion of the peritoneum should be resected away along with the bladder wall itself and the defect repaired afterwards. The bladder is opened then and the contemplated area of resection carefully mapped out and cut away with the electrosurgical knife; the bladder is then resutured in two layers with chromic No. 1 catgut and a large Pezzer catheter left in. Drains are placed beside either side of the bladder and the wound closed in layers. Should the tumor be found to extend down one lateral wall far enough to make it desirable to carry away one corner of the trigone including the ureteric orifice on that side, this ureter may either be reimplanted into the bladder or deliberately tied off, thereby sacrificing the kidney. In such cases, one will always have determined the presence of a normal kidney on the opposite side and therefore the sacrifice of one kidney is not necessarily objectionable. This shortens the time of operation and obviates the danger of failure of reimplantation in a bladder which is already considerably mutilated by resection of the tumor. Except in the cases in which the kidney to be sacrificed is infected, it will be found that tying off this ureter does not complicate in any way the postoperative course of the patient. If infection is present in such a kidney, sepsis will follow and this kidney can then be promptly removed when the symptoms of infection become obvious. We feel that postoperative irradiation by deep roentgen ray in these cases is a valuable adjunct to treatment.

Bilateral Uretero-intestinal Anastomosis and Complete Cystectomy.—In those cases of high grade malignancy which do not lend themselves to partial or segmental resection of the bladder and yet show no gross evidence of metastasis, *complete cystectomy* is indicated (Fig. 498). A necessary prerequisite to cystectomy is diversion of the urine. This is best accomplished by bilateral uretero-intestinal anastomosis. If this should for any reason be impractical, bilateral cutaneous ureterostomy can be done. However, this is not as desirable from the standpoint of the patient as the former and is only indicated, as a rule, in instances in which dilatation of the ureters makes it difficult or impossible to implant them into the intestinal wall.

It is our practice to do the intestinal anastomosis and cystectomy in two stages. The first stage consists of the implantation of the right ureter into the sigmoid. After the patient has fully recovered from this procedure (usually in about two weeks), we proceed with implantation of the left ureter followed by total cystectomy at the same time. At the time of the first implantation it is possible to explore the bladder and adjacent structures so as to be sure that the bladder is freely

movable and that cystectomy will therefore be feasible. A further consideration at this point is the fact that even if some evidence of metastasis is present, cystectomy may still be desirable, if mechanically possible, for the reason that the patient's future course will be far more comfortable without having to contend with a sloughing tumor and an irritable, spastic bladder during the remainder of his life. Furthermore, postoperative irradiation in such cases may have a favorable influence on those metastases present, to the extent that the operation becomes worth while.

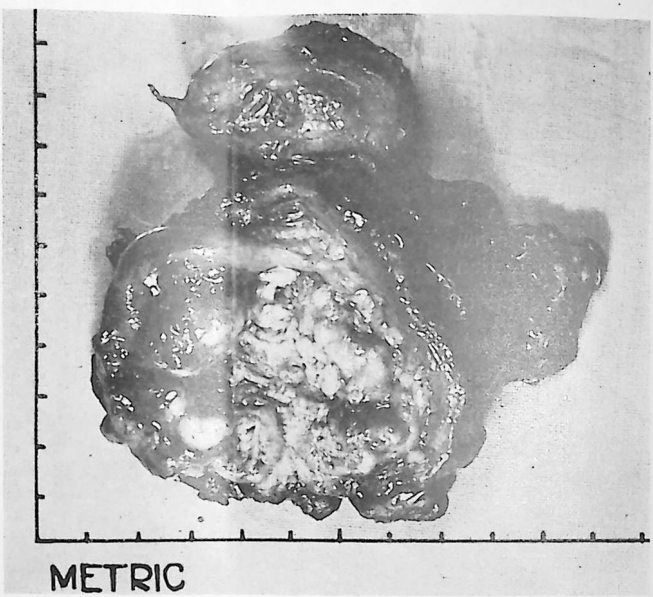

Fig. 498.—Specimen of infiltrating carcinoma of bladder after total cystectomy.

Preoperative Preparation.—Prior to operation the patient is hospitalized and an intestinal antiseptic and nonresidue diet are given. Sulfasuxidine (3 gm. four times daily) is administered in an effort to sterilize the intestinal tract partially. Twenty-four hours before operation a laxative is given and enemas are ordered for the night preceding the operation and the morning of operation. A rectal tube is left in place after the last enema and the patient is taken to the operating room. Parenteral fluids and whole blood should be freely given during the operation to prevent shock and fluid loss.

First Stage.—We prefer the Coffey type 1 procedure for *ureterointestinal anastomosis* as modified by Mayo.[3] The right ureter is trans-

planted first. A longitudinal incision is made to the right of the midline; the muscles and fascia are divided and the peritoneum opened. The patient is placed in the Trendelenburg position and the intestinal mass is packed off. The sigmoid is mobilized and an area as far down toward the rectum as possible is prepared for anastomosis. This is important as it leaves the remaining portion of the sigmoid above free of adhesions so as to be more easily handled later on for the second anastomosis. After the point of bowel to be used has been determined, this area is isolated with an intestinal clamp for a distance of several inches with one of the longitudinal bands presenting. The ureter is then identified through the parietal peritoneum, a small window made

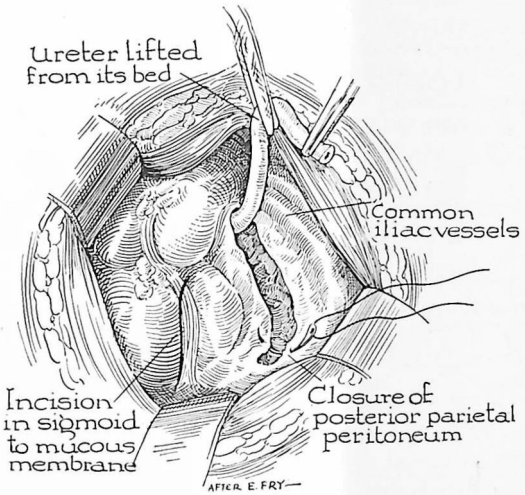

Fig. 499.—Mobilization of ureter prior to transplantation.

in the peritoneum and the ureter dissected free (Fig. 499). It is divided and ligated close to the bladder and the proximal end then brought up to the intestine. This end is cut obliquely and then split longitudinally for about 1 cm. in order to avoid stricture of the end of the ureter later. An atraumatic No. 0 chromic suture is taken through each of the flaps thus created by cutting the distal end of the ureter. The bowel wall is then incised along the longitudinal band for a distance of about 5 cm. going down to but not through the mucosa. The muscularis and serosa are then carefully dissected laterally on each side in order to provide a free flap to close over the ureter later on. An incision is then made through the mucosa at the distal end of this trough and each of the previously prepared catgut

sutures passed through the bowel and then out at a distance of at least 3 cm. below this opening. A small piece of catgut is placed in

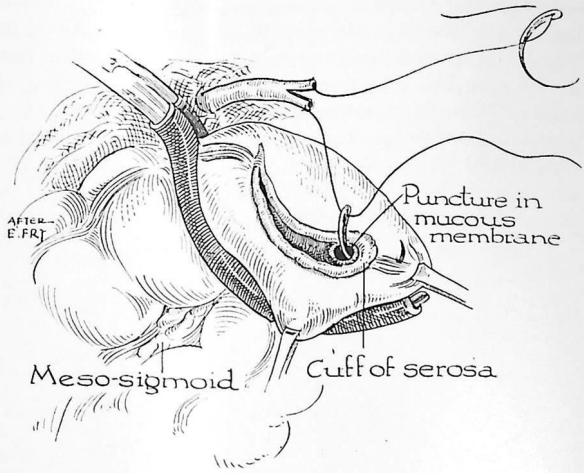

Fig. 500.—Transplantation of ureter into sigmoid.

the open end of the ureter in order to keep it open temporarily and the ureter is then passed down into the intestinal lumen (Fig. 500).

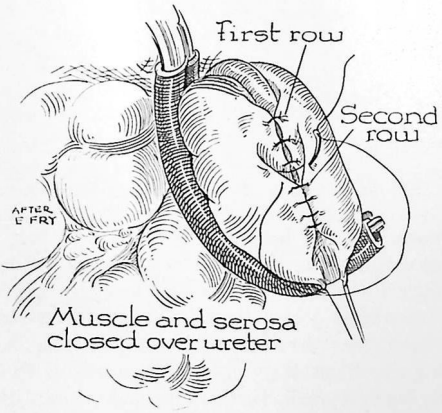

Fig. 501.—Closure of muscles and serosa of sigmoid after ureter has been transplanted.

The sutures previously taken are tied on the outside. The ureter is then buried in the bowel wall for the entire length of the trough by

atraumatic catgut sutures in the flaps previously prepared. Occasional small bites are taken through the outer coats of the ureter as the sutures are put in so as to anchor it further in position. Several layers of sutures are taken in all, completely burying the ureter (Fig. 501). When the operation is finished, the ureter should not be under any tension and should present itself in a straight line coming down from the kidney and entering the bowel. This area of intestine is then rotated slightly and the edges of the posterior peritoneum, previously opened for access to the ureter, are sutured to the intestinal wall so as to extraperitonealize the field of operation. The peritoneum is closed with catgut and the wound is closed in layers, with catgut for the muscle and fascia and silkworm and dermal for the skin.

Postoperative Care.—The patient is given parenteral fluids up to 3000 cc. a day. A rectal tube is kept in place, no laxatives are given and suitable urinary antiseptics may be administered. In the presence of undue fever or tenderness over the right kidney during the postoperative period we administer one of the sulfonamides in doses of 0.5 gm. four times a day with sodium bicarbonate, or the elixir of mandelic acid.

Second Stage.—After the patient has sufficiently recovered, usually in about two weeks, excretory urograms are made in order to demonstrate the presence of a normally functioning kidney on the side of the first operation and if all is well, the second stage is planned. Should this right kidney fail to function or continue to give evidence of obstruction and infection in the form of pain and fever, the second stage can be postponed or abandoned. We feel that this is the chief virtue in doing a two-stage operation, in addition to lessening the shock and operating time for the second stage.

In the second stage the left ureter is first transplanted by the same technic previously described for the right. As mentioned before, the upper portion of the sigmoid will be found freely movable and easily accessible for this purpose. The incision here should be to the left of the midline. The peritoneum is then dissected completely off the bladder wall if possible but if it has been found that the tumor has invaded the peritoneum, that portion of the peritoneum is taken along with the bladder and the defect in the peritoneum repaired. Then, dissection of the bladder from above is begun, the lateral and posterior aspects of the bladder are gradually freed and the vesical arteries clamped, divided and ligated with transfixion sutures of chromic No. 2 catgut as they are encountered. The ureteral stumps are identified and pulled up. The vas deferens on each side is likewise clamped and ligated. The base of the prostate and seminal vesicles are freed from the rectum and the prostate then dissected free on both sides by blunt dissection with the finger. The urethra is clamped at the apex of the prostate and the entire specimen including the

bladder, prostate and seminal vesicles removed. The urethral stump is transfixed by chromic No. 2 catgut and any bleeding encountered in the prostatic plexus of veins is controlled by mattress sutures. If convenient a stab drain opening is made through the perineum to the outside in order to provide dependent drainage for the large cavity left after removal of the bladder. Cigarette drains are likewise placed down to the base of the wound coming out from the lower angle of the incision and the wound closed in layers with catgut for the muscle and fascia and silkworm and dermal for the skin. Here again, a rectal tube is left in place and intravenous fluids and whole blood are given to insure an adequate intake and to prevent shock.

We have found penicillin of value during this postoperative period as it seems to promote wound healing and retard secondary infection. It is usually given by intramuscular injection of 20,000 to 30,000 units every three hours. Deep roentgen ray therapy over the lower abdomen is considered a valuable adjunct to treatment after the wound has completely healed.

CONCLUSIONS

1. Painless hematuria should be considered presumptive evidence of malignancy in the urinary tract until proved otherwise.

2. Cystoscopy offers a certain means of diagnosis of bladder tumors and should be accompanied by biopsy with microscopic grading of the specimen since the plan of treatment will largely depend upon the grade of the tumor.

3. Transurethral excision and fulguration with or without some type of irradiation therapy is the treatment of choice for those bladder tumors of low grade malignancy.

4. Experience and refinements in surgical technic have made radical excision of highly malignant bladder tumors less dangerous than ever before.

5. Wide resection of highly malignant tumors offers the greatest promise of cure and should be the treatment of choice in all such cases which are considered operable.

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COTTON SUTURES IN VAGINAL PLASTIC OPERATIONS ABOUT THE BLADDER AND URETHRA

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IN 1939 Meade and Ochsner[1] demonstrated the superiority of cotton over any other absorbable or nonabsorbable material available for use as sutures. Since then numerous reports have appeared in the literature stressing the advantages of cotton for this purpose. In 1942 we[2] reported a series of cases in which gynecologic and obstetrical operations had been performed with cotton as the suture material. Since that time we have used cotton sutures exclusively in gynecologic and obstetrical surgical procedures whether the operation was performed abdominally or vaginally.

ADVANTAGES OF COTTON SUTURES

In vaginal plastic repair the advantages of cotton sutures include (1) minimal reaction in the tissues, (2) diminished amount of postoperative vaginal discharge and (3) increased comfort for the patient. Its use also permits early ambulation and a subsequent decrease in the number of urologic complications such as cystitis or pyelitis by 85 per cent.[2] Early ambulation and lack of tissue reaction reduce the necessity for postoperative catheterizations in a large number of patients. Furthermore, earlier postoperative and postpartal examination is possible because the patient experiences less pain on vaginal or speculum examination when cotton sutures have been used than when other material is utilized. When cotton has been employed, it is possible to examine a woman vaginally or with a speculum after the second or third postoperative or postpartal day with little or no discomfort. We have noted less scar tissue about the vagina months after operation with cotton sutures than with any other absorbable suture material. In addition, the vagina, bladder, rectum and urethra are adequately supported and the tissues are much more pliable and plastic instead of being rigid as in cases in which nonabsorbable sutures have been used.

This communication will be limited to the use of cotton sutures in the repair of cystocele, urethrocele, vesicovaginal fistula and urethral diverticulum.

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PREOPERATIVE CARE

Plastic operations in women who are still within the menstrual age are best performed within the first two weeks following a menstrual period. In this way considerable undesirable oozing or bleeding can be eliminated. As in all surgical work, the patient should be brought to the operating table in the best general condition possible. The blood count and hemoglobin should be within normal limits and for weeks before the operation the patient's diet should include adequate proteins and vitamins, especially vitamin C, since normal serum protein and vitamin C have been shown to promote wound healing.

In women who have reached the climacteric the vaginal mucous membrane, because of the lack of estrogenic hormones, reverts to the type found in the preadolescent period; that is, there are atrophic changes manifested by a thin epithelium usually six to eight layers of cells deep containing little or no glycogen. The atrophic membrane and lack of glycogen predispose to vaginal infection produced by pathogenic organisms and, in addition, it is technically more difficult to dissect a very thin and atrophic mucous membrane from the underlying tissues. These two objectionable features can easily be remedied by the use of estrogenic suppositories administered nightly for three weeks prior to the date of operation, the dosage being 2000 to 2500 international units of estrogenic substance either in the form of natural estrogen or 0.5 mg. of stilbestrol in suppositories. The preoperative use of suppositories containing estrogenic hormone converts the atrophic mucous membrane to the type found in the healthy young woman, that is, the membrane becomes twenty-four to twenty-six layers of cells in thickness, the cells contain an adequate amount of glycogen and the vaginal *p*H and flora are reestablished to an optimal condition. It is our impression, although this has not been substantiated by biopsy, that not only is the vaginal epithelium affected by the use of estrogenic suppositories but the underlying pubocervical fascia seems to be thickened and tougher and more adaptable for suturing.

OPERATIVE TECHNICS

In regard to nonabsorbable suture material in surgical procedures the principles set down by Halsted should be followed unequivocally; that is, there must be thorough hemostasis, the suture material should be as fine as compatible with tissue strength, fine bites should be taken, mass ligation of tissue should be avoided and the suture should be cut close to the knot. Deviation from these tenets will, of course, produce undesirable results.

At the operating table the vagina is thoroughly scrubbed with green soap and water, the excess water is removed by means of alcohol and the vagina and vulva are painted with any antiseptic solution the

operator prefers. After thorough cleansing with green soap and water and alcohol the use of an antiseptic solution about the vagina and vulva is of questionable value.

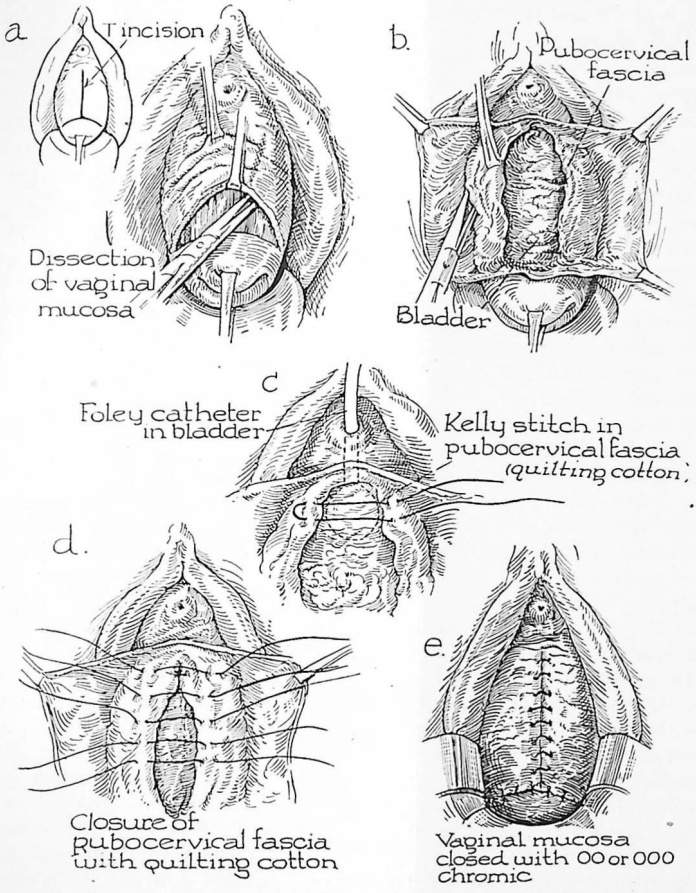

Fig. 502.—Technic in repair of cysto-urethrocele. For details, see text.

Cystocele.—In the repair of cystocele a linear incision down the midline or a deep T-shaped incision is made through the vaginal mucous membrane (Fig. 502, *a*). The vaginal mucosa is then reflected from the pubocervical fascia and bladder by means of initial sharp dissection with a small scalpel blade. This dissection is continued

widely on either side from the midline with scalpel or scissors (Fig. 502, *b*) and the bladder is fully mobilized. A Foley catheter is inserted into the bladder and the bladder neck identified. A Kelly stitch of quilting cotton is then placed in the pubocervical fascia in the region of the bladder neck and tied (Fig. 502, *c*). The pubocervical fascia is then brought together with interrupted sutures of quilting cotton placed approximately 0.75 cm. apart (Fig. 502, *d*). The sutures are tied and then cut at the knot. Occasionally, in very large cystoceles in elderly women two rows of sutures are used. The excess vaginal mucosa is trimmed away and the vaginal mucous membrane approximated with No. 00 or 000 chromic catgut (Fig. 502, *e*). Very fine catgut is used in the vaginal mucous membrane because we do not like to have to remove sutures from this structure postoperatively or postpartally. We have used very fine cotton sutures in the vaginal mucous membrane (cotton No. 150 or 200) in humans and observation of these patients for months after operation has shown that ultimately the suture is either absorbed or has slipped out aseptically. However, for purposes of convenience, we do not use cotton in the vaginal mucous membrane itself although there is no surgical contraindication to its use in this structure.

Urethrocele.—The vaginal mucous membrane over the urethra is divided in the longitudinal axis of the vagina down to the urethra or pubocervical fascia (Fig. 502, *a*). The dissection is carried out widely, laterally, and the urethra is freed along its entire course. Any adhesions to the pubic arch are separated by sharp dissection. A catheter, preferably of the Foley type, is inserted into the bladder to identify the bladder neck. A first layer of Kelly stitches of interrupted quilting cotton is placed at the bladder neck (Fig. 502, *c*) and then a second layer of interrupted quilting cotton sutures is placed through the pubocervical fascia. The sutures are spaced anywhere from 0.75 to 0.5 cm. apart. The vaginal mucous membrane is then approximated with chromic No. 00 or 000 catgut.

In plastic operations in which cystocele and urethrocele coexist, the technic outlined previously is used; i.e., a longitudinal incision or inverted T-shaped incision is made through the vaginal mucosa extending from just below the urethral orifice to the cervix. Whether or not a T-shaped incision is used or just a single longitudinal incision depends upon whether or not the cystocele extends down to the region of the internal os of the cervix. There is no need for a T-shaped incision in cases in which the cervix and uterus have been removed or the cystocele does not involve the cervix. The remainder of the procedure is as described under the correction of cystoceles and urethroceles.

Vesicovaginal Fistula.—The end results in cases of vesicovaginal fistulas depend upon (1) the amount of mobilization obtained at the

time of operation and (2) the ability to approximate the bladder mucosa and pubocervical fascia without tension. Accordingly, irrespective of the site or cause of the fistula, we believe it best to make an initial incision down the midline (Fig. 503, *a*) extending from just beneath the urethra to the cervix or to where the cervix would have been should it have been removed at a previous operation. If the fistula is in the midline, it is encircled and the bladder is freed by means of wide dissection to the most lateral portion of the vaginal

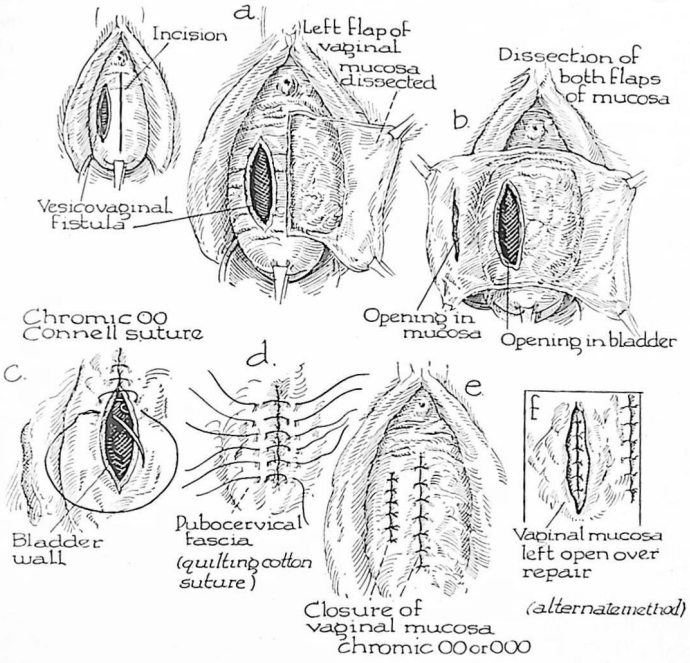

Fig. 503.—Technic in repair of vesicovaginal fistula. For details, see text.

wall. Should the fistula be on either the right or the left side and not in the midline, the bladder is first freed on the side opposite the fistula; that is, if the fistula is on the right side, the left side is dissected first and vice versa (Fig. 503, *a*). The bladder is freed to the most lateral portion of the vaginal wall. The dissection is then carried to the side on which the fistula exists (Fig. 503, *b*), the fistula encircled and the vaginal mucous membrane reflected from the bladder or pubocervical fascia as far laterally as possible. In this manner we are able to obtain maximum mobilization of the bladder and conse-

quently a suture line which will be under minimal stress irrespective of the location of the fistula. The margins of the fistulous opening into the bladder are then freshened, the scar tissue cut away and the bladder mucous membrane approximated by a Connell suture of chromic No. 00 or 000 (Fig. 503, *c*). Nonabsorbable suture material is not used to close the bladder mucosa. A second line of sutures consisting of interrupted quilting cotton is placed through the pubocervical fascia and/or bladder muscularis about 0.5 cm. apart (Fig. 503, *d*) and the bladder mucosa and/or pubocervical fascia approximated over the suture line in the bladder mucosa. Occasionally, it is possible to put in a second row of cotton sutures. Quilting cotton has considerable advantages over larger sized catgut or sutures such as stainless steel wire or silver wire in this particular part of the operation as cotton sutures of this size will break before one can tie them under tension, which is not true of stainless steel or silver wire. Thus, closure of the bladder muscularis and/or pubocervical fascia over the suture line in the bladder mucosa guarantees that the suture line is not tied under tension; this greatly enhances the possibilities of healing. The vaginal mucous membrane down the midline is then closed with chromic No. 00 or 000 sutures (Fig. 503, *e*). Whether or not the vaginal mucosa is closed over the site of the fistula is of little or no import. If the mucous membrane can be brought together without tension, then it is closed with interrupted, chromic No. 00 or 000 sutures. If the defect is so large that it cannot be closed, or cannot be closed without undue tension, the mucous membrane is not closed (Fig. 503, *f*). Thus, the cardinal principles involving the healing of vesicovaginal fistulas have been fulfilled; that is, (1) wide mobilization of the bladder to insure a suture line which is tied without tension and (2) closure of the fistula in layers without tension. We believe that this approach to the closure of vesicovaginal fistulas far surpasses the direct attack on the fistula itself. To reiterate, the approach to closure should be (1) an initial line of incision down the midline of the vaginal mucosa, (2) free mobilization on the uninvolved side first, and (3) the bladder near the fistula mobilized as a latter part of the operation.

Postoperatively, a retention catheter of the Foley type is put in the bladder, the patient placed on a Bradford frame on her abdomen and the catheter connected to a bottle on the side of the bed. The catheter is removed on the twelfth or fourteenth postoperative day. Vaginal suppositories of estrogenic substance, either 0.5 mg. of stilbestrol or 2000 international units of natural estrogen, are inserted into the vagina twice daily to promote healing, especially in cases in which it was not possible to approximate the vaginal mucosa over the site of the fistula. This insures more rapid growth of the epithelium over the defect.

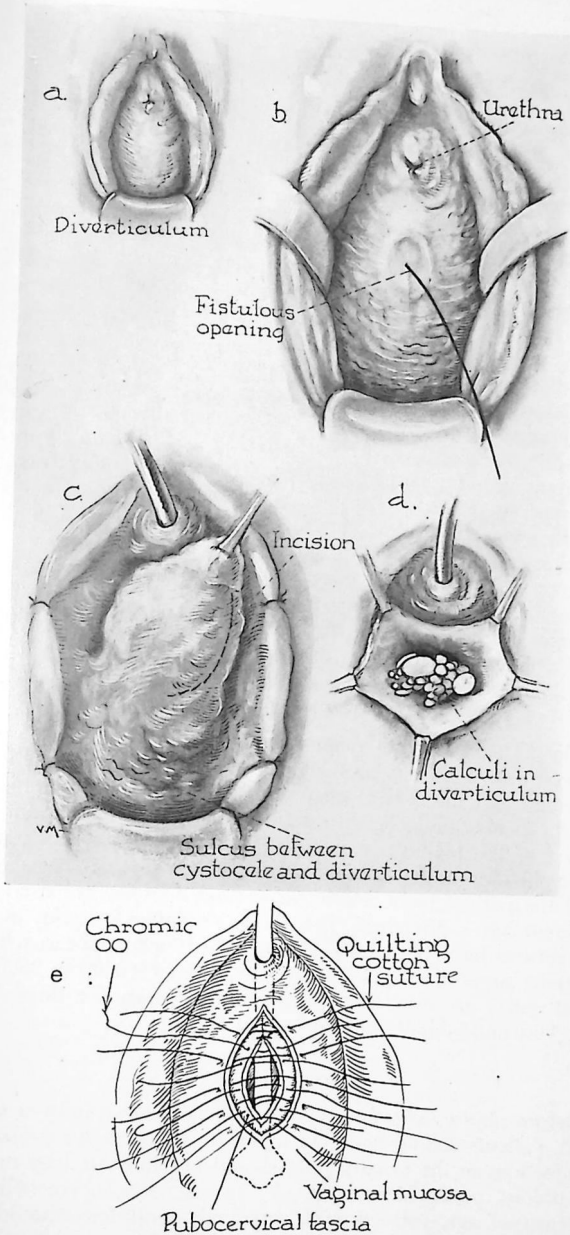

Fig. 504.—Technic in repair of urethral diverticula. For description, see text.

Diverticula of the Urethra.—Although this condition is rarely encountered, its possible presence should always be kept in mind. Diverticula may vary in size from 1 cm. to 10 cm. in diameter and may or may not contain calculi. The differentiation of diverticula from urethroceles and cystoceles is not difficult if the condition is kept in mind and, when suspected, if a urethral sound or small endoscope is placed into the urethra, the diverticulum can be palpated over the sound or endoscope. The diagnosis of urethral diverticula associated with stones is especially easy as the stones give a typical "chicken craw" feel.

Technic.—An incision is made just below the urethral meatus down the midline as far posteriorly as necessary (Fig. 504, *c*). The bladder mucosa is dissected away from the wall of the diverticulum and the diverticulum opened. It is then excised (Fig. 504, *d*) and the urethral wall closed with interrupted chromic No. 00 or 000 sutures. The vaginal mucous membrane is then closed over the suture line in the urethra by means of quilting cotton, interrupted sutures (Fig. 504, *e*). A retention catheter is left in place from twelve to fourteen days and then removed; the quilting cotton sutures are removed from the anterior vaginal wall at the same time. Occasionally, the diverticulum is so large and contains so many stones that an actual erosion and fistulous opening are found in the diverticulum (Fig. 504, *b*).

POSTOPERATIVE CARE

We do not advise or use vaginal packs postoperatively. The patient is allowed out of bed as soon as the effects of the anesthetic have disappeared and she is encouraged to walk about and to remain out of bed for as long periods as possible. In this way, earlier spontaneous emptying of the bladder is obtained, the incidence of postoperative thrombophlebitis and phlebothrombosis is greatly decreased and in general the patient feels better. No vaginal douches are used unless the patient has a discharge. This is the exception in cases in which cotton sutures have been utilized. In patients who have reached the climacteric, suppositories of estrogenic substance (2000 to 2500 international units) are used each night postoperatively for three to four weeks. This undoubtedly aids in wound healing.

CONCLUSIONS

1. Before plastic operations about the bladder and urethra are performed, patients should have the following preoperative preparation: (*a*) Infections in the urinary tract should be eliminated by means of sulfonamides, penicillin or both. (*b*) In women who are still within the menstrual age, correction of pathologic conditions should be attempted only within the first two weeks following a menstrual period

because during this time the chances of excessive oozing are minimal. (*c*) For the patient in the postmenopausal age or at the menopause when the vaginal mucous membrane has become thin and atrophic, the preoperative use of suppositories of 0.5 mg. of stilbestrol or 2000 international units of natural estrogen in oil each night for three weeks greatly increases the thickness of the vaginal mucous membrane and the pubocervical fascia, makes dissection easier and aids in eliminating any infection which may accompany senile vaginitis.

2. The use of quilting cotton sutures in the bladder wall or pubocervical fascia not only results in a neater operation but definitely decreases the amount of postoperative pain and vaginal discharge and reduces the necessity for postoperative catheterization because of early ambulation.

3. Retention catheters should be used only in patients who have had repair of a urethral diverticulum or vesicovaginal fistula.

4. In postmenopausal or menopausal patients the postoperative use of suppositories hastens wound healing.

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CLEARANCE AND SATURATION TESTS OF RENAL FUNCTION

THOMAS FINDLEY, M.D., F.A.C.P.*

WITH the possible exception of the eye, no organ in the human body lends itself so well to mathematical treatment as does the kidney. In the 100 years which have elapsed since William Bowman's famous observations laid the groundwork for studies in renal physiology, clinical research in this field has brilliantly justified itself. The purpose of this paper is to describe briefly and without full historical background the methods which yield quantitative renal function values of remarkable accuracy in the intact human body.

RATE OF GLOMERULAR FILTRATION

Rehberg[1] was the first to point out that the rate of glomerular filtration could be measured if there were available a substance which passes freely across Bowman's membrane but does not traverse the tubular epithelium in either direction. Thus, if a beaker containing 1000 cc. of a 1 per cent salt solution is allowed to evaporate until the final volume is 100 cc., the final saline concentration becomes 10 per cent (concentration $\times$ volume $=$ concentration $\times$ volume). Figure 505 illustrates the application of this principle to a single nephron in which the volume of glomerular filtrate is large and that of the bladder urine small; the tubular cells reabsorb water but leave the number of dissolved molecules unchanged.

If three of the four factors are known, the fourth is easily calculated. Wishing to determine the volume of glomerular filtrate formed per minute, we rearrange the equation to read $V = \frac{C_1 V_1}{C}$. The two items in the numerator are supplied by determining the concentration of the test substance in bladder urine and the rate of urine flow per minute. The denominator is procured indirectly; we cannot obtain glomerular filtrate from an intact animal but the requirement has already been made that the concentrations in plasma and glomerular filtrate are identical so that we have only to analyze a sample of venous plasma to obtain an equivalent figure. Substituting plasma (P) for glo-

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merular filtrate and using more familiar symbols, the equation becomes V (glomerular filtration rate) $= \frac{UV}{P}$. This is equivalent to stating that $V = \frac{\text{mg. excreted per min.}}{\text{mg. per cc. plasma}}$.

The actual application of this principle to the patient is none too difficult. An adequate and reasonably constant concentration of the test substance in the blood stream is maintained by appropriate intravenous or subcutaneous injection, a catheter is placed in the bladder and, after a suitable period of equilibration, urine collections are

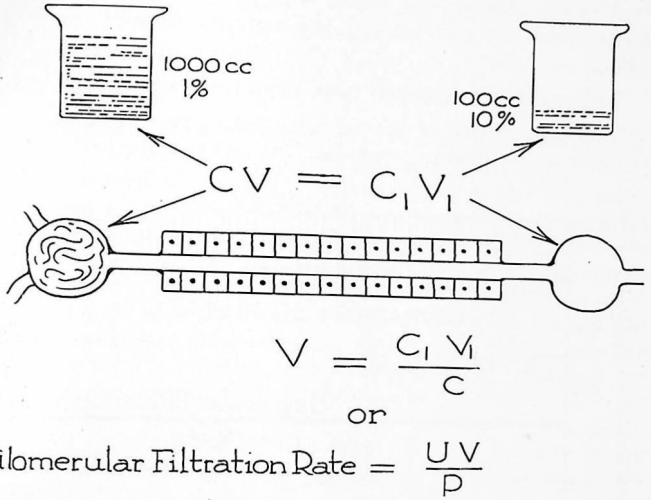

Fig. 505.—Illustration of the principles whereby the rate of glomerular filtration may be measured in intact subjects. See text.

made at arbitrary intervals by washing the bladder out with saline. Usually three or four twenty-minute periods are obtained and blood samples are withdrawn from the antecubital vein at the middle of each collection period. Details concerning the precise procedures are available.[2]

No substance which occurs naturally in the human body meets the requirements so that foreign materials must be employed. Of these, inulin is most widely used. Introduced independently by Richards and co-workers[3] and Shannon and Smith,[4] it has received the widest acceptance.[5] The more recent demonstration that other substances (hexitols,[6] thiosulfate[7]) yield identical results substantiates the current belief that the rate of glomerular filtration can be measured with great

accuracy in the intact normal subject. The problem of the diseased kidney will be referred to later.

The establishment of this technic for measuring the rate of glomerular filtration has been of the utmost theoretical and practical importance, but the formula which makes it possible may also be usefully applied to the study of any other urinary constituent, since it $\left(\frac{UV}{P}\right)$ is essentially a concentration ratio $\left(\frac{U}{P}\right)$ to which a time factor (V) has been added. It is now the custom to express the excretion rate of any substance in relation to its plasma (or whole blood) concentration, and results may be grouped into those substances which are excreted (*a*) less and (*b*) more efficiently than inulin.

SUBSTANCES EXCRETED LESS EFFICIENTLY THAN INULIN

All the constituents of normal urine belong to this category with the possible exception of creatinine. The fact that the exact chemical

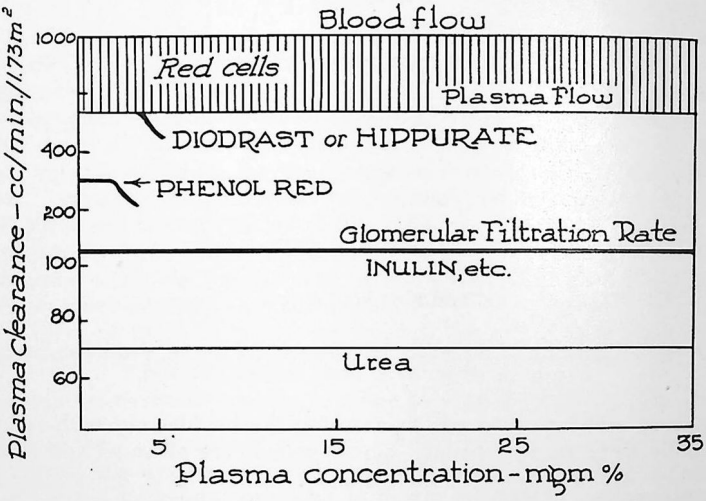

Fig. 506.—The relationship between renal blood flow and the plasma clearance of various substances.

nature of the chromogenic substances which react with the Jaffé reagent are unknown makes creatinine a difficult material with which to work. Differences of opinion on this matter exist[8] and it would serve no useful purpose to include creatinine in the present discussion.

Figure 506 depicts the application of this formula to a representative number of substances. Smith,[9] who has had the largest experi-

ence in this matter, reports that the glomerular filtration rate in normal man averages 131 cc. per minute. For the sake of simplicity, however, and because other observers have found somewhat lower values, the normal volume of glomerular filtrate is put at 120 cc. per minute.* When the excretion of another substance is studied in the same manner and the answer turns out to be less than 120, it may be assumed that that substance has been eliminated by a process of glomerular filtration and subsequent tubular reabsorption. In any event, it is unnecessary to invoke tubular secretion as an explanation for its appearance in the urine. If, however, the figure for a third substance is greater than 120, it is certain that a portion of this material must have been extruded into the tubular lumen by active vital processes residing within the tubular cells. Obviously, tubular reabsorption diminishes the efficiency of renal excretion and tubular secretion enhances it.

As examples of the manner in which naturally occurring substances are handled by the kidney, glucose and urea may be chosen. Since glucose is known to occur in glomerular filtrate in the same concentration as in plasma[10] and since normal urine is glucose-free, tubular reabsorption must be complete. When the formula is applied to urea, however, the average for normal adults is about 75 cc. per minute,[11] a finding which must mean that approximately 40 per cent of that amount of urea which is filtered is reabsorbed by the tubules. Other naturally occurring substances, the excretion of which have been studied by current methods, are: sodium chloride,[12] sulfate,[13] phosphate,[14] amino acids,[15, 16, 17, 17a] hemoglobin,[18] vitamin C,[19] beta-hydroxybutyric acid,[20] pantothenic acid,[21] lactic acid[21a] and uric acid.[22] All these substances have been found to be excreted by a process of glomerular filtration and subsequent tubular reabsorption.

SUBSTANCES EXCRETED MORE EFFICIENTLY THAN INULIN

Of greater physiologic interest are certain foreign substances whose rates of renal elimination are high because bodily conservation is useless or harmful. In order to increase the efficiency of the excretory process, the kidney may modify its normal machinery in two ways. First, tubular reabsorption may diminish or cease altogether, in which event the excretion rate will approach or become equal to the rate of glomerular filtration. Secondly, an extra moiety may be added to the urine by a process of active tubular secretion. Figure 506 also

* By way of illustration, this figure would have been achieved by maintaining plasma inulin concentration at 20 mg. per cent and finding that when urine was formed at the rate of 2 cc. per minute the urinary concentration of inulin was 1200 mg. per cent $\left(V = \frac{1200 \times 2}{20}\right)$.

illustrates the manner in which certain substances are excreted by this double process of glomerular filtration and tubular secretion.

Phenol red (phenolsulfonphthalein) was one of the first such materials to be studied. In 1923 Marshall and Vickers[23] first proved the existence of tubular secretion in dogs by showing that much more phenol red appeared in bladder urine than could possibly be accounted for by glomerular filtration alone, and it is now agreed that if tubular secretion did not exist, the rate of glomerular filtration in man would have to be at least as high as 350 cc. per minute in order to account for all the dye excreted. This is regarded as an impossible figure, and still other substances (diodrast, hippuric acid derivatives, etc.) have been shown to be excreted approximately twice as efficiently as phenol red.[24]

The importance of these studies lies in the fact that they provide at least a theoretical way of measuring the renal blood flow in intact subjects. This conception is best illustrated by a consideration of the so-called *extraction ratio.* It is not difficult to explant a dog's kidney just under the skin to a position which permits withdrawal of blood from the renal vein at will; blood obtained simultaneously from a peripheral vein is regarded as chemically equivalent to the blood entering the kidney through the renal artery and the formula $\frac{A-V}{A}$ represents the ability of the kidney to extract a given substance from the blood which perfuses it. Recently, extraction ratios have been obtained in man by passing a catheter up the median basilic vein, through the right auricle, down the inferior vena cava and into the renal vein itself.[25] If the concentration of substance X in peripheral vein plasma is 12 mg. per cent and in renal vein plasma 9 mg. per cent, the extraction ratio is $\frac{12-9}{12} = 25$ per cent; the kidneys are eliminating one quarter of the material brought to them.

If, then, a substance could be found the extraction ratio of which is 100 per cent (i.e., all the material is removed from the blood during one circulation through the kidney), measurement of its urinary excretion rate in relation to the blood concentration would give a figure equal to the rate of renal blood flow, since it is obviously impossible for the kidneys to eliminate more of the substance than is brought to them by the blood stream per unit of time. Figure 507 shows diagrammatically the approximate extraction ratios of representative substances in normal man and their direct proportionality to the $\frac{UV}{P}$ values.

Physiologists have therefore searched for substances which are excreted so efficiently that virtually none escapes the kidney by way

of the renal vein and presumably also the lymphatics. Figures 507 and 508 show that diodrast and certain hippuric acid derivatives virtually meet the requirements, since their extraction ratios in man are approximately 90 per cent.[24] The fact that the ratios are not 100 per cent is not a valid criticism for it, as Smith[26] has pointed out that some of the blood entering the renal artery is distributed to connective or fatty tissue and thus never comes in contact with true kidney parenchyma at all. The method has, therefore, been described as a measure of "effective renal blood flow." For example, if it be found that 1100 mg. of diodrast are appearing in the bladder urine per minute and that peripheral vein plasma contains 2 mg. per cc., then

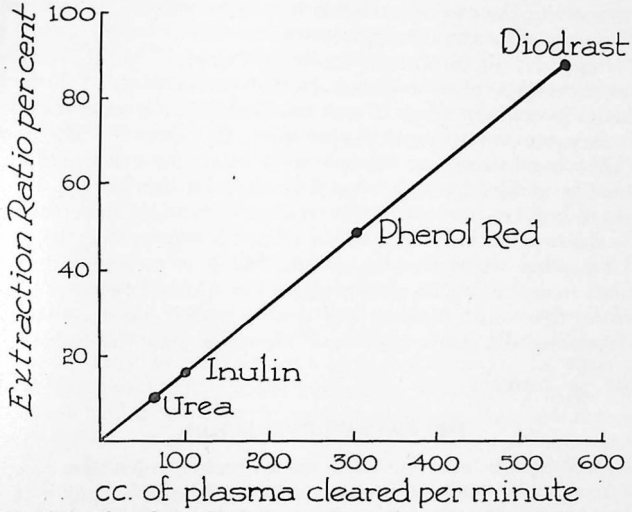

Fig. 507.—The relationship between plasma clearance and extraction ratio.

550 cc. of plasma must have come in contact with tubular tissue each minute. If, furthermore, the hematocrit is 45 per cent, the effective whole blood flow is $\frac{550}{0.45} = 1222$ cc. per minute. In twenty normal human subjects Bradley[27] has found that the extraction of *p*-aminohippurate ranged from 89.5 to 95.6 per cent with an average figure of 92.4 per cent.

It will be observed from Figure 506 that this technic is valid for the measurement of renal blood flow only when the blood concentrations are kept low enough to permit maximal extraction; the capacity of tubular cells to transmit material is easily exceeded and, when this is done, the extraction ratios obviously fall.

DEFINITION OF CLEARANCE

Thus far the word "clearance" has been studiously avoided because it seems to impose a handicap upon the average student. Actually, the required arithmetic is extremely simple and the concept not too difficult. The formula $\frac{UV}{P}$ has already been explained; it was first introduced by Möller, McIntosh and Van Slyke,[28] in a study of urea excretion and was defined by them as "the volume of blood which one minute's excretion of urine suffices to clear of urea." Another way of saying the same thing is that "clearance" is that volume of blood which contains the amount of substance excreted by the kidney in one minute. In the case of urea this is a hypothetical rather than an actual value; since the extraction ratio for urea is only about 8 per cent (Fig. 507), the blood is obviously not "cleared" but it represents a convenient concept nevertheless. In the case of diodrast, however, the blood is virtually "cleared" and the diodrast clearance, therefore, becomes equivalent to renal plasma flow. To determine the "clearance" of any substance one has only to calculate the number of cubic centimeters of blood which must flow through the kidneys in one minute in order to account for the amount of that substance appearing in the urine in the same unit of time. Clearances may be calculated for either whole blood or plasma but it is preferable in most instances to deal only with plasma clearances. Unless otherwise stated, therefore, the word *clearance* will denote *plasma* clearance and in the foregoing discussion the word *clearance* may be substituted for the $\frac{UV}{P}$ formula.

THE FILTRATION FRACTION

These clearances have more than static absolute value, however, for they are capable of depicting changes in renal hemodynamics. If, for example, one divides the inulin clearance (glomerular filtration rate) by the plasma diodrast clearance (renal plasma flow), the figure obtained represents the proportion of plasma filtered through the glomerular membrane; this has been termed "the filtration fraction" by Smith.[26] Although it is a value which can be altered by many factors (permeability of Bowman's membrane, intrarenal tissue pressure, the osmotic pressure of plasma proteins, the viscosity of the blood, etc.), changes in this ratio are generally interpreted as representing fluctuations in intraglomerular pressure due to variations in the caliber of the arterioles entering and leaving the glomeruli.[29] Thus, constriction of the afferent arterioles would result in a proportional drop in blood flow and filtration rate whereas preferential constriction of the efferent glomerular arterioles would diminish renal blood flow (diodrast clearance) but would raise intraglomerular pres-

sure and thus tend to maintain the inulin clearance at its preconstriction level. Conversely, dilatation of these arterioles might be expected to produce increases in diodrast clearance but simultaneous inulin clearance might rise or fall, depending upon whether the vasodilatation takes place proximal or distal to the glomeruli. It must be pointed out, however, that changes in the secretory capacity of the tubules will produce apparent fluctuations in the "filtration fraction" which is, after all, only a ratio.

THE MEASUREMENT OF TUBULAR SECRETION

Acceptance of diodrast clearance as a measure of renal plasma flow need not depend upon any notions concerning the manner in which the kidney handles diodrast any more than a urea clearance tells us anything about the machinery of urea excretion; in either case it is enough to know simply that diodrast and urea are somehow extracted by the kidney and extruded into the urine. By altering experimental conditions, however, it is possible to obtain quantitative information concerning the capacity of renal tubules to transport materials and thus to assess tubular function separately from glomerular filtration.

Figure 506 shows that plasma diodrast clearance can be interpreted as a measure of renal plasma flow only when the concentration of diodrast-iodine in the plasma is kept at a very low level, less than 5 mg. per cent. The clearances of phenol red are, likewise, valid only under similar and even more rigid restrictions. If plasma concentrations are raised progressively, the corresponding plasma clearances fall proportionately until at very high plasma levels the clearances become depressed almost to the inulin level. This is because the ability of the renal tubules to secrete certain substances is readily exceeded; if more material is offered to the tubules than they can transport with maximal efficiency, the extraction ratio falls and the plasma clearances become uninterpretable on a physiologic basis. At some definite point the tubule transfer mechanism will become saturated and excess amounts brought to the kidney can be excreted only by the glomerular route, which has no such limitations. Thus, at very high plasma concentrations the amount excreted by glomerular filtration so greatly exceeds that contributed by tubular secretion that the total clearance closely approaches the value for inulin itself. Indeed, this asymptotic relationship between clearance and plasma concentration is one of the standard methods of detecting tubular secretion itself.[5]

Smith[26] was the first to make quantitative estimates of the secretory capacity of the renal tubules. From simultaneous plasma clearances of inulin and diodrast it is possible, with the aid of a nomogram[30] depicting the amount of free or unbound phenol red and diodrast at various plasma concentrations, to calculate the glomerular and tubular contribution to total urinary output. For example, if one multiplies

the amount of free or filtrable diodrast in 1 cc. of plasma by the glomerular filtration rate, he obtains a figure representing the absolute quantity of diodrast filtered per minute; the difference between this and the total rate of diodrast secretion, of course, gives the tubular contribution. It is this latter value which is of such interest because of its quantitative limitation.

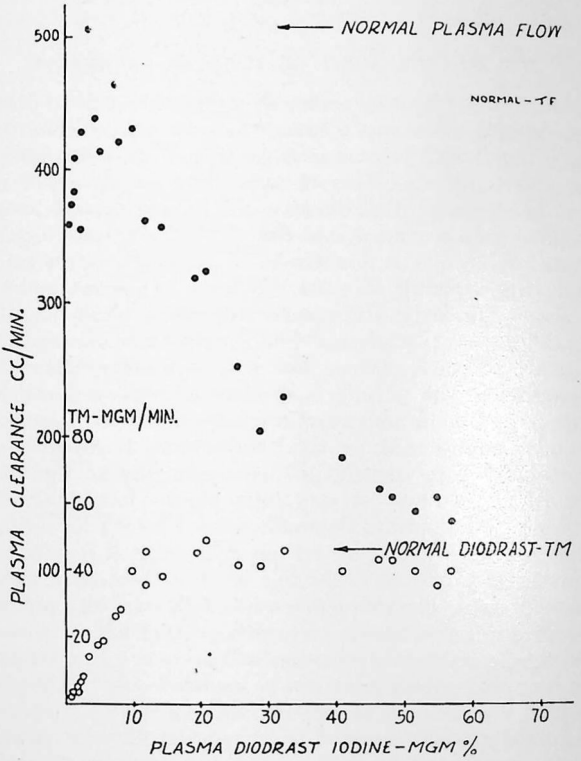

Fig. 508.—The relationship between plasma concentration, plasma clearance and tubular excretion of diodrast-iodine in a normal human subject.

Figure 508 shows the relationship between the concentration of plasma diodrast and the amount secreted by the tubules of a normal human subject. The open circles represent the milligrams of diodrast-iodine secreted per minute and show that at a plasma level of approximately 51 mg. per cent this value becomes constant and that the tubules are unable to secrete more than 45 mg. of diodrast-iodine per minute regardless of further increases in the load of diodrast

offered to them. This value has been termed by Smith *diodrast-Tm* (the maximal rate of tubular excretion), and may be accepted as one method of estimating the functional capacity of the renal tubules. Smith's studies[31] indicate that the renal tubules of normal man are capable of secreting about 52 mg. of diodrast-iodine per minute, those of women slightly less. Our average diodrast-*Tm* on a much smaller series of mixed subjects was 40 mg. per minute.[32]

Substances other than diodrast may, of course, be used for this purpose provided they are in part eliminated by tubular secretion. Figure

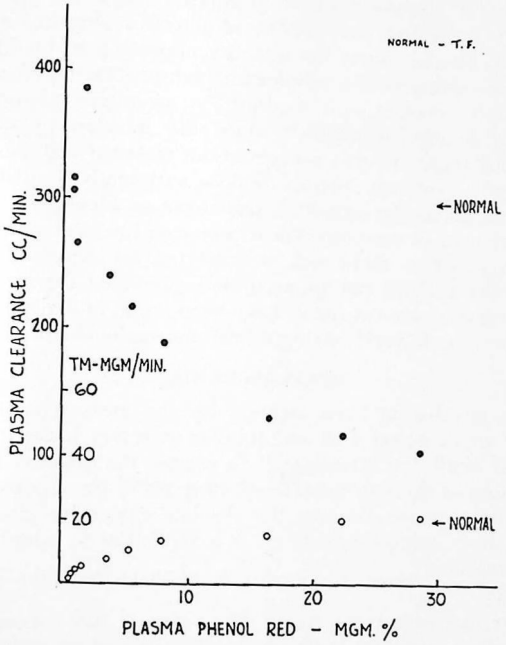

Fig. 509.—The relationship between plasma concentration, plasma clearance and tubular excretion of phenol red in a normal human subject.

509 illustrates observations of a similar character in which phenol red was employed. As already stated, the kidney handles this substance with considerably less efficiency than it does diodrast or certain hippuric acid derivatives so that the absolute values are different, but the principle of estimating the functional capacity of the tubular excretory mass by measuring the maximal tubular output of the dye (phenol red-*Tm*) is equally valid. For several reasons, the use of phenol red for these purposes is unwise and Smith's observations[24]

indicate that sodium *p*-aminohippurate will probably be the substance of choice for this as well as for the determination of renal plasma flow.

Glucose-Tm.—Tubular function may also be studied from the standpoint of absorption rather than secretion and for this purpose glucose has been most widely employed. Ordinarily, all the glucose in glomerular filtrate is reabsorbed but it is possible, by progressive elevation of the plasma concentration, to reach a point at which the amount of glucose offered to the tubules is just equal to their capacity for reabsorption (renal threshold). Using the normal dog, Shannon[33] has shown that glycosuria suddenly appears when this plasma level is exceeded. Thereafter, the quantity of glucose reabsorbed will equal the quantity filtered minus the quantity appearing in bladder urine. The maximal ability of the tubules for reabsorption (glucose-*Tm*) is as remarkably constant as is diodrast-*Tm*, averaging about 375 mg. per minute in normal adults.[31] Since the infusion of such large amounts of glucose (plasma concentrations of about 400 mg. per cent are required) produces intense diuresis and tends to disturb fluid balance and glomerular activity,[31] this is not an ideal procedure, and the measurement of secretory *Tm* is preferred for most purposes.

Whichever test is employed, it must not be supposed that the weight of the kidneys can be accurately predicted therefrom. Some of the lowest diodrast-*Tm* values have been found in malignant hypertension when the kidneys have not been unusually small.

RENAL ISCHEMIA

If, then, one has at hand technics for the measurement of renal plasma or whole blood flow and tubular excretory mass, it becomes possible, as Smith has advocated,[26] to express the quantity of plasma of blood flowing through the kidneys in terms of the amount of functioning tubular tissue. Because the absolute values for plasma clearance vary from subject to subject, it is far better to adopt the ratio $\frac{\text{renal plasma flow}}{\text{Tm}}$ since this gives a figure describing the volume of plasma per unit of tubular tissue. The value of this concept will be more clearly established in the following discussion concerning the diseased kidney.

Figure 510 illustrates the kind of information which may be obtained with these methods. It illustrates the changes in renal hemodynamics produced by epinephrine in a normal adult. The diagram is somewhat deceptive since it suggests that measurements of diodrast clearance and diodrast-*Tm* were made simultaneously, an obvious impossibility; they were actually done on successive days but are charted together for the sake of convenience.

In the resting control periods renal plasma flow (plasma diodrast clearance) averages about 500 cc./min./1.73 sq. m. surface area;

glomerular filtration rate (plasma inulin clearance) about 100 cc./min.; and the maximal secretory capacity of the tubules for diodrast-iodine about 32 mg./min. The proportion of plasma filtered through the glomerular bed (filtration fraction) $= \frac{C_I}{C_D} = 18$ per cent, and the volume of plasma perfusing each unit of renal secretory tissue $\left(\frac{C_D}{Tm_D}\right) = 16.17$.

After the subcutaneous injection of 1 mg. of epinephrine, a sharp reduction in renal plasma flow takes place, C_D falling to a minimum

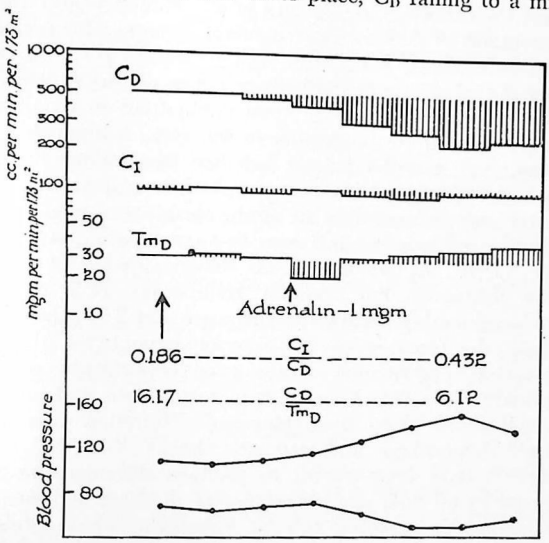

Fig. 510.—Effect of epinephrine on renal hemodynamics and blood pressure in a normal human subject.

level of slightly more than 200 cc./min. That vasoconstriction is taking place predominantly in the postglomerular or efferent arteriolar bed is suggested by the fact that the rate of glomerular filtration (C_I) maintains itself virtually unchanged; had the constriction occurred in the proximal side of the glomerular bed, a sharp reduction in inulin clearance would have been anticipated. As it is, the rise in intraglomerular pressure is such as to increase the filtration fraction to 43 per cent, and the renal plasma flow per unit of Tm_D drops to 6.12, nearly one third its former rate.

It should be pointed out, however, that such relatively simple interpretations as these have been questioned on theoretical grounds.

On purely mathematical grounds Lamport[34–37] has derived formulas which suggest that change in the caliber of the afferent arterioles must also take place. Shannon,[38] however, has pointed out that neither theory is entirely satisfactory.

INTERPRETATION IN THE PRESENCE OF DISEASE

The measurements of glomerular filtration rate, renal plasma flow and *Tm* appear to yield valid results in normal subjects, but the presence of disease imposes certain limitations upon their unqualified acceptance. In Bright's disease, particularly, it would seem more than likely that the distorted architecture of the kidney would also entail some perversion of function which might not only be undetectable by clearance methods but might even invalidate them. It must be remembered that clearance methods are over-all procedures and can hardly be expected to reveal subtotal fluctuations in renal function; for example, it is quite impossible to tell from a urea clearance of 50 per cent whether the patient has had one kidney removed or whether both kidneys are working at half their normal rates. Indeed, some have felt[39] it hazardous to apply clearance methods at all to seriously diseased kidneys, and even in anatomically normal kidneys certain extrarenal factors have been shown capable of profoundly modifying clearances. For example, Heinbecker, Rolf and White[40] have produced marked changes in clearance and *Tm* values by interfering with the function of the anterior hypophysis, thyroid and adrenal cortex. Testosterone causes renal hypertrophy and an increased diodrast-*Tm*.[41, 42] Vitamin A increases urea and inulin clearances[43] and renal blood flow, glomerular filtration rate and diodrast-*Tm*.[44] Hemorrhagic and traumatic shock[45, 46, 47, 48, 49] and renal anoxemia[50, 51] have been shown to produce discrepancies between actual renal blood flow and clearances of diodrast and *p*-aminohippurate because of impaired tubular extraction. These observations illustrate the fact that the mechanism whereby tubular cells move materials from the blood stream to the tubule lumen depends in part upon adequate supplies of hormones, vitamins and oxygen, and that one cannot assume that this transport mechanism is of equal efficiency in all patients or even in all parts of the kidney parenchyma of a given patient. Reduction in tubular clearance may be affected as much by the impaired extraction as by reduction in blood flow.

It is not difficult to imagine many conditions in which tubular extraction capacity may be so diminished that plasma clearance falls far short of actual plasma flow. Sodium tartrate,[52] uranium[53] and carbon tetrachloride[54] have been shown to produce this effect and doubtless mercury does also. We[32] felt that diminished tubular extraction of diodrast rather than reduction in renal plasma flow was responsible for the high filtration fraction shown by some of our

hypertensive patients, although there is much good evidence that the same relative figures may be achieved by efferent glomerular arteriolar constriction.[55] Corcoran and Page[56] accept the plasma inulin clearance as a true measure of glomerular filtration rate and the plasma diodrast clearance as a true measure of renal plasma flow in chronic glomerulonephritis and malignant hypertension but say that "the equivalence of plasma diodrast clearance with effective renal plasma flow is invalid in conditions of widespread tubular renal injury." Although the relationships between urea and inulin clearances are usually well maintained in renal disease, they occasionally approach unity,[57, 58] a circumstance attributed to diminished urea reabsorption rather than to backward diffusion of inulin. It is apparent that in many instances of severe tubular damage the clearance of diodrast or hippurate may fail to give an even approximate index of renal blood flow.[59, 60]

These criticisms have been recognized and apparently answered by Smith[59] who points out that clearances must be interpreted in relation to the mass of functioning tubular tissue. In Bright's disease the proportion of excretory to inert tissue progressively diminishes with the result that extraction ratios also decrease, but the ratio $\frac{\text{plasma clearance}}{\text{Tm}}$ still gives an indication of the amount of blood-perfusing, functioning renal tissue. The absolute clearances may then be untrustworthy in disease but they continue to have significance if considered in relation to the separate assays of tubular function.

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UNNECESSARY ABDOMINAL OPERATIONS FOR PATHOLOGIC LESIONS OF THE GENITOURINARY TRACT

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THE clinical manifestations of pathologic lesions originating in the genitourinary tract so closely mimic lesions of the intra-abdominal viscera that unnecessary laparotomies with sacrifice of abdominal organs are done all too frequently. Cabot once stated that the most common operation for stones in the right ureter is appendectomy. It is not of rare occurrence to examine a patient who has had one or more abdominal operations for the relief of abdominal pain only to discover that a lesion of the kidneys or ureters has been the cause of the pain and the long unrelieved morbidity. Some patients have suffered for years from recurrent abdominal pain, losing their ovaries and tubes, appendix or gallbladder and obtaining complete relief only after a ureteral stricture has been dilated or hydronephrosis or pyonephrosis has been adequately treated.

Dr. Edgar Burns of the Department of Urology of the Clinic has observed that over 40 per cent of the patients with anomalies of the genitourinary tract visiting the department have had abdominal operations not only without relief of symptoms but with definite progression of the urologic disease. A review of the literature reveals similar statistics regarding unnecessary abdominal operations for the relief of abdominal pain due to lesions confined to the urinary tract.

Kruse,[1] writing on Hunner's ulcer, stated that half of his first eight patients had extravesical operations without relief. Wright[2] observed that in Hunner's series of ureteral stricture 30 per cent of the patients had abdominal scars from "misapplied surgery." Brown and Wakefield[3] reported two cases of patients with typical prolonged gallbladder symptoms in whom removal of the gallbladder gave no relief. Both patients had stones in the right kidney and obtained complete relief after their removal. Campbell[4] reported 213 cases of abdominal pain in children with urologic disease. Fifty per cent of these had acute or subacute urinary infection; of the latter cases, fourteen were diagnosed as acute appendicitis and thirteen had previous appendectomies without relief. Caulk[5] found that 27 per cent of his patients with renal or ureteral calculi or both had had appendectomies with-

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out relief from pain. In Cecil's[6] series of 300 cases of urologic lesions 28 per cent of the patients had stones in the kidney or ureter producing abdominal pain as the predominating symptom; 20 per cent of these had had abdominal operations without relief. Martin and Chynoweth[7] in a review of 400 consecutive patients with urologic disease wrote that 50 per cent of the patients sent to the urologic department for cystoscopic data had come for some trouble other than that of the kidneys and that 50 per cent had more abdominal than genitourinary symptoms. They also stated that 25 per cent of cases of renal disease with abdominal symptoms are incorrectly diagnosed. Martin,[8] discussing hydronephrosis, stated that when the lesion was on the right side the most common diagnoses were appendicitis, disease of the gallbladder or lesions of the tubes and ovaries and that following removal of these organs without relief the patients were then treated for such conditions as neurosis, lumbago, ptosis or indigestion. Massenburg[9] reported a case of left pyohydronephrosis with abdominal pain in which appendectomy and later uterine suspension were done without relief. O'Neil,[10] reporting his cases of urologic disease at the Massachusetts General Hospital, stated that 25 per cent of the patients with ureteral calculi, operated upon for the stones, had had previous operations for appendicitis or some other supposed intra-abdominal lesion without relief. Braasch[11] found that one third of his 143 patients with renal stones had had unnecessary laparotomies. He reported some very interesting findings in his series. Eighty-three of the patients had stones in the right kidney, fifty-five in the left kidney and five in both kidneys. There were twenty-three patients with stones in the left kidney who had had either appendectomies or cholecystectomies without relief of symptoms. In Cabot's[12] 157 cases of stones in the kidneys or ureters or both, twenty-six had the following unnecessary laparotomies without relief: appendectomy, ten; exploratory laparotomy, seven; fixation of the kidney, four; operations for gallbladder disease, one; and decapsulation of the kidney, salpingo-oophorectomy, suprapubic cystotomy and removal of adhesions, one each.

From this brief review it can readily be seen that 25 to 30 per cent of patients with pathologic lesions of the kidneys, ureters or both have had previous laparotomies for nonexisting lesions of the abdominal viscera. A large number of these improperly treated patients have been attended by the average surgeon who specializes in general surgery but also does general practice. The percentage cited is undoubtedly low; it probably would reach 35 to 40 per cent as a general average.

That urologic disease constantly manifests itself clinically as an acute or chronic abdominal lesion has been reported by many authors. Atherton[13] reported a case of a urologic lesion of the upper urinary

tract producing pain in the upper right quadrant of the abdomen simulating gallbladder disease. Brown and Wakefield[3] reported several cases of renal stones in which the clinical symptoms suggested disease of the gallbladder and removal of the gallbladder gave no relief. In this same paper they discussed the "enterorenal syndrome of Mayo," which is a condition seen in elderly patients who have signs and symptoms of intestinal obstruction, accompanied by an elevation in the blood urea nitrogen content and a decreased urinary output. They reported two cases, in both of which recovery ensued, in one instance following conservative treatment and in the other after exploration. Campbell[4] believed that the urologic lesions which cause abdominal symptoms are predominately obstructive in character and that grave urologic lesions with abdominal pain may exist despite the presence of normal urine. This certainly adds confusion to the accurate diagnosis of urologic diseases.

In Cecil's[6] 300 cases of lesions in the upper urinary tract there were a large number in which the pain was limited to the abdomen. Twenty-eight per cent of the cases with stones in the kidney and ureter had abdominal pain without pain in the back. In 26 cases with typical back pain referable to the kidney, pain was also referred to the abdomen; in two of these cases the abdominal pain was diffuse. In forty cases of tuberculosis of the kidneys there were seven cases with no pain in the back, the pain being limited to the abdomen. Cecil listed the percentage of urologic lesions that presented clinical symptoms of abdominal disease without back pain as follows: stones in the kidney and ureter, 28 per cent; renal tuberculosis, 17.5 per cent; pyelonephritis, 5.5 per cent; hydronephrosis, 15 per cent; and tumor of the kidney, 50 per cent (small series). The most common site of referred pain was the gallbladder and appendix. Stone, according to Braasch,[14] reported 251 urologic cases in which pain and tenderness in the kidney region was present in only 117. In twenty-six cases pain was abdominal and generalized. Pain was referred to the gallbladder in thirty cases; to the lower abdomen in thirty-two cases; to both sides of the abdomen in fifty-six cases; to the affected side of the abdomen in forty cases; and to the contralateral side of the abdomen in sixteen cases. Squires and Bateman[15] described a "retroperitoneal syndrome" from reflex action of the gastrointestinal tract from stimuli arising in the kidney and passing through the celiac plexus. In ninety-eight cases of this syndrome they found 50 per cent with gastrointestinal symptoms and 25 per cent with no symptoms of renal disease. Martin and Chynoweth[7] found that in 400 urologic cases only 30 per cent presented the classical urologic symptoms. Peacock and Hain[16] in a study of seventy-six cases of ureteral stricture stated that 29 per cent of the patients had a dull pain in the abdomen simulating abdominal disease.

Why should a pathologic lesion of the genitourinary tract manifest itself without symptoms pertaining directly to the lesion but with reflex symptoms which are entirely abdominal in character? The chief symptom in both intra-abdominal lesions and urologic diseases is *pain*. This pain is due primarily to involvement of either the somatic or sympathetic nervous systems or both and secondarily to involvement of contiguous organs or structures. The viscera in both the abdomen and the genitourinary tract are either solid or hollow. The hollow viscera are composed almost entirely of neuromuscular tubes whose function is secretory, absorptive and excretory. The solid viscera also have the same function. They not infrequently contain, within their parenchyma, tubes lined with epithelium. The gross difference between the two is that the solid viscera are encased in a comparatively unyielding fibrous capsule whereas the hollow viscera are elastic and yield to increases of pressure. Both the solid and hollow viscera are supplied by similar nerves and have similar blood supply and lymphatic drainage. Therefore, they are closely if not intimately associated with each other. The sympathetic nerve supply to both the genitourinary tract and abdominal viscera has a common dispatcher or intergrating point, the celiac ganglion and celiac plexus. The latter is a composite of the splanchnic and associated plexuses. Thus, pain from lesions in the genitourinary tract and the abdominal viscera may be widespread and irregular because of intimate integration of both the somatic and sympathetic receptive fibers. The pain originating from the kidneys and abdominal viscera is referred to the tenth, eleventh and twelfth dorsal and the first lumbar spinal segments.[17] The stimuli again may be distributed up and down the spinal cord to many segments before being relayed to the brain. Another source of stimuli is that the kidneys and ureters are in close association anatomically with the parietal peritoneum (with its sensory nerve supply) the hepatic and splenic plexuses of the colon, the duodenum and the ileohypogastric, ileo-inguinal and lateral cutaneous femoral nerves. That the symptoms of both the abdominal and urologic viscera can mimic each other is understandable from this cursory description of the anatomy and associated anatomic relationships with other important organs and structures.

It would appear that the mechanism of production of pain in the urologic tract is similar or identical to that in the abdominal cavity. Pain is produced primarily by obstruction, which may be acute or chronic in character. Obstruction of the ureter, if sudden, not only causes dilation of the ureter but also of the distensible components of the kidney. Since the ureter as well as the gastrointestinal tract is endowed with peristaltic activity, the pain produced by obstruction to the lumen of each is characteristically intermittent or colicky. If the obstructing process is gradual, the pain is more of a dull type

which also may or may not be intermittent. The character of the pain and its clinical manifestations may vary from time to time depending upon the intensity of the dilation of both ureters and kidneys and even the bladder. Acute obstructions of the urologic tract may be due to either infection or renal or ureteral stones, or both. Chronic obstruction is produced by either stones or stricture or both associated with subacute or chronic infection. In the solid viscera the pain is produced, in the majority of instances, by infection of the parenchyma and tubular components or new growths which distend the unyielding fibrous capsule, and the pressure is secondarily offered to the arteries, veins and nerves producing somewhat of a vicious cycle. The character of the pain is dull and more or less continuous. However, acute distention of the parenchyma will in turn produce acute pain, which is continuous, whereas that of the hollow viscera (ureters, small and large bowel and biliary ducts) is intermittent. Therefore, pain from lesions of the kidney or ureter at the pelvic junction is not infrequently referred to the right upper quadrant of the abdomen, simulating the pain of acute pathologic processes of the gallbladder and ducts or ruptured peptic ulcer. On the other hand, if the lesion is low in the ureter or bladder, the pain may be referred to the appendix, sigmoid or female generative organs. Pain from lesions of the seminal vesicles may also be referred to the appendix or sigmoid. The slowly progressive lesions occurring in the upper or lower portions of the urinary tract produce symptoms referable to the abdomen simulating diseases of the abdomen, i.e., gallbladder, pancreas, appendix, sigmoid and female adnexa. The signs and symptoms common to acute lesions of both the abdominal and urologic viscera are pain, anorexia, nausea and vomiting, abdominal rigidity, distention, fever and leukocytosis; in chronic lesions they are pain, anorexia, distention, loss of weight and anemia.

According to Connell,[18] the renal lesions which are likely to be confused with intra-abdominal lesions are renal or ureteral stones, Dietl's crisis, unilateral hematogenous infection, uremia, perinephric abscess and pyelonephritis. Braasch[11] stated that in his 251 cases of kidney stone, only 117 had typical pain and tenderness in the kidney region; general abdominal pain was present in twenty-six cases, pain was referred to the gallbladder in thirty cases, to the lower abdomen in thirty-two cases, to both sides of the abdomen in forty cases and to the unaffected side of the abdomen in sixteen cases.

In Campbell's° series of 213 cases, over 50 per cent had an acute or subacute urinary infection that was suspected at once or after an early examination. However, he pointed out that grave urologic lesions may be present despite the evidence of normal urine. He also

° Campbell[4] has given an excellent classification of the lesions of the genitourinary tract which may produce abdominal symptoms.

suggested that in patients with lower abdominal pain, the presence of vesical residual urine should be determined.

According to Eisendrath[19] the urologic lesions that mimic appendicitis or upper abdominal diseases are: (1) acute blocking of the outlet of the renal pelvis or upper ureter, (2) kinking of the ureter and torsion of the renal pedicle, (3) acute occlusion of the outlet of the renal pelvis or upper ureter by an anomalous vessel crossing the ureter and (4) acute infection of the kidney or its surrounding fat with or without stones. Those that simulate appendicitis are: (1) ureteral calculi in the iliac or pelvic portion, (2) ureteral strictures in the iliac or pelvic portion, (3) ureteral kinks (abnormal renal mobility), (4) chronic nephritis of the painful type (nephritis dolorosa), (5) passage of uric acid or oxalate of calcium crystals, (6) tabetic ureteral and renal crises, (7) ureteritis (usually associated with pyelonephritis) and (8) seminal vesiculitis with secondary involvement of the ureteral wall. Lesions imitating symptoms of abdominal tumors are: (1) iliac renal ectopia, (2) pelvic renal ectopia, (3) crossed (fused) ectopia, (4) horseshoe kidney and (5) unilateral double kidney. Hertzler,[20] writing on acute localized infection of the kidney, stated that the pain may be abdominal and simulate appendicitis, gallbladder disease or perforation of a peptic ulcer of the duodenum or stomach. He also stated that the urine may show few or no changes.

Jablons,[21] in discussing the retroperitoneal syndrome, stated that the innervation of the gastrointestinal tract arises from the same centers as that of the kidney and ureter and that the gastrointestinal tract is supplied by the vagus nerve, celiac plexus and sympathetic fibers which traverse the greater and lesser splanchnics. In the celiac plexus, reflexes are set up by impulses originating in the kidney, ureter or posterior parietal peritoneum. This explains the reflex abdominal symptoms from urologic lesions because the urologic symptom complex is submerged by the predominant abdominal signs and symptoms.

Squires and Bateman[15] reported ninety-eight cases of renal disease; 50 per cent of the patients had gastrointestinal symptoms and 25 per cent had no symptoms of renal disease. The gastrointestinal manifestations were nausea, vomiting, pain, abdominal distention, belching, heartburn, epigastric distress, constipation or diarrhea. In twenty-two cases of pyelonephritis terminating in uremia, sixteen had abdominal symptoms; i.e., pain, nausea, and vomiting.[22] Enlargement of the liver, hematemesis and melena were only occasionally present.

In the short review given in the preceding paragraphs it is apparent that almost any disease of the urologic tract from the kidney and perirenal tissues to the bladder, prostate and seminal vesicles can mimic any one of the various pathologic diseased states occurring

within the abdomen. This becomes increasingly true when the signs and symptoms are lacking in urologic disorders.[4, 6, 7, 20, 21, 23, 24, 25]

It therefore becomes of paramount importance to make an accurate differential diagnosis if unnecessary operations are to be prevented. In the majority of instances an accurate diagnosis of urologic disease can be made provided one constantly keeps in mind the abdominal mimicry of genitourinary disease, takes a most careful history and does a complete physical examination. Carefully selected diagnostic laboratory procedures should be included to establish the diagnosis.

It is impossible and not desirable to give the clinical manifestations and differential diagnosis of each pathologic lesion of the genitourinary tract, but the causative factors and their delineations and the methods that will aid in the diagnosis will be discussed. The urologic problems can be divided into two main groups—the acute and chronic, the latter being responsible for the greater number of mistakes. The acute conditions are due mainly to infection produced by both the coccal and bacillary groups of organisms. In acute infections, the parenchyma, the renal pelvis or both may be involved. The infection may be superimposed on a preexisting lesion such as hydronephrosis, chronic pyonephrosis with or without stones, or septic infarcts of Brewer. The perirenal tissues may be involved by ruptured pyonephrosis, cortical suppuration or perinephritic abscess. Acute infections of the ureters, either ascending or descending with or without stones, may be secondary to acute infections of the bladder, kidneys or periureteral lymphatics.

The noninfectious lesions producing acute symptoms are primarily the result of a sudden block of the renal pelvic outlet or ureters. The obstruction may be due to stones, anomalous arteries (upper pole arteries, 4 per cent, lower pole arteries, 3 per cent[26]), ureteral strictures or ectopic kidneys.

The symptoms of acute lesions of the genitourinary tract are characterized by sudden onset. There may or may not be chills, the fever is higher than that seen in abdominal lesions and the pulse rate is lower. The white cell count is higher and more stable in urologic than in abdominal disease unless the latter is associated with complications. Nausea and vomiting are less common in acute renal lesions than in intra-abdominal lesions. Muscle spasm, when present, is of greater diagnostic importance than is pain or tenderness.[5] Moderate to severe ileus may or may not be associated with acute infections; as a rule, it is more common in the acute nonbacterial lesions. In acute disease of the infectious or noninfectious type pain is due to obstruction (renal or ureteral) of the outflow of urine. In the nonbacterial form the predominating symptom is pain, with little or no systemic reaction. In both, the pain may be of an intermittent or colicky type. In cases of infection the urine will, in all probability, reveal the presence of

pus and bacteria. However, in cases in which the ureter is blocked the infected material cannot be passed; therefore, the urine may appear normal on microscopic examination. According to Campbell,[4] in over 50 per cent of his cases of acute or subacute urinary infections the character of the lesion was suspected at once or after an early examination. In the nonbacterial acute lesions the urine may be without pathologic significance.

The laboratory investigations that will aid in diagnosis and prevent unnecessary abdominal operations are: roentgenography, including excretory pyelograms, retrograde pyelograms, and cholecystograms; gastrointestinal studies; and thorough cystoscopic examinations. Gastrointestinal studies and cholecystograms are more useful in the chronic than in the acute urologic lesions with abdominal symptoms.

The roentgenogram will reveal stones in the urologic tract, enlarged kidneys and obscuration or obliteration of the lateral border of the psoas muscle. The most important findings revealed by excretory pyelograms pertain to kidney function, stones and distortion or block of the pelvis or ureters. The excretory pyelogram is by far the simplest, most rapid and most useful test in determining urologic disease although it may sometimes be necessary to supplement it by cystoscopic examination and retrograde pyelographic studies. Nevertheless, even in very acute urologic or abdominal disease the excretory pyelogram can, in a few minutes, give aids in diagnosis that would eliminate unnecessary operations. In fact, I am so convinced of its diagnostic value that I not only believe but recommend that it should be a routine procedure in all patients forty years or more of age. The almost routine use of excretory pyelographic studies in both the army and urologic clinics has demonstrated a high incidence of anomalies of the urologic tract which in the past have been overlooked. In cases in which acute ileus is secondary to urologic disease and simulates intestinal obstruction, the roentgenogram is of definite value in differential diagnosis. In acute ileus associated with genitourinary disease, gas can be seen in both the distended small and large bowels; whereas in ileus originating in the gastrointestinal tract, gas is present only in the small bowel. Gas and fluid levels are more commonly associated with ileus arising in the intestinal tract.

According to Eisendrath[18] the most common abdominal diagnosis in the case of urologic lesions is appendicitis. The appendix is erroneously removed in from 10 to 30 per cent of cases. The gallbladder has frequently been removed for hydronephrosis and renal stones. Occasionally, the urologic lesion is on the left side. However, it seems that the most common abdominal organs removed for urologic disease are the appendix and the female adnexa. If both were as difficult to remove as the lumbar sympathetics, herniated disk, or the gallbladder, the frequency of error would be practically nil.

CONCLUSIONS

In reviewing the literature on the abdominal manifestations of urologic lesions, an attempt has been made to explain the peculiar symptomatology upon an anatomic and neurophysiologic basis. The interrelationship of the somatic and sympathetic nerve supply of both the urologic and the gastrointestinal tracts explains the abdominal reflex symptoms from urologic disease. It should be remembered that when there exist both urologic and abdominal symptoms, the latter not infrequently overshadow the former. In from 30 to 40 per cent of cases of urologic disease the signs and symptoms are abdominal and not genitourinary, and less than 50 per cent of patients with urologic lesions exhibit classical genitourinary symptoms. The abdominal symptoms of acute and chronic urologic lesions so closely mimic abdominal disease that from 20 to 30 per cent of patients with urologic conditions have had previous laparotomies not only without relief but with progression of the urologic lesion.

Every patient with abdominal symptoms and urologic manifestations, however slight, must be thoroughly evaluated by both the surgeon and the urologist before abdominal section is advised. Patients with indefinite abdominal pain should have a thorough urologic survey before the appendix, female adnexa or gallbladder is removed. The laboratory and roentgenographic studies (including excretory pyelograms) will give inestimable information which will prevent unnecessary removal of nonoffending abdominal organs. A complete laboratory study of the urine in all suspected or nonsuspected urologic diseases will reveal sufficient pathologic states to warrant complete urologic surveys. The high incidence of unnecessary abdominal operations for urologic lesions can be reduced or almost completely eliminated only by constantly keeping in mind those lesions of the genitourinary tract which closely or completely mimic acute or chronic lesions of the intra-abdominal organs.

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THE PATHOLOGY OF GENITOURINARY NEOPLASMS

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To understand the nature of tumors it is important to know their characteristic gross and microscopic appearance, to recognize the various anatomic complications produced by them, and to be familiar with a few of the theoretical considerations which recur in scientific discussions regarding them. This discussion is concerned primarily with tumors of the kidney, renal pelvis, ureter, urinary bladder and prostate gland. Carcinoma of the prostate gland is the only genital tumor included in this communication.

KIDNEY

The commonest and most interesting tumor of the renal parenchyma is the malignant growth derived from renal epithelium and best known by the name *hypernephroma.* It occurs predominantly in men over 45 years of age. The hypernephroma is interesting because it is grossly and microscopically distinctive, because, although it commonly follows a stereotyped clinical pattern, symptoms from metastatic growths may be dramatic and bizarre, and finally, because it has been the subject of an academic controversy for a number of years.

Grossly, the hypernephroma may involve the kidney at either pole or at any point between the two poles with no apparent predilection for any one site. It bulges into the capsule and often into the renal pelvis as a result of which the classical symptom of painless hematuria is produced; less commonly, it may involve the renal vein. The latter anatomic complication of renal tumors is important because, as shown by McDonald,[1] involvement of the renal vein increases the gravity of the prognosis. Tillisch and co-workers[2] have reported cases in which the tumorous thrombus extended from the renal vein into the inferior vena cava and heart. It is possible that many of the bizarre metastatic tumors originating from hypernephromas are the result of invasion of the renal vein and subsequent hematogenous spread of the growth. Among the unusual forms of metastasis are those often located in bones. These may give rise to initial symptoms caused by the secondary growth such as pathologic fracture when the primary tumor in the kidney has remained clinically silent. Such cases may not be com-

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mon but they are sufficiently dramatic so that probably a disproportionate number have been recorded.

The cut surface of the hypernephroma has a distinctive appearance which is largely due to the yellow lipoid content associated with hemorrhage and fibrosis (Fig. 511). The result of this combination is a brilliantly yellow, friable tumor with contrasting areas of bright red or darker brown hemorrhage and white fibrous tissue at the edges or in more scirrhous parts of the tumor. Two notable exceptions to this gross picture occur. One of these is the tumor which contains less lipoid and is consequently not as yellow, and the other is a papillif-

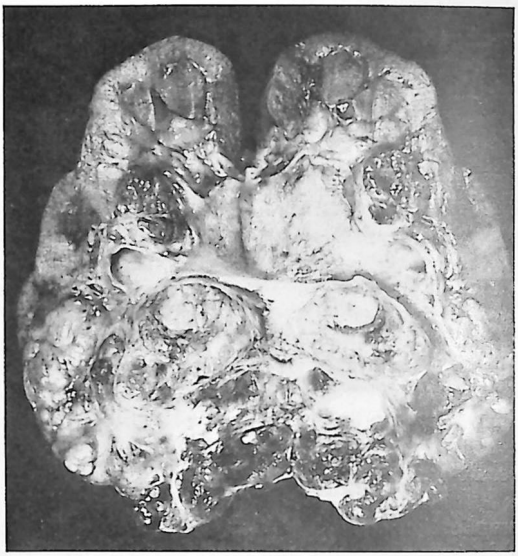

Fig. 511.—Hypernephroma of lower pole. Involvement of a medium-sized renal vein is apparent on the left.

erous cystic tumor which often contains appreciable deposits of calcium salts. The latter lesion seems to be a slow growing or low grade hypernephroma but is given an especial designation such as papillary adenoma by some authorities. Higgins[3] has reported a group of such adenomas.

Microscopically, the usual picture in hypernephroma is that of clear cells in papillary or alveolar arrangement invested by a delicate reticular lacework of stroma. The clearness of the cells has not been adequately explained because it is apparent that lipoid accumulations alone do not account for this peculiarity. Fite[4] has called attention to

glycogen deposits in these cells and it is probable that this observation will prove helpful in explaining the clear cells. Less characteristically, the cells may contain a brownish pigment.

Variations in the degree of anaplasia of hypernephroma cells have been observed by Hand and Broders,[5] who classified 193 cases of hypernephroma into Broders' four grades of malignancy; they found that, as the degree of anaplasia increased, the prognosis became poorer. In their series, 50 per cent of the tumors were of grade I or II malignancy, the slower growing varieties. This is somewhat surprising in view of the common impression that the hypernephroma is an especially "wild" tumor, and it is apparent that in some cases the dramatically malignant aspects of the tumor have been overemphasized.

Other variations in the standard microscopic picture just described are seen when the cells are not clear—the dark cell type. The darker cells seem to occur perversely without good reason irrespective of the degree of anaplasia of the tumor. Another variation is that the tumor may be polymorphous. It may resemble the sarcoma in some areas, the angioma in others and the typical hypernephroma in still other regions. In fact, the polymorphous character of hypernephromas is so outstanding that some authorities list the variations of form that may be present in a single tumor as one of the characteristics of this specific form of neoplasm.

The hypernephroma was named by Grawitz,[6] who conceived the name because he postulated that the tumor was derived from cell rests of adrenal gland tissue in the kidney. He was soon opposed by Stoerck,[7] who insisted that the tumor was derived from renal rather than adrenal cells. Stoerck[7] and Wilson[8, 9] who, among others, translated the controversy into the American literature, disproved most of Grawitz's contentions and although Grawitz still has a few distinguished supporters, the majority of authorities now concede that this characteristic tumor of the kidney is derived from renal cells rather than from adrenal rests as Grawitz supposed.

Those who adhere to the renal cell origin of this tumor are placed at a disadvantage by the tenacity of the name "hypernephroma," which has established itself in spite of the best anatomic evidence that the prefix "hyper," which implies adrenal origin, is a misnomer. Those who have attempted to substitute other designations such as adenocarcinoma of the kidney, nephroma, malignant nephroma or renal cell carcinoma are eventually compelled to explain that the name used really means the "so-called hypernephroma." A simple, if not logical, solution would be to retain, without explanation or apology, the term hypernephroma as a distinctive name for a distinctive tumor and discard the Grawitz theory of origin from adrenal rests.

It is evident that pathologists are loathe to abandon the Grawitz

theory entirely because from time to time there is recorded an occasional case of renal tumor which, because of its close resemblance to adrenal cortical tissue, is said to be a "true" hypernephroma derived from adrenal rests as distinguished from the ordinary hypernephroma derived from renal tissue. Higgins,[3] for instance, recorded an endocrine effect, notably hypertension, evidently produced by one of the six cases of adenoma which he reported, and Mitchell and Angrist[10] described cases in which there was anatomic evidence of derivation of hypernephromas from adrenal rests.

This ancient controversy might be summarized by stating that the remaining points in favor of the Grawitz theory are: (1) a tenacious name; (2) the presence of lipoid in the cells of both the hypernephroma and the adrenal cortex; and (3) the fact that adrenal rests do occur in the kidney. The weakest features of the Grawitz theory are the facts that: (1) even those tumors which most closely resemble adrenal cortex anatomically have not produced endocrine disturbances except possibly the case reported by Higgins; and (2) hypernephromas resemble small adenomas of the renal cortex more closely than they do adrenal rests. It is evident that adenomas of this type are derived from renal cells and that hypernephromas are derived from adenomas, because as Bell[11] and Trinkle[12] have stated, any sharp line of division of renal tumors into adenoma on the one hand and hypernephroma on the other is purely arbitrary since the relationship is close.

The two benign lesions of the kidney, adenoma and adrenal rests, have been mentioned so often in the discussion of hypernephroma that a description of these smaller and less significant nodules seems pertinent. The *adenoma* can be found only when the capsule of the kidney is stripped and the cortex searched for suspicious yellow nodules which may vary in size from a pin point up to 4 cm. in diameter. All those over 4 cm. in diameter are arbitrarily designated as hypernephroma. Most of those encountered are less than 0.5 cm. in diameter. The cortex must be scrutinized carefully and suspicious yellow nodules sectioned. Usually the adenoma is found on the surface, but occasionally one that has not reached the surface may be found on section. This latter type may resemble an abscess except that the contents are solid.

Microscopically, the adenoma is usually papillary and of dark cell rather than clear cell type. Deposits of calcium salts are common and are said to indicate slow growth. The cells and especially the nuclei are small and uniform in character. Less commonly, the adenoma may be alveolar in type and this variety is more likely to contain clear cells resembling those of hypernephroma. The stroma of the adenoma is scanty like that of normal renal parenchyma and the edge of the tumor is usually found adjacent to normal renal parenchyma with

little or no capsule interposed. The golden yellow color of these tumors seen grossly is not easily explained on the basis of the microscopic appearance because it is difficult to demonstrate lipoid in these tumors but lipoid material similar to that found in hypernephromas has been demonstrated in some adenomas and it is probable that the yellow color is due to lipoid content.

If a careful search is made for adenomas, they can be found in about 10 per cent of kidneys in adults. Trinkle[12] thought that they occurred more commonly in scars and in scarred kidneys than in normal kidneys. It is apparent that adenomas, like hypernephromas, are found more commonly as age advances.

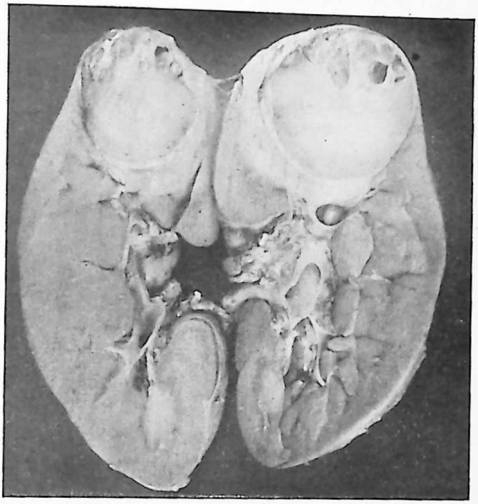

Fig. 512.—Wilms' tumor. This tumor was bilateral and the major involvement was on the opposite side.

The presence of *adrenal rests* in the kidney and along the structures which lead from the adrenals to the gonads is explained by the embryologic origin of the adrenals, kidneys and gonads from the mesoderm of the mesonephric ridge. It is apparent that bits of adrenal cortical tissue may be carried downward by migration of the gonads or may develop as adrenal tissue on the surface of the kidney. Such bits of adrenal tissue or rests are rarely observed in association with the gonads and are usually discovered by chance.

Adrenal rests in the kidney occur as small plaques of adrenal cortical tissue on the superior pole and may be found as bright yellow or orange spots after the capsule has been stripped. The incidence of

adrenal rests seems to be the same for children as for adults and has been variously given as from 1 to 3 per cent. Microscopically, the rest is composed entirely of adrenal cortical tissue and is so intimately associated with the renal substance that an occasional renal tubule may be noted in the center of the adrenal cell mass. The cell rest does not contain tissue of the adrenal medulla. Occasionally, the entire adrenal gland may be attached to the superior pole of the kidney. This latter anomaly is called heterotopia.

Wilms' tumor of the kidney is less common than the hypernephroma. In the 117 cases of malignant tumor of the kidney reported by Bixler and his associates,[13] there were ninety-four cases of carcinoma of the cortex and thirteen cases of Wilms' tumor. According to Weisel, Dockerty and Priestley,[14] 20.4 per cent of all malignant tumors occurring in children are Wilms' tumors. Although this neoplasm is probably the commonest single variety of malignant tumor found in children, it occasionally occurs in adults. In Weisel's series of forty-four chiefly surgical cases none of the Wilms' tumors were bilateral, although bilateral Wilms' tumors have been reported at necropsy. An example of bilateral Wilms' tumor encountered at necropsy is illustrated in Figure 512. In this case a large tumor appeared in the left kidney and the photograph shows the tumor in the right kidney which was removed at necropsy.

Grossly, Wilms' tumor is homogeneous, white or pink and encephaloid. Areas of hemorrhage and necrosis occur. The tumor grows rapidly and may metastasize readily. Microscopically, the most characteristic cell is a mesodermal fibroblast which may differentiate into renal tubules or glandular structures. The cellular tumor composed of mesenchymal cells and glands is characteristic and closely resembles the structure of the outer edges of the renal cortex in the human fetus prior to the seventh month of gestation. In some Wilms' tumors there are striated muscle fibers and other mesodermal elements. These latter elements are most easily seen microscopically when the Wilms' tumor has been treated preoperatively with roentgen therapy. Under such circumstances the roentgen rays destroy most of the essential mesodermal cells of the tumor and leave a residuum of the other better differentiated tissues.

It is generally supposed that the Wilms' tumor does not have a benign tumor in close relationship to it such as the relationship which the adenoma bears to hypernephroma, but there is a curious, small, fibrous tumor occurring in the kidney which is a mixture of well differentiated mesodermal elements. There is no evidence to suggest that the fibroma of the cortex of the kidney is a slowly growing or early Wilms' tumor but the presence of multiple tissues of mesodermal origin indicates that the fibroma is distantly related to the Wilms' tumor.

Grossly, the *fibroma of the cortex* is a tiny, white lesion encountered when the capsule of the kidney is stripped. Part of the tumor adheres to the capsule but the greater part remains in the cortex of the kidney (Fig. 513). Microscopically, this tumor is composed chiefly of the adult type of collagenous fibrous tissue but it also contains occasional renal tubules, smooth muscle cells, adipose tissue and perhaps other mesodermal elements, all completely differentiated. It evidently has no clinical importance.

Other benign tumors of the renal parenchyma occur. *Lipomas* are not common. *Fibromas*, often myxoid in character, are occasionally encountered in the pyramids of the renal medulla. According to Bell,[11]

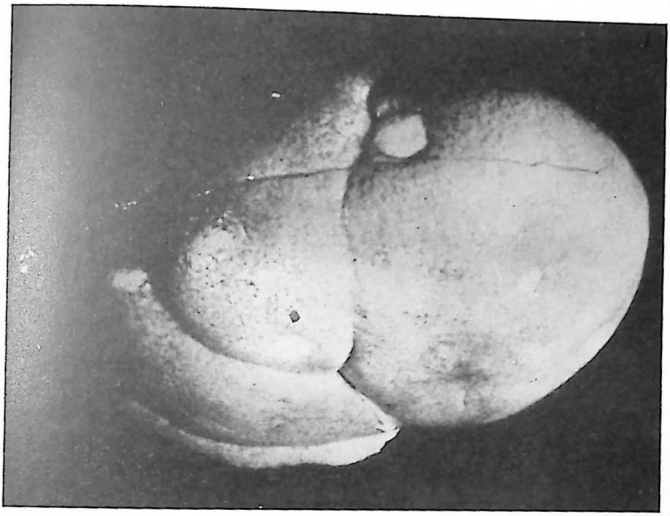

Fig. 513.—Capsular fibroma. Three fibromas are present but only one is clearly illustrated.

these are probably not true neoplasms. They never exceed 1 cm. in diameter and apparently never become malignant.

Hemangiomas of the kidney may produce hematuria assumed to be "essential" because of normal urograms. Cases have been reported by Rives and Pool[15] and Rottino and Mohan.[16] Bell has reported that one such case occurred in 30,000 necropsies in his experience.

Sarcomas of different varieties occur rarely in the kidney. A convenient reference is Rademaker[17] who has reviewed the literature.

It is possible that an especial form of *carcinoma of the kidney* with its origin in the tubules of the renal medulla may occur. Small alveolar neoplasms which do not fit ordinary classifications of renal tumors

occur rarely in the region of the hilus of the renal parenchyma. Since the collecting tubules of the medulla have a different embryologic origin from the tubules of the cortex, it is probable that a distinctive tumor derived from the collecting tubules will eventually be discovered if it has not already been described.

RENAL PELVIS

Papillary transitional cell carcinomas of the renal pelvis are embryologically and morphologically related to tumors of the bladder. They may be warty, papillary tumors or they may be more sessile and infiltrating. McDonald and Priestley[18] have reported seventy-five cases

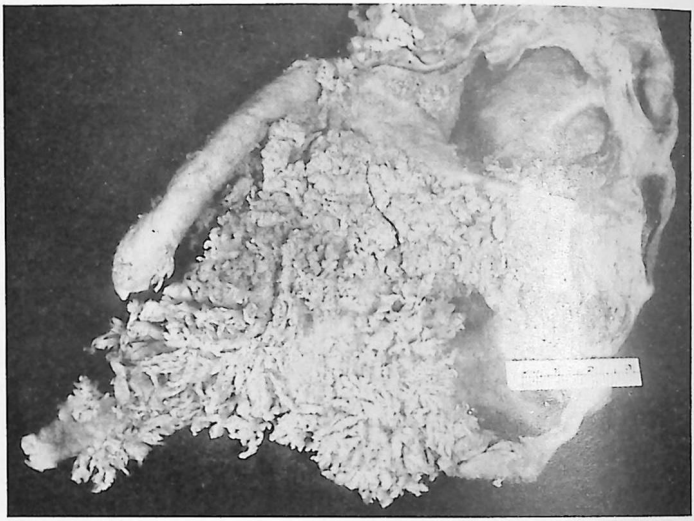

Fig. 514.—Papillary carcinoma of renal pelvis. Spread down the ureter is apparent.

in which they noted that the prognosis is influenced by the degree of anaplasia of the tumor and by whether or not the renal vein is involved.

It is known that papillary tumors of the urinary tract may spread down the ureter into the bladder and even into the urethra but the process by which this spread takes place is not clearly understood. McDonald suggests implantation, lymphatic spread and carcinogenic irritation of the urinary epithelium as three possibilities. Melicow[19] also suggests the possibility that a disease of uroepithelium vulnerable to a carcinogenic agent may be a factor in the seeding of papillary growths along the urinary tract. Figure 514 illustrates the appearance

of shaggy papillary tumors of the renal pelvis extending down into the ureter. It is essential that urologists understand this type of spread so that they will investigate the entire urinary tract if a papillary tumor is found in some portion of it. It is also essential to understand this principle of spread if operations on the kidney are going to be sufficiently radical to include ureterectomy with nephrectomy in cases of carcinoma of the renal pelvis.

URETER

Primary tumors of the ureter have been reported recently by Barnes and Kawaichi,[20] Kraus[21] and McMahon.[22] Recently, interest in endometriosis involving the urinary tract has increased. Recent references are O'Conor and Greenhill,[23] Goodall,[24] Kretschmer[25] and Marshall.[26]

URINARY BLADDER

Carcinomas of the urinary bladder occur predominantly in elderly men and are more common than carcinomas of the kidney and ureter. The pathologic picture of papillary carcinoma of the urinary tract is the same as that of the pelvis, ureter or bladder. Grossly, these lesions are composed of tentacle-like masses of papillary tumor. In the bladder there seems to be no tendency toward retrograde spread of the papillary growth and urethral implants do not seem to occur but multiple carcinomas of the bladder mucosa may occur and it is apparent that secondary tumors may appear on the portion of the mucosa which contacts the tumor when the bladder is collapsed—the "kissing cancer." Microscopically, the tumor is composed of transitional epithelium which surrounds a thin central core of connective tissue containing a capillary.

In the lowest grade papillary carcinoma the transitional epithelium of the papillary projection closely resembles the transitional epithelium of the bladder and may differ chiefly in that it seems more robust and less easily desquamated by handling than the normal. In the grade II papillary carcinoma, the epithelium is thicker and the cells are more pleomorphic. The papillary character of the grade III papillary carcinoma is less apparent and the pleomorphism and irregular polarity of cells are more striking. This tumor is nearly always infiltrating as well as papillary. In the grade IV carcinoma monster nuclear forms are present and pleomorphism of cells is extreme. Some remnant of the papillary character of the tumor may persist but this is not a prominent feature of the tumor. The nucleoli are large and stand out clearly in vesicular nuclei in the higher grade tumors. The notorious complication of lower grade transitional cell carcinomas is recurrence. Higher grade tumors metastasize readily; lower grades less readily.

Squamous cell carcinoma of the urinary tract differs from transitional cell carcinoma in that the former are keratinizing tumors and form keratin pearls like the ordinary squamous cell carcinoma of the lip. Grossly, this tumor is usually a crater-like ulcer and is infiltrating; it metastasizes but does not appear to implant. The squamous cell carcinoma of the urinary tract is supposed to arise from areas of leukoplakia or keratinizing metaplastic epithelium which in turn is known to be associated with urolithiasis or other chronic inflammatory disease. The actual association of squamous cell carcinoma with leukoplakia in the mucous membranes of the mouth is well known, but the association of squamous cell carcinoma of the bladder or renal pelvis with leukoplakia in these regions is more difficult to demonstrate. However, the assumption of their association is reasonable in view of the microscopic morphologic picture of the two keratinizing lesions.

Among malignant tumors of the bladder, there occur *unusual tumors* that do not fit readily into ordinary classifications. An example of such a tumor is one of primary osteogenic sarcoma reported by Tremblay, Crane and Harris,[27] and another, apparently a carcinoma associated with sarcoma arising from the pelvic bones, reported by Shoemaker and Robertson.[28] Colloid (mucoid or gelatinous) carcinomas may be primary in the urinary bladder, and, when they occur, they are found in the dome. This location is significant because colloid carcinomas occur in the urachus and it has been assumed that colloid carcinomas of the dome of the bladder have their origin from the site of attachment of the urachus.[29]

PROSTATE

Carcinoma of the prostate is a relatively common disease of the elderly. Grossly, it is characteristically stony hard and yellow in color, but actually it is rather difficult to distinguish carcinoma of the prostate grossly except in the more obvious cases and it has never been possible to make a diagnosis from gross inspection of surgical material with any degree of certainty. Clinical impressions obtained by rectal palpation of the gland seem to be more consistently accurate than impressions gained by gross pathologic examination.

Microscopically, the diagnosis of carcinoma of the prostate is not entirely easy because of a number of confusing factors. There may be proliferation of the epithelium around the urethra and that lining the prostatic ducts around the urethra which is actually benign but requires some experience and care to distinguish from carcinoma. Distortion of prostatic acini by compression of contiguous cysts or by inflammatory reactions must be interpreted with care. On the other hand, the alterations in carcinoma produced by orchiectomy and stilbestrol are not completely understood so that the pathologist must live in some fear of missing, after such therapy, a carcinomatous growth

which may have been obvious on a previous examination. None of the established criteria for the diagnosis of malignancy ever seems to help in a questionable case; neural involvement is rarely seen, and the cells of prostatic carcinoma are so small that the ordinary nuclear and nucleolar changes characteristic of many varieties of carcinoma do not appear in carcinoma of the prostate. Finally, since prostatic malignancy commonly begins in the posterior part of the gland and the tissue removed by surgical operation is taken from around the urethra, the pathologist might be unable to demonstrate carcinoma in a case in which the clinical diagnosis has been established by palpation of the posterior portion of the gland.

In spite of all these difficulties there is a reasonable correlation between pathologic diagnosis, clinical impressions and follow-up observations. Microscopically, the average carcinoma of the prostate is characterized by small glands lined with small cuboidal cells in which the nuclei have lost their polarity. This is a most important distinction because in the normal or hyperplastic prostate, the cells are tall columnar and the nuclei are arranged regularly along the basement membrane with their long axes perpendicular to it. The carcinomatous glands infiltrate the smooth muscle and fibrous stroma of the prostate in such a way that the stroma is crowded and thinned. Most cases of carcinoma of the prostate are graded II. Some are lower grade; the glands in grade I carcinomas are larger but there is no real difficulty in distinguishing these from the normal because of hyperchromatism of the carcinomatous glands. The more anaplastic carcinomas are not difficult to diagnose because of diffuse infiltration by small, poorly formed glands and more evident pleomorphism of nuclei.

SUMMARY

The gross and microscopic picture of the benign and malignant tumors of the kidney, renal pelvis, urinary bladder, and prostate gland have been discussed. Some theoretic considerations concerning the origin of these tumors and the possible relationships between certain of the benign and malignant tumors have been reviewed. References are given to some of the less common lesions that involve these organs.

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THE MANAGEMENT OF BLADDER NECK OBSTRUCTION

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There are many entities which, although differing in their pathologic appearance, occlude the vesical neck, produce the same symptoms and eventually cause identical changes in the bladder and upper urinary tract. The principal causes of bladder neck obstruction in adults are benign prostatic hypertrophy, carcinoma of the prostate, contracture of the vesical neck or median bar and acute prostatitis. In children the condition is produced by congenital valves of the posterior urethra, congenital hypertrophy of the verumontanum and congenital contracture of the vesical neck. In addition to the management of bladder neck obstruction due to these conditions the newer concept of the treatment of the neurogenic bladder in both sexes, based on obstruction, will be discussed.

ETIOLOGY

Benign hyperplasia of the prostate is seen most frequently between the ages of 55 and 70. Various theories have been advanced to explain its etiology. The *arteriosclerotic* theory of the French was popular for many years. It was accepted because hyperplasia and arteriosclerosis occurred in patients of the same age group, but pathologically and clinically this theory was eventually disproved. Not all patients with prostatic hyperplasia have arteriosclerosis and vice versa. For a while the *inflammatory* theory was accepted but here again it was later proved that inflammation, whether specific or nonspecific, played no role. The *neoplastic* theory is still disputed. Some contend that the hyperplasia represents a true new growth and others that it is pure hyperplasia. It is thought to stem from submucosal glands found beneath the mucosa of the posterior urethra and trigone. The *endocrine* theory has been advanced more recently and for some years many urologists have attempted to treat hyperplasia of the prostate with the male sex hormone and later the female sex hormone.

Carcinoma of the prostate is seen in about 20 per cent of all cases of prostatism.[1] It most frequently originates in the posterior lobe and

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occurs usually after the age of 40 but most often between the ages of 60 and 70.

Contracture of the vesical neck occurs at any age—congenitally in children and between the ages of 25 and 60 in adults. It is due either to muscular hypertrophy of the internal urethral sphincter (which is comparable to congenital pylorostenosis) or to fibrosis of the vesical neck. Urethral valves are congenital but an adequate explanation has not been given for this embryonic defect.

The etiology of the neurogenic bladder is varied. Trauma to the central nervous system, syphilis, acute inflammatory diseases of the spinal cord, tumors of the spinal cord, spinal anesthesia and spina bifida are relatively frequent causes. Most urologists now agree that in the female there are glands situated in the posterior urethra morphologically similar to the prostate.[2] Such glands infrequently cause true bladder neck obstruction.

PATHOLOGY

The pathologic appearance of benign prostatic hyperplasia or hypertrophy varies with the size and type of gland. One lobe may be larger than another although the enlargement is usually uniform. There are seven possible lobes which may enlarge singly or in combination. However, the three most frequently encountered hypertrophied lobes are the two laterals and the median. Found hypertrophied less often are the Albarran, the anterior and the subtrigonal lobes. The cut surface of the hypertrophied prostate is light in color. Each lobe consists of smaller lobules bound together by fibrous tissue. Within the lobule there are smaller ones called spheroids. The hypertrophic or hyperplastic tissue compresses the original prostate laterally to form the surgical capsule of the hypertrophied prostate.

Most prostatic malignancies are adenocarcinomatous. The growth is usually limited by Denonvillier's fascia but it does frequently invade the seminal vesicles. Its origin is usually in the posterior lobe and from there it invades the other lobes or spreads to the urethra, bladder or rectum, the urethra being the most frequent site of invasion. The most common regions of metastasis are the lumbar spine, pelvic bones and deep pelvic lymph nodes. Nerve trunks are sometimes involved and more rarely distant bone or visceral metastases are observed.

Median bar and contracture of the vesical neck are usually the result of chronic inflammation at the bladder neck or in the prostate. The bar, composed of fibrous tissue, stretches across the floor of the internal urethral orifice and is covered by the epithelial lining of the bladder. Contracture may be associated with median bar formation and there is usually also shortening of the posterior urethra.

The same type of contracture as that encountered in adults is seen

congenitally in children. Posterior urethral valves of congenital origin appear as redundancies or folds of mucosa and are either attached to the verumontanum or are anterior or posterior to it. Occasionally, in children the interureteric ridge may become hypertrophied and produce obstruction.

Acute prostatitis, whether gonorrheal or nonspecific in origin, produces obstruction from a uniform swelling of the entire gland; occasionally, a true abscess cavity may develop within such a gland.

In all types of bladder neck obstruction the pathologic changes in the bladder itself and in the upper urinary tract are familiar. There is first hypertrophy of the detrusor muscle of the bladder with thickening of the wall. The wall of the bladder becomes trabeculated as it attempts to compensate for the increasing obstruction at its outlet. Small, herniated areas called cellules develop between the hypertrophied muscle bundles. These cellules may develop into diverticula. Later, when there is residual urine, the constant intravesical pressure may become so great that the bladder dilates and loses its tone, thus becoming decompensated, thin-walled and atonic.

As urine accumulates, infection frequently occurs and stones may form. As the intravesical pressure increases from greater retention of urine, back pressure is transmitted up the ureters to the kidneys due to destruction of the physiologic valve normally in operation at the ureterovesical junction. A reflux of urine up the ureters from the bladder may also occur. In time, the renal pelves and infundibula become dilated and the calices clubbed. Later, the renal cortex becomes compressed and thinned out with resulting loss of renal function; there may be an accompanying pyelonephritis. Pyonephrosis is the ultimate stage of this process.

SYMPTOMATOLOGY

The symptoms of obstruction at the neck of the bladder vary with the type, duration and degree of obstruction. The onset is frequently insidious. The first symptom is usually *frequency*. The patient at first pays little attention to frequency during the day but as he begins to get up at night to void, his attention is immediately focused on the genitourinary tract. Later, there may develop *difficulty in urination* with hesitancy in starting, reduced stream, starting and stopping and terminal dribbling. *Acute retention of urine* may finally appear, often precipitated by weakness resulting from some other illness. *Hematuria* may appear as gross hemorrhage with clots rapidly filling the bladder or merely as a few drops of blood terminally.

If retention of urine is of long standing, the patient often complains of weakness, lassitude, backache, pain in the legs and loss of appetite. If renal failure occurs with high blood concentration of the nitrogenous products, typical uremic symptoms supervene ending ultimately

in death. If the urine is infected, chills and fever, dysuria, renal pain and other typical symptoms of acute pyelonephritis may develop.

Carcinoma of the prostate is essentially a silent disease until symptoms of obstruction or metastasis occur. Bone metastases or pressure on nerve trunks due to metastasis will cause backache, pain in the legs and, frequently, typical sciatica, which is undiagnosed until the prostate is considered. In the late stages rectal symptoms are sometimes predominant. Gross hematuria is infrequent. Anemia, weakness and cachexia constitute the end picture as in all other malignancies.

Children with congenital obstruction are often brought in for examination because of a distended abdomen or because of straining to void with dribbling and crying from the effort required. The clinical picture may unfortunately be vague at first and consist merely of intermittent pyelonephritis with gradually developing cachexia and no obvious evidence of bladder neck obstruction until late. This fact emphasizes the necessity for a complete urologic study on any child with a urinary infection or frequency.

The neurogenic bladder presents a variety of symptoms. There may be complete retention, frequency and pseudo-incontinence with considerable residual urine, or a true and complete incontinence; similar rectal symptoms are usually also present. The history and physical examination will indicate the underlying etiology.

DIAGNOSIS

A careful history and complete physical examination are essential to make the diagnosis of bladder neck obstruction. This should include a study of the cardiovascular, respiratory and gastrointestinal systems since it is important to evaluate the patient's general health accurately before any instrumentation is planned.

The second of a two glass voided specimen of urine in the male or a catheterized specimen in the female is examined for albumin, sugar, red blood cells, casts and finally for infection by means of a stained slide of the centrifuged sediment. Urine cultures are done when indicated. The prostate is then palpated. In benign hypertrophy there is a definite palpable enlargement, usually smooth and symmetrical, and rubbery in consistency. The degree of hypertrophy noted on rectal palpation, however, is not necessarily a true indication of the amount of obstruction present within the urethra because of the possible variations in the lobes not palpable rectally. In the presence of vesical contracture or median bar formation the prostate is small and fibrous on palpation. The carcinomatous gland is stony hard, irregular and fixed on palpation and the malignancy may have extended on to the seminal vesicles and laterally beyond the confines of the prostatic capsule. In early cases palpation may reveal only a single, firm nodule, sur-

rounded by normal prostate. At the time of rectal examination the prostate is massaged, the vesicles stripped and the expressed secretion examined for pus in the wet fresh specimen.

Following this a phenolsulfonphthalein renal function test is done. One cubic centimeter of the dye is injected intravenously and a single specimen of urine collected by having the patient void at the end of one hour and ten minutes. A reading of 50 per cent or more for this specimen indicates satisfactory renal function with at least complete renal compensation and also demonstrates that the patient has emptied the bladder adequately. If the phenolsulfonphthalein excretion is less than 50 per cent, this indicates either impaired renal function or residual urine in the bladder. A No. 18 F. coudé catheter is gently introduced under aseptic conditions and the bladder emptied. The residual urine is measured and then tested for phenolsulfonphthalein excretion and the total renal function for seventy minutes obtained.

The prostate and bladder are then examined through the cystoscope in borderline cases in which the physical findings have not been thus far adequate to explain the symptoms. From this examination information is obtained regarding the type and size of the intravesical obstruction. The presence of bladder stones, tumors or diverticula can also be determined. The examination is done under local anesthesia (4 per cent metycaine) with a No. 20 F. McCarthy panendoscope and there is relatively little urethral reaction from it. In the female obstructive granular tissue at the bladder neck can be seen and, if there is a neurogenic bladder, the presence of bladder neck obstruction can be determined. In children the McCarthy miniature cystoscope is used. The child is hospitalized and cystoscopy is performed under general anesthesia. Whatever treatment is necessary is carried out at the same time with the same instrument.

Routine roentgenograms are then made in all cases. In men with definite prostatic obstruction a roentgenogram of the kidneys, ureters and bladder and cystograms are obtained. The roentgenogram of the kidneys, ureters and bladder will indicate the presence or absence of stones in the bladder or kidney, metastases to bones in cases of carcinoma, or prostatic calculi. The cystograms indicate the presence of vesical diverticula and furnish information as to whether or not a diverticulum empties adequately. Large infected diverticula which do not empty spontaneously should be removed surgically prior to prostatic operation. Otherwise, the clinical result from the prostatic operation alone will be inadequate and the postoperative course of the patient stormy. Preoperative cystoscopy need not be performed in those cases with advanced and obvious prostatic enlargement; thus, a possibly serious instrumental reaction which might complicate the operation later may be avoided. Excretory urograms are also obtained in all patients with a history of hematuria or stones or anything else

pointing to possible disease in the upper urinary tract. In children excretory urography is employed routinely and has the added value of furnishing an entirely satisfactory renal function test in children too young to cooperate for the phenolsulfonphthalein test.

TREATMENT

The treatment of bladder neck obstruction is surgical. The indications for surgical intervention vary widely in individual cases. Each patient must be carefully studied over a period of time before the decision in favor of operative intervention is made.

In cases in which there is no urinary retention or only a small amount of residual urine (up to 100 cc.), conservatism is indicated. If the obstruction is benign, repeated prostatic massage to eliminate any infection present as well as to empty the gland may be of considerable symptomatic benefit. The patient is instructed to avoid excessive temperature changes, too much physical exercise and long rides. The bowels should be kept regulated and alcohol and highly seasoned food should be excluded from the diet. Urinary antiseptics should be used if urinary infection is present. Renal function should be periodically checked and the amount of residual urine periodically determined. Any significant change will usually indicate the necessity for surgical intervention.

Prostatic operation is ordinarily not indicated in cases with good renal function and no appreciable residual urine. One exception to this, however, occurs in those patients who have an extremely hypertrophied bladder wall with resulting reduction of capacity and bladder irritability producing marked frequency. Surgical intervention is indicated in such cases from a purely symptomatic standpoint regardless of the presence or absence of residual urine.

There are three methods of approach for prostatic operations: the transurethral, suprapubic and perineal routes. The most popular method today is transurethral prostatic resection. It is an exacting operation, most difficult to master and attended by dangerous consequences when improperly done. However, it offers the patient with benign obstruction a satisfactory clinical result, obtained with less shock and morbidity and a lower mortality rate than any other method. Those who routinely employ this method consider it the operation of choice in all cases of benign obstruction except those presenting exceptionally extensive benign hypertrophy, in which suprapubic enucleation can be more easily and quickly performed. Suprapubic enucleation is practicable only in cases of benign hypertrophy of the prostate, as a good line of cleavage between the prostatic hyperplasia and the compressed surgical capsule is essential. Radical perineal prostatectomy offers the possibility of cure in a few carefully selected cases of prostatic carcinoma and is usually employed for this purpose.

Preoperative Treatment.—Patients retaining large amounts of urine are provided with indwelling catheter drainage upon being hospitalized. There is no danger, as was formerly believed, in drawing off rapidly whatever amount of residual urine is present. A No. 18 F. coudé or Foley catheter is used. Fluids are maintained at 3000 cc. daily and are given either by mouth or by infusion of a solution of 5 per cent glucose in saline if necessary. An accurate record of the intake and output of fluid is kept. A complete blood count is obtained and whole blood given if indicated. Determinations of the blood nonprotein nitrogen, sugar, carbon dioxide and creatinine are obtained and the phenolsulfonphthalein test is repeated if necessary. The cardiovascular system is carefully examined and any other positive findings in the history or physical examination properly studied. Should the renal function as well as all other of the above factors be satisfactory, the operation is performed. If renal function is poor, operation is postponed until the patient's condition is more favorable. The restoration of normal renal function, or at least stabilization of function in these latter cases by continuous catheter drainage and adequate fluid intake, is one of the most important factors in the success or failure of prostatic operations. It is far more important than age, a past history of severe heart disease or diabetes or any other consideration. It is the chief factor enabling urologists to operate successfully, in the presence of urine and infection, on patients in an extremely elderly age group. After prolonged catheter drainage in these cases with advanced renal damage, it matters little at what level of function the kidneys stabilize. The nonprotein nitrogen may remain constantly at seemingly prohibitive levels and yet, if properly stabilized, the patient will stand operation well.

If there is evidence of acute urinary tract infection as manifested by fever, tenderness in the kidney regions and pyuria, the patient is given a urinary antiseptic, preferably small doses of sulfathiazole or sulfadiazine, 0.5 gm., four times a day, with a teaspoonful of sodium bicarbonate. If renal function is poor, mandelic acid, 2 to 4 teaspoonfuls four times daily, may be substituted to avoid possible renal reactions from sulfonamides in already damaged kidneys.

Suprapubic cystotomy is occasionally necessary as an emergency procedure in cases of acute retention with either an impassable prostatic obstruction or urethral obstruction. It is also necessary in those patients requiring prolonged drainage prior to prostatic operation if they cannot tolerate a urethral catheter because of infection or irritability.

The same fundamental principles that apply to adults with bladder neck obstruction apply to children and preparation for operation is identical.

Neurogenic Bladder.—Recent experience has shown that transure-

thral resection of the bladder neck in cases of neurogenic bladder with partial or complete retention of urine is beneficial in almost every case. This is true regardless of the age or sex of the patient and regardless of whether or not there is any preexisting obstructive tissue at the bladder neck. The etiology of the neurogenic bladder and its duration are likewise unimportant. The improvement is most probably due to removal of the internal sphincter by resection and to the overall enlargement of the urethrovesical junction.

Surgical Treatment.—*Transurethral Prostatic Resection.*—Transurethral resection is most frequently done with the Stern-McCarthy

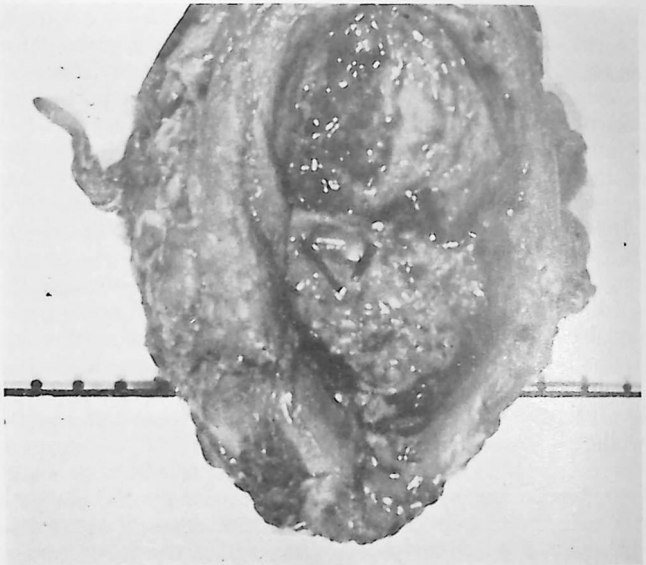

Fig. 515.—Specimen removed by subtotal transurethral prostatic resection.

electrotome and any thoroughly dependable electrosurgical unit. A subtotal prostatectomy is accomplished, during which all prostatic tissue down to the surgical capsule is removed (Figs. 515, 516, 517). The anesthetic of choice for this procedure is a low spinal. Before resection is begun, bilateral vasoligation is performed to prevent postoperative epididymitis, which would otherwise occur in from 5 to 7 per cent of cases and prove of considerable annoyance during the postoperative period, possibly resulting in loss of the testis. The bladder is then carefully examined with the observation and retrograde lenses. Tumors or nonopaque stones can thus be identified if present, and removed. All prostatic tissue possible is removed out to the

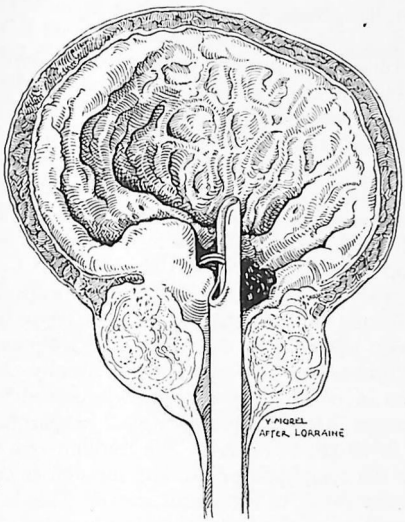

Fig. 516.—Diagrammatic sketch showing first stages of prostatic resection. (After Lorraine, in Dodson, A. I.: Urological Surgery, St. Louis, C. V. Mosby Co., 1944, pp. 713–719.)

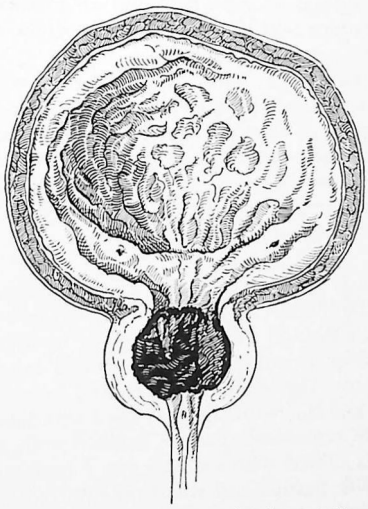

Fig. 517.—Diagrammatic sketch showing completed prostatic resection. (Also after Lorraine.)

verumontanum. To obtain a good result it is necessary not only to give the patient a channel through which to void but to remove all the tissue possible. This prevents recurrence of obstructing tissue, minimizes infection in the remaining tissue and enables the patient to empty the bladder completely. Following resection of the tissue all bleeding points are carefully coagulated and the urethra carefully checked with the Vest and retrograde lenses to be sure that no obstructing tissue remains. A No. 26 F. Foley catheter is then introduced and the bag inflated to 30 cc. The catheter is irrigated until the return fluid is clear. If this is impossible, the instrument is reintroduced and further coagulation of bleeding points carried out.

In children with bladder neck contracture or posterior urethral valves the McCarthy miniature operating cystoscope is used with a special small loop powered by the usual high frequency unit.

Suprapubic Cystotomy.—This operation is usually done under low spinal anesthesia or occasionally gas when indicated because of cardiovascular changes. After the usual surgical preparation, an incision about 10 cm. in length is made in the midline one to two fingerbreadths above the symphysis pubis. The incision is carried through the skin and fascia down to the rectus sheath. This is incised in the midline and the fibers of the rectus muscle separated. The bladder is then distended with air by means of an insufflator. The peritoneum is reflected from the anterior surface of the bladder with a gauze sponge. The bladder is grasped on each side and an incision made through the wall. The bladder will usually contain a slight amount of urine which should be aspirated by suction.

At this stage the technic varies depending on whether a one- or two-stage prostatectomy is contemplated. The two-stage procedure has the advantage of dividing the operative shock and shortening the operating time for each procedure. It also prepares the prostatic bed for later infection, thereby lessening the systemic reaction after removal of the prostate. However, those patients who are relatively young and in good general health can withstand a one-stage procedure very well.

If the operation is to be done in two stages, a finger is inserted into the bladder and the bladder explored. Any stones present are removed. After exploration a No. 30 Pezzer catheter is inserted into the bladder and the bladder closed with two layers of interrupted chromic No. 1 catgut sutures. The bladder is then fixed by a chromic suture to the rectus sheath and the rectus sheath closed with interrupted chromic No. 1 catgut. The prevesical space is drained with a Penrose drain, the external fascia closed with chromic No. 1 continuous sutures and the skin closed with dermal and silkworm sutures.

The second-stage enucleation of the prostate is carried out whenever the patient is considered ready. This may vary from a week to

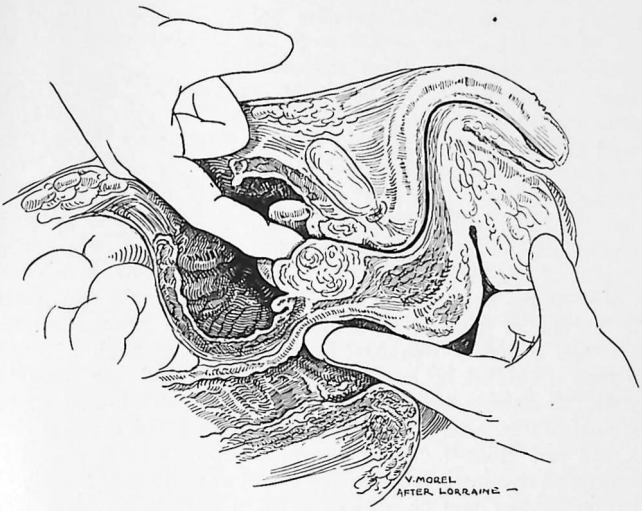

Fig. 518.—Prostatic enucleation, showing roof of urethra being broken.

Fig. 519.—Prostatic enucleation showing lobes being enucleated.

many months after the cystotomy, depending on the amount of postoperative reaction to the first operation and the general health of the patient. If necessary, the second stage can be abandoned and the suprapubic catheter left in place permanently.

Prostatic Enucleation.—Two fingers of *one* hand are inserted into the rectum and the prostate pushed anteriorly. The other hand is introduced as far into the bladder as possible from above through the same exposure as for cystotomy and the index finger introduced into the posterior urethra. The roof of the prostatic urethra is broken through first (Fig. 518). A line of cleavage is then found between the hyperplasia and the compressed surgical capsule and by a sweeping motion of the finger both lateral lobes are easily enucleated (Fig. 519). If the large middle lobe is hypertrophic, it is enucleated at the junction of the lobe with the trigone. After enucleation the prostatic bed should be examined for any tissue left behind. Bleeding is then controlled by inserting a Pilcher bag into the prostatic cavity with its catheter end pulled out through the urethra and applying traction to this. After the bag has been inflated, the urethral portion is tied to a Hunt-Hamer wire cage. A Freyer tube is placed in the suprapubic opening and the wound closed as previously described. Tension on the bag must be released in six to eight hours when adequate hemostasis will have been obtained. If this is not done, damage to the sphincter may result. The Pilcher bag is usually removed in from twenty-four to forty-eight hours and replaced by a Pezzer catheter.

The *postoperative* care of patients who have had either transurethral or suprapubic prostatectomy is the same. In those patients who have lost a considerable amount of blood, blood transfusions are given. In the first twenty-four hours fluids are administered parenterally in the amount of 2000 to 3000 cc. The average patient is able to take adequate fluids by mouth after this and in forty-eight hours is usually on a full diet.

The immediate postoperative attention to catheter drainage of the patient subjected to a transurethral operation is of utmost importance. For the first twenty-four hours the catheter is irrigated regularly to assure normal continuous drainage and to remove any clots formed in the bladder. This enables the bladder to remain empty and at rest and also prevents obstruction of the catheter by clots.

The catheter is usually removed in from four to six days postoperatively when the urine is clear and the patient afebrile. If the patient continues to have fever, the catheter is left in several days longer. Fever, when present, is usually due to pyelonephritis and can be controlled by the oral administration of a good urinary antiseptic.

The patient is allowed up the day the catheter is removed and may leave the hospital in from seven to ten days. Patients who live

out of town are required to remain in the hospital through the fourteenth postoperative day, for it is usually during the second postoperative week that secondary hemorrhage occurs. If hemorrhage is severe, it can usually be controlled by emptying the bladder of clots and thorough irrigation. If bleeding continues in the presence of an indwelling catheter, coagulation of the bleeding points under anesthesia will be necessary. Before the patient leaves the hospital, the amount of residual urine should be less than 100 cc. Those patients who have had chronically distended bladders for some time preoperatively will be slow to regain bladder tone even after all obstruction has been removed and will continue to show some residual urine for a while.

The postoperative course of the patient who has undergone enucleation is longer for it usually takes ten to fourteen days for the suprapubic wound to heal and in some cases three weeks or longer. All patients should be examined postoperatively at regular intervals. All patients will have a residual urinary infection, which cannot be cleared up during the first few weeks postoperatively, as sloughing in the prostatic bed continues for at least six weeks. Urinary antiseptics, therefore, should be used only for acute flare-ups of infection with fever during this period. After six weeks it is usually possible to sterilize the urine permanently with a good urinary antiseptic.

In children excretory urograms are repeated postoperatively at six months to determine changes in the upper urinary tract following the relief of obstruction. Residual urinary infection is cleared up if possible with urinary antiseptics.

Postoperative urethral strictures frequently occur following transurethral resection, usually at the external urinary meatus or at the bladder neck. They should be repeatedly dilated during the first few months, after which, unlike other strictures, they usually resolve.

COMMENT

The treatment of carcinoma of the prostate is unsatisfactory notwithstanding recent discoveries in the field of hormonal therapy and despite the fact that a few early cases lend themselves to radical perineal removal. Aside from these few cases, the disease is admittedly incurable when first seen and all treatment is palliative.

Prostatic resection is performed when obstruction occurs in order to provide normal urination but without hope of removing the entire malignancy. Hormonal therapy as represented by the administration of stilbestrol or orchidectomy, or both, is widely used by every urologist. However, it is as yet unsettled as to how and when these measures may best be employed for the good of the patient. Consequently, there is great variation in clinical practice in this respect and no single

program of treatment has as yet been proved best. Fortunately, this question should definitely be settled in the next few years.

CONCLUSIONS

The management of bladder neck obstruction is a phase of urologic treatment in which tremendous strides have been made during the past twenty years. Patients whose disease was once considered inoperable because of advanced age or debility are now operated upon with relative safety. If the underlying physiologic and pathologic changes in the upper urinary tract in cases of bladder neck obstruction are properly cared for, the low morbidity and excellent operative results are gratifying regardless of the type of operation employed.

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ADDITIONAL ARTICLE

RADIOSURGERY: FOREIGN BODIES IN THE NECK REMOVED UNDER FLUOROSCOPIC CONTROL

CARLOS SANTOS, M.D.°

THE removal of foreign bodies under direct fluoroscopic control is often discredited and considered a difficult and dangerous method.

I have used this method since 1921 and have succeeded in removing, up to now, about 2000 foreign bodies without the slightest damage to the patients, my assistants or myself.

In previous publications[1] I have indicated the technic I use, some new instruments I have designed, indications of the method, and so forth.

It is generally believed that only foreign bodies situated in the soft parts of anatomically unimportant, nondangerous regions can be removed under the direct control of x-rays. I came to quite different conclusions. In order to make the possibilities of radiosurgery more widely known, I am presenting here two cases of foreign bodies situated in dangerous regions of the neck, in which I was able to effect removal under the direct control of the screen, without damage to the patients. I am of the opinion that successful removal could hardly have been accomplished by any other known method.

CASE I (Figs. 520, 521 and 522).—A young man, 22 years of age, was referred to me by Dr. Alvaro Gamboa, of Alpedrinha. Three days earlier he had been shot in the thorax with a revolver fired at almost point-blank range. At the time he did not suffer much, and he had been able to walk about three miles.

When I examined him, he felt slight pain on pressure in the front wall of the thorax, at a point about 8 cm. above the right nipple. He complained, too, of dull pain in the cervical region and mild discomfort in swallowing. He had a simple protective dressing over the orifice where the projectile had entered. This orifice was on the right side of the anterior wall of the thorax, three fingerbreadths above and three fingerbreadths to the right of the nipple.

Fluoroscopic and radiographic examination of the thorax revealed no abnormality. Roentgenograms of the cervical region showed no damage in the bones but did reveal a revolver bullet, which had not lost its shape, lodged vertically point upwards, to the right of the body of the seventh cervical vertebra, slightly in front of the respective transverse process.

The bullet must have passed in front of the ribs, grazing them, then under the clavicle, whence it must have crossed the base of the neck to the position it was occupying.

° Aggregate Professor of Radiology, University of Lisbon, Portugal.

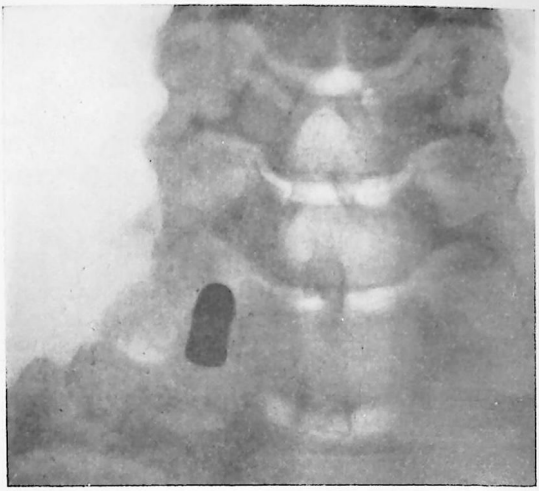

Fig. 520 (Case I).—Front view. A bullet can be seen projected on the right transverse process of the 7th cervical vertebra.

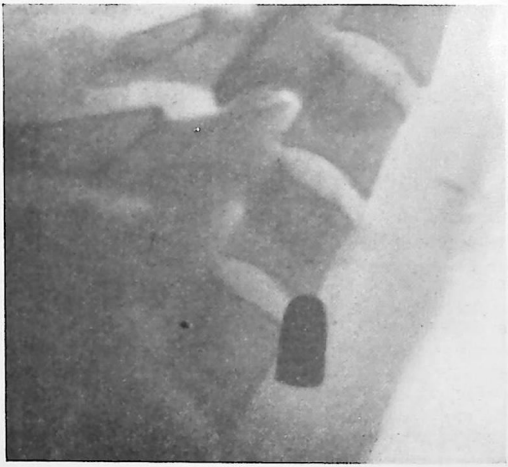

Fig. 521 (Case I).—Side view. The bullet is seen to be situated just in front of the 7th transverse process.

Indications for Operation.—The position of the bullet near the cord of the cervical sympathetic, near the stellate ganglion and also in proximity both to the roots of the brachial plexus and to the vertebral

artery, caused me to fear the later development of fibrous tissue which might envelop and exert pressure on the cervical sympathetic or the roots of the brachial plexus. If this occurred the necessary surgical intervention would be far more difficult than at present, and there would be risk of injury to the nerves; furthermore, it might no longer be possible to eliminate the already developed fibrous tissue with its attendant symptoms. In the circumstances, and in the light of my experience in previous cases, immediate operation under the control of the screen appeared indicated, even though the patient was not in great pain.

Fig. 522 (Case I).—After the intervention. The bullet, now removed, is resting on the cassette.

Intervention.—I operated in my own consulting room, the operation being effected in two stages, but in a single sitting.

Novocaine (0.5 per cent) with adrenalin was applied as a local anesthetic to the superficial tissues. The first stage of the intervention was carried out in the usual manner by my colleague Passos Angelo. A 3 cm. incision was made at the base of the neck, in front of the anterior border of the trapezius muscle and dissection was carried out through successive layers passing behind the carotid artery, jugular vein and pneumogastric nerve to the muscular layer on the posterior surface of the supraclavicular fossa. The rest of the operation was performed by myself in the dark, by radiosurgical methods.

The special circumstances of the case prevented my following the intervention on the screen by means of the so-called perpendicular ray, as usual. I had to feel my way inwards in a direction parallel to the screen, which renders depth orientation infinitely more difficult.

After probing with other instruments, I employed my own curved forceps. I produced, purposely, only partial anesthesia of the deeper regions in order that I might be able to guide myself by the patient's reactions. Indeed, as I gradually penetrated deeper, the patient occasionally complained of a pain radiating in the direction of his arm. This most often coincided with my receiving, transmitted from the point of the instrument, a sensation that I was touching the roots of the plexus. I had to feel my way to the bullet by means of slow and smooth perforating movements, little by little, under fluoroscopic guidance, while endeavoring to pass through parts which did not offer resistance and in which my movements caused the patient merely local pain and not the pain radiating towards his arm. As the anesthesia cannot be perfect with such a technic, it is absolutely necessary to keep the patient in good spirits by a flow of kind remarks so that he will be quiet in spite of the pain he always feels. I carefully watched the patient's general condition, and also his pupils.

Finally I succeeded in reaching the bullet and seized it transversely. Next, I proceeded gradually to extract it, by means of gentle zigzag movements, guiding myself by fluoroscopy and by feeling, so as to free it by degrees from the structures which impeded its way to the surface.

The operation occupied in all about two and a half hours. The time taken by the radioscopic intervention amounted to between half and three quarters of an hour. (Repeating what was already said in my previous works, I must insist upon the fact that such long radioscopic exposures are only possible without danger of dermatitis when a very small radioscopic field is used—in this case, for instance, never larger than one square inch.)

No hemorrhage occurred, the wound being perfectly dry when the intervention ended.

The wound was cleansed with ether. At the lower extremity of the incision, which was closed by two horse-hair stitches, a small horse-hair drain was placed.

After-effects.—At the conclusion of the intervention the patient was somewhat shocked, his pulse being rather weak. His pupils were equal and normal in size, and their reactions to light were also normal. There was no abnormality in his circulation or in the sensibility or motor power of his arm.

I gave the patient a cup of coffee. He was able to get up and to walk unaided. I gave him a local application lasting thirty minutes of red and infra-red rays, with the Sollux-lamp (as I always do in such cases). He remained lying down for another half hour, after which I saw him again. His pulse had recovered. He went home without requiring assistance.

I saw him on the following day. He had had a good night. He had practically no pain and was able to move his neck a little more freely. The wound was in a good condition. I removed the drain, which brought away a little slightly hemorrhagic serum. The patient was once more given thirty minutes under the Sollux-lamp.

The next day, when I saw him again, he was feeling better, the pain having further lessened and movements having become still more easy. I removed the stitches. Where the lower stitch had been, there was a tiny opening of about 1 mm. in size, whence a drop of blood oozed. I applied iodized alcohol and an aseptic dressing. The patient left the same day for his village in the country—that is to say, just two days after the operation.

Later I learned that this patient made a quick and perfect recovery, no complications having developed.

CASE II (See Figs. 523 to 526).—A policeman had been shot with a revolver six days before I saw him for the first time. I was informed that after the accident he had walked about two miles.

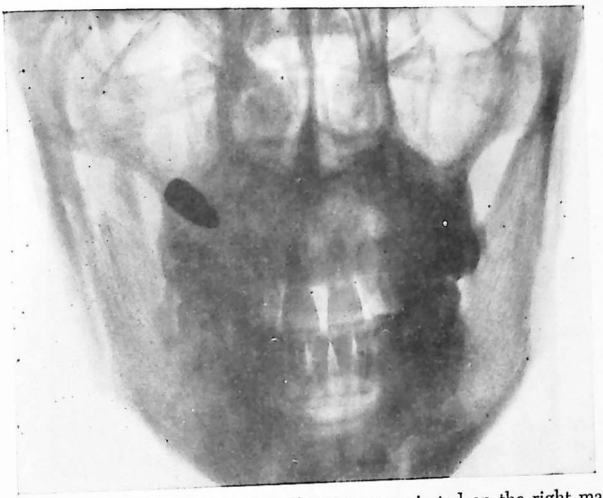

Fig. 523 (Case II).—Front view. A bullet is seen projected on the right maxillary sinus of the patient.

I found a painful swelling of the soft parts of the right side of the face. The entrance wound of the bullet (already closed) was situated about 1 cm. above the right angle of the mouth. There was a hematoma of the soft palate on the right side and trismus was present.

Roentgenograms of the head, one from the occipitofrontal angle, one exactly in profile and one in the usual oblique position for the separate projection of the right side of the lower jaw, were made. The films show several fracture lines in the ascending ramus and coronoid process of the right lower jaw, without displacement of the different fragments. A revolver bullet with a slight deformation is to be seen. It can be localized in the soft parts of the right side of the neck

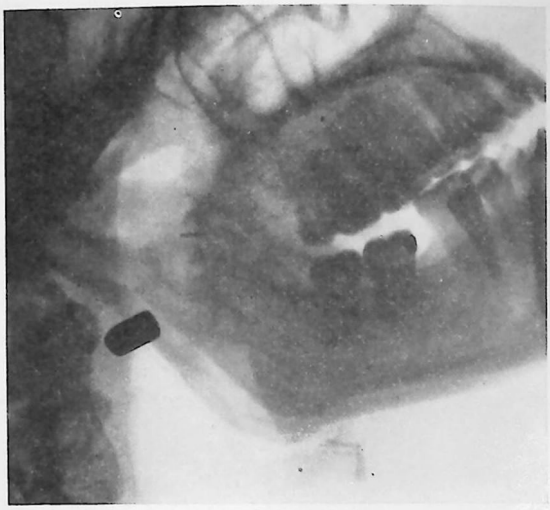

Fig. 524 (Case II).—Side view. It is apparent that the bullet is situated in the soft parts of the neck, between the pharynx and the neurovascular sheath, at the level of the 1st cervical vertebra.

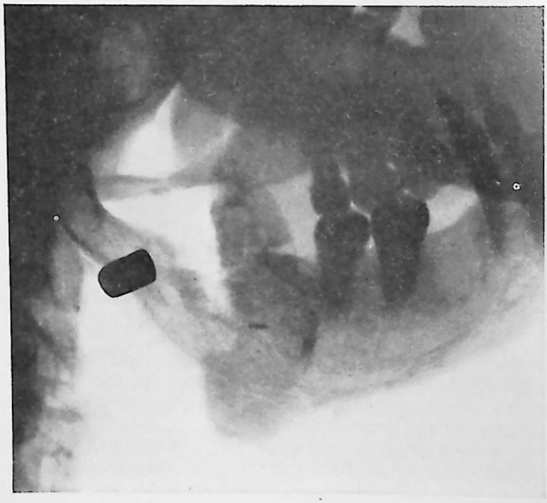

Fig. 525 (Case II).—Oblique view. Several fracture lines can be detected in the lower jaw.

about 3 cm. to the inner side of the posterior border of the ascending ramus of the lower jaw at the level of the body of the first cervical vertebra. I estimated that the bullet in this location must be situated between the pharynx and the neurovascular sheath, under the arteria maxillaris interna, in the region of the pterygoid venous plexus, in near relationship to the inferior dental and the lingual nerves.

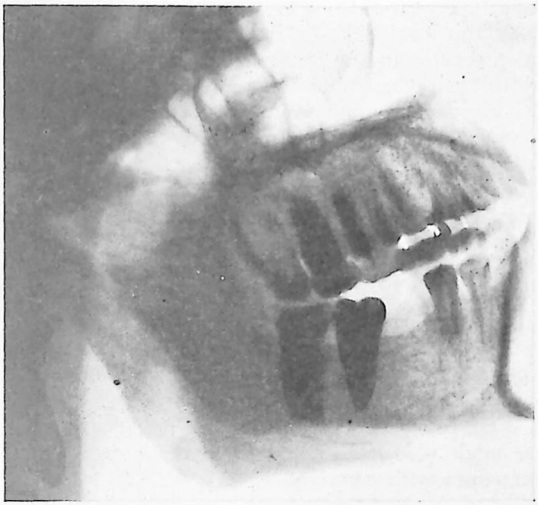

Fig. 526 (Case II).—Side view after the intervention. A clip placed at the wound on the skin projected between teeth 3 and 4 of the upper jaw.

The patient brought with him some roentgenograms taken three days earlier in which the foreign body could be seen in contact with the lower surface of the inferior wall of the skull, i.e., about 3 cm. above the situation it had now.

Indications for Operation.—Although the bullet was supposed to be somewhat free in the tissues of the neck (otherwise it would not have moved down since the first film) it did not move about during palpation. As in the first case, it was reasonable to expect that later formation of the usual granuloma would interfere with some of the local nerves, making operation far more difficult. Immediate intervention was indicated if the foreign body could be removed without great danger or great trauma. I thought that this was possible.

Surgical Approach.—The shortest route, from the side of the neck, was dangerous because of the proximity of the parotid gland, the facial nerve and the neurovascular sheath. Examining the patient under the screen, I saw the possibility of taking another route which, although much longer, was free from danger. With the patient under the screen, his head in an oblique position (R.A.O.), I could see the

foreign body projecting between the upper and the lower jaw. In this position the only anatomical features which I would have to avoid were Stenon's duct and the inferior dental and the lingual nerves; in the neighborhood of the foreign body no violent movements would be permissible, lest contact be made with the pterygoid venous plexus. I would have to be careful not to move the forceps towards the external side of the foreign body, in order to avoid contact with the neurovascular sheath; to the inner side, in order to avoid damaging the wall of the pharynx; or to the posterior side, in order to avoid contact with the last cranial nerves. It seemed to me these pitfalls could be avoided.

Intervention.—The operation was performed in my consulting room the day after my first observation. I anesthetized the soft parts of the face with novocaine (0.5 per cent) and adrenalin. I next inserted a needle from the outer aspect of the face pointing backwards and inwards, until the patient indicated a pain in the teeth, in order to determine the position of the inferior dental nerve. Then I placed the head of the patient in a position that would permit me to move in a straight line from the skin to the foreign body without touching this nerve, but just passing it by. After anesthetizing (not very completely) the deeper parts, I made a horizontal incision of 12 mm. through the skin about 3 cm. above and lateral to the angle of the mouth. The incision was made only in the epidermis and dermis, in order to bypass Stenon's duct with certainty.

I next inserted through the wound a special pair of forceps of my own construction (the same referred to in the aforementioned case). These forceps have their extremity somewhat wedge-shaped, so that they can separate the tissues, and easily pass between the fibers of muscles or between nerves or vessels. As the borders are not sharp, these forceps simply push aside, rather than cut, the different tissues. The borders have no indentations.

As the face was swollen, I could easily pass the forceps without touching the mucosa of the mouth, thus avoiding infection of the operative wound. (I had not chosen the oral route originally because of the danger of infection.) I passed outside the buccinator muscle until I touched the anterior border of the coronoid process. Then I took an oblique course between the upper and the lower jaw, through Bichat's pad of fat (the sucking pad of infants). I came to the region where the bullet was situated. All the time, I was "probing" my way, as it were, by slow, smooth perforating movements. When I came in contact with the bullet, I had the sensation of reaching a sort of cavity, where the movements were freer. When I tried to grasp the foreign body, however, it slipped easily from the jaws of the forceps which were too small for such a bullet. It was evident that a larger pair of forceps was required. When pulling back my first forceps, I opened

them and tried to increase the size of the channel I had made from the skin to the foreign body in order to facilitate the introduction of the larger pair.

With the larger forceps, which were similar in construction to the first pair, I was able to grasp the foreign body lengthwise and remove it without great difficulty.

This operation was much easier than in Case I. It took about twenty-five minutes altogether.

No hemorrhage occurred, the wound being dry at the end of the intervention. No nervous lesions of any kind complicated the procedure. One clip was sufficient to close the wound.

After-effects.—After the intervention I made the usual application of red and infra-red rays with the Sollux-lamp (thirty minutes). The patient walked out unaided and came back daily for six days to have other applications of the Sollux-lamp. Through a misunderstanding of my instructions the clip was not removed on the second day, as is customary in my cases of this nature, but on the third day.

The fracture caused this patient discomfort for a certain time, some swelling and trismus, but from the foreign body and from the intervention not the slightest complication has appeared, and later all symptoms disappeared completely.

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