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Modern Surgery - Chapter 2. Asepsis and Antisepsis

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II. ASEPSIS AND ANTISEPSIS.

THE effort in all operations is to secure and maintain scrupulous surgical cleanliness. What is known as the antiseptic method we owe to the splendid labors of Lord Lister, and the aseptic method is but a natural evolution of the antiseptic method. It is true that Agostino Bassi, over half a century ago, convinced that various maladies were due to parasites, treated wounds with a solution of corrosive sublimate. It is also true that Semmelweis in 1847 demonstrated the infectiousness of puerperal fever and the method of preventing it; that Jules Lemaire in 1863 published a treatise on carbolic acid and advocated the use of this drug in the treatment of wounds in order to destroy living germs, and that Bottini in 1866 employed carbolic acid in the treatment of putrid and suppurating wounds because he believed germs to be responsible for such conditions (Monti on "Modern Pathology"). In spite of the above facts, Lister is the real father of asepsis and taught all nations how to prevent infection. Monti says: "But Lister, with that practical spirit which forms one of the best characteristics of English genius, from the scientific studies of Pasteur, deduced the general laws of antisepsis and the rules for their methodical application to practical surgery." Lister called the attention of the profession to a new method of treating wounds, compound fractures, and abscesses in 1867.* The processes first employed were extremely complicated, but have been made in the last few years simple and easy of performance. Lister believed the chief danger to be from air. It is now believed that the chief danger is from actual contact of hands, instruments, dressings, or foreign bodies with a wound. Air carries but few micro-organisms unless it is filled with dust. Infection through air is most apt to occur if the air is dusty, and is more common after an aseptic than an antiseptic operation.

Of course, some bacteria from the air must settle in every wound, but the majority of air fungi are harmless. Comparatively few reach the wound unless the air is dusty, and these few the tissues are usually able to destroy. Schimmelbusch made experiments in von Bergmann's clinic when the students were present. He found that "the number of bacteria which settle upon the surface of a wound a square decimeter in extent, in the course of half an hour, is about 60 or 70," and thousands are usually required to produce infection.

There is no danger of the breath alone producing infection. Air which comes from the lungs is germ-free, and even a large class will not infect the air by breathing, but will rather help free it from bacteria, for the lungs are filters for air laden with micro-organisms.

In performing any surgical operation cutting is better than tearing by blunt dissection. The former method makes an incised wound, the latter a lacerated wound, and a lacerated wound is much more apt to become infected than is an incised wound.

Surgical cleanliness may be obtained by either the *aseptic* or the *antiseptic* method. In the *aseptic method* heat, chemical germicides, or both are used to cleanse the instruments, the field of operation, and the hands of the surgeon and his assistants, the surface being freed from the chemical germicide by

*The Lancet.

washing with boiled water or with saline solution. After the incision has been made no chemical germicide is used, the wound being simply sponged with gauze sterilized by heat; if irrigation is necessary, boiled water or normal salt solution is used, and the wound is dressed with gauze which has been rendered sterile by heat. The effort of the surgeon is simply to prevent the entrance of micro-organisms into the tissues. Some micro-organisms must enter, but the number will be so small that healthy tissues will destroy them. The aseptic method should be used only in non-infected areas. If chemical germicides are not used, the amount of wound-fluid will be small, the surgeon can often dispense with drainage, and repair will be rapid. If a wound is to be closed without drainage, every point of bleeding must be ligated. It is often advisable to sew up the wound with Halsted's subcuticular stitch. If this stitch is employed, the skin staphylococcus does not obtain access to stitch-holes, and stitch-abscesses are not apt to arise. This suture may consist of catgut, silk, or, preferably, silver wire, this latter agent being capable of certain sterilization by heat and exercising a powerful inhibitory action on micro-organisms. If a wound is closed without drainage, firm compression is applied over the wound to obliterate any cavity which may exist. Drainage must be used if the wound is very large, if its shape or structure prevents the obliteration of the cavity by pressure, if there is any doubt as to the perfect cleanliness of the part, if the patient is very fat, for in such individuals fat necrosis predisposes to sepsis and to fat embolism, and if the skin is so thin that we fear pressure will produce sloughing ("A Manual of Surgical Treatment," by Cheyne and Burghard). In some regions of the body wounds are sealed with collodion or iodoform-collodion. If irrigation is not practised and the wound is dressed with dry sterile gauze, the procedure is said to be by the "dry" aseptic method. In the *antiseptic method* the same preparations are made for the operation as in the aseptic method, but during the operation sponges impregnated with a chemical germicide are used, and the wound is dressed with gauze containing corrosive sublimate or some other chemical germicide. If the wound is not flushed with a chemical germicide, and is dressed with dry antiseptic gauze, the operation is said to be by the "dry" antiseptic method. The antiseptic method is preferred in infected areas. Dry dressings are usually preferable to moist dressings, because they are more absorbent and do not act as poultices, and dry dressings may be used, even when the wound has been flushed. Some surgeons question the value of antiseptic irrigation in a septic wound, but we believe it removes many bacteria and much poisonous matter and also antidotes toxic material. In suppurating areas it is often best to use moist dressings in the form of antiseptic fomentations. Year by year the aseptic method becomes more popular. Surgeons have learned that the most important factor in asepsis is mechanical cleansing by means of soap and water. The chemical germicide plays a secondary rather than a vital part. By mechanical cleansing great numbers of micro-organisms are removed along with dirt, grease, and epithelium. Many organisms remain, but vast hordes are washed away, and the danger of infection is greatly lessened by thus diminishing the number of bacteria. If a chemical germicide is used without preliminary mechanical cleansing, it is useless, because it cannot destroy bacteria in the epithelium and in masses of oily matter. After the use of mechanical cleansing the germicide is active

in destroying the comparatively few bacteria which are naked on the surface. In many regions a strong chemical germicide must not be used (in the abdomen, in the brain, in joints, in the pleural sac, and in the bladder), and in other regions (mucous surfaces and fatty tissue) it is productive of harm rather than good.

Preparation for an Operation.—If the operation is to be performed in a hospital, a particular room is always ready. If it is to be done in a private house, much careful preparation is desirable. A room in which an operation is to be performed should be well lighted and well ventilated. It is advantageous to have an open grate in the room, for then a fire can be quickly made to take a chill off the air and ventilation is improved. The morning before the operation furniture should be removed, the carpet taken up, and curtains and hangings taken down. If the ceiling and walls are papered, they must be thoroughly brushed. If they are painted, they must be washed with soap and water. Dust is thus removed, and the danger of dust falling into the wound is averted. The floor is scrubbed with soap and water. The windows should be opened for many hours to thoroughly dry and freshen the room. On the morning of the operation the patient's bed is brought into the room and placed in a position where there will be plenty of light for future dressings, and where the surgeon will have access from either side. Never use a big broad bed; use a narrow bed. Never have a feather bed, but insist on Treves's advice being followed, and employ a metal bed with a wire netting and hair mattress.

A piece of carpet or rug is spread upon a portion of the floor and the table is set upon it. The table should be so placed that there will be a good light on the field of operation. A kitchen table does very well. On the table is placed a folded comfortable or several folded blankets.

Around the operating-table at proper distances are arranged a table for instruments, a table for dressings, a table for sponges and a basin of bichlorid, and a table for soap and a basin of water. A couple of buckets should be placed on the floor near at hand. The nurse and assistants should have ready the ether cone, wrapped in a clean towel, sterile sheets, sterile gowns, sterile towels, sterile gauze for sponges and dressings, trays for instruments, iodoform gauze, catgut, silk, silkworm-gut, etc., according to the nature of the operation. The surgeon should pick out the instruments required. The anesthetizer should lay out a mouth-gag, tongue-forceps, a hypodermatic syringe in working order, ether or chloroform, brandy, tablets of strychnin, and also of atropin.

If the operation is to be performed in a hospital, it is desirable to have the patient admitted two or three days before. He adjusts himself to his surroundings, becomes accustomed to diminished activity, forms an acquaintance with his nurses and physicians, and, as a rule, becomes less nervous and more calmly confident of the result. The patient is prepared the day before the operation, except in an emergency case.

When the time for the operation arrives, the surgeon and his assistants remove their coats, roll up their sleeves, and, after sterilizing the hands and forearms, envelop their bodies in aseptic or antiseptic sheets or gowns, to protect the patient and themselves. It is a good plan for the surgeon and his assistants to wear sterile muslin caps. The caps prevent hair, dandruff,

and sweat falling into the wound. Mikulicz and some other operators wear over the mouth and nose a respirator or piece of gauze in order to prevent saliva or mucus being projected into the wound while the surgeon talks.

It is a difficult or impossible matter to absolutely sterilize the hands, but it is fortunate, as Mikulicz and Flügge say, that most of the bacteria of the skin are harmless. The staphylococcus epidermidis albus, however, is constantly present in the epidermis. The hands of some persons are more easily sterilized than those of others. For instance, a hairy, creased hand is more difficult of sterilization than a smooth and almost hairless one; a hand grossly neglected, than one reasonably clean. Germs abound in the epidermis, in the fissures and creases, under and around the nails, on hairs, and in the ducts of glands. The surface of the hands may be thoroughly sterile at the beginning of an operation and become infected later, because germs in gland ducts are forced to the surface. Hence, in a prolonged operation, the surgeon should stop from time to time and wash his hands, first in alcohol and then in corrosive sublimate solution (Leonard Freeman).

In view of the difficulty of cleansing the hands, every student must be taught how to do it, and he must become impressed with the fact that the surgical hand is to be regarded as reaching to the elbow. The more hands used in an operation, the greater is the danger of infection of the wound. The surgeon uses retractors and forceps whenever possible, but his fingers must enter the wound. The fingers of no other person should enter unless absolutely necessary. The basis of all plans of sterilization and the most important part of any plan is mechanical cleansing by scrubbing with soap and water. By this means a quantity of loose epidermis is removed and with it great numbers of bacteria.

Mechanical Cleansing.—The hands and forearms may be sterilized in several ways. Any method is preceded by mechanical cleansing, which is carried out as follows: Scrub for five minutes with soap and hot sterile water, giving special attention to the nails and creases in the skin. The brush is rubbed in the long axis of the extremity and also transversely. The creases on the back of the hands and fingers will be partially opened by flexing the fingers, and transverse scrubbing will clean the furrows. The furrows on the palmar surface will be opened by extending the fingers, and will be best cleaned by transverse scrubbing (George Ben Johnston). The best soap is the ethereal soap of Johnston, which is a solution of castile soap in ether. Green, or castile, or synol soap can be used. The brush employed should be kept in a 1 : 1000 solution of corrosive sublimate or should have been recently sterilized with steam. The nails are cut short, are cleansed with a knife, and the hands are again scrubbed.

Fürbringer's Method: After washing off the soap in sterile water the hands are dipped in 95 per cent. alcohol and held there for two or three minutes while the forearms are being rubbed with alcohol. Alcohol removes the soap which has entered into follicles and creases, removes desquamated epithelium, enters under and about the nails, and favors the diffusion of the corrosive sublimate under the nails and into the follicles, when the hands are placed later in the mercurial solution. After using the alcohol the hands are then dipped in a hot solution of corrosive sublimate (1 : 1000), and with the forearms are scrubbed for at least a minute, the nails receiving especial care.

The Welch-Kelly Method: After the hands or forearms have been cleaned mechanically and have been rinsed in sterile water they are immersed for two minutes in a warm solution of permanganate of potassium (a saturated solution in distilled water) and are then immersed in a warm saturated solution of oxalic acid and are held there until decolorized. They are then to be well washed in sterile water, are next immersed for two minutes in a 1 : 500 solution of corrosive sublimate, and finally are rinsed in sterile water and dried on a sterile towel. The solutions for use in the above method should be contained in jars of the shape of a druggist's percolator so that both the hands and forearms can be immersed at the same time.

The Weir-Stimson Method: The hands should be cleansed mechanically as previously directed or, as Weir prefers, by scrubbing with a brush and green soap and in running hot water and cleaning under the nails with a piece of soft wood. Place about a tablespoonful of chlorinated lime in the palm of the hand, place upon the lime an equal amount of crystalline washing-soda, add a little water, and rub the creamy mixture over the arms and hands until the rough granules of sodium carbonate are no longer felt. Place the paste under and around the nails by means of a bit of sterile orange-wood. Wash the arms and hands in hot sterile water.* The combination forms nascent chlorin, a most efficient germicide. This method has proved extremely satisfactory in the clinic of the Jefferson Medical College Hospital. It is important that crystalline washing-soda be employed. If the bicarbonate is used, nascent chlorin will not be produced, but hydrochloric acid gas will be formed, and the latter gas irritates the skin and is not a satisfactory germicide.

The Use of Gloves.—Some surgeons are so impressed with the impossibility of sterilizing the hands that they wear gloves in operations. Hunter Robb is said to have suggested the use of gloves in 1894, but Halsted began to use rubber gloves in 1889. Mikulicz uses white cotton gloves. Lockett has proved that cotton and silk are not impervious to micro-organisms, but that rubber is. The thin, seamless rubber gloves which are now made are very satisfactory. They are sterilized by boiling, are then dried, and are wrapped in a sterile towel. In order to insert the hand in them, the interior of the glove should be first dusted with sterile starch or talc powder, and then the nurse should hold the glove while the surgeon inserts his fingers into the proper compartments and pushes the hand in.

If, during an operation, a glove becomes infected, a clean one can be substituted for it. Gloves somewhat impair the sense of touch, but a surgeon soon learns to work with them. If they are to be used, the hands should be sterilized just as carefully as when they are not to be used, because, during the operation, the gloves may tear or be punctured by a needle. That it is absolutely necessary to wear gloves in all cases has not been proved. Their use does contribute to success in brain operations, abdominal operations, and joint-operations. They are of great value in military surgery.

When a surgeon is obliged to place his fingers in an area of virulent infection he may be poisoned. Gloves will save him from this danger. Again, a surgeon should try to avoid bringing his hands unnecessarily in contact with putrid or purulent matter. Though it may not poison him, it grossly

* Medical Record, April 3, 1897.

infects the surface, renders subsequent cleansing difficult, and endangers other patients. Gloves will prevent this danger. A surgeon should wear gloves if he is making an examination or performing an operation which is sure to infect the bare hands, and he should wear gloves in an operation if in a previous operation his hands were infected.*

Instruments are disinfected by subjecting them to the action of steam in a special sterilizer, or better by boiling them for fifteen minutes in a 1 per cent. solution of carbonate of sodium. They are wrapped into a bundle by means of a towel or piece of gauze and are dropped into the solution. The blades of knives should first be wrapped in cotton to prevent scratching and dulling. After boiling, the instruments should be rinsed in hot sterile water or in a 5 per cent. solution of carbolic acid and be kept until needed in a pan of sterile water. The carbonate of sodium prevents rusting. In a clinic the boiling is carried out in a Schimmelbusch sterilizer (Fig. 19). In a private house it can be done in a sterilizer such as that shown in Fig. 20, or in a pan, a kettle, or a wash-boiler. A sterilizer with a tray is better than an ordinary pan or kettle, because, when the latter is used, the metal instruments lie in the bottom of the vessel, where the heat is very great, and the temper may be impaired. Boiling unfortunately destroys to some extent the keenness of cutting instruments, the ebullition throwing them about. Hence the knives should be wrapped in cotton to preserve the edges. After sterilization the instruments are placed in trays containing boiled water. After the completion of the operation the instruments should be scrubbed with soap and water, boiled in soda solution, and dried and placed in a closet with glass shelves so they will not gather dust. Instruments can be partially disinfected by keeping them for thirty minutes in a 5 per cent. solution of carbolic acid or in a 2 per cent. solution of formalin. Instruments with handles of wood must not be boiled. If such instruments are used, they can be disinfected by the use of carbolic acid, but they should not be used. Metal instruments, whenever possible, should consist of one smooth piece. Grooves and letters are objectionable, as dirt gathers in such depressions. Ivory handles cannot be boiled.

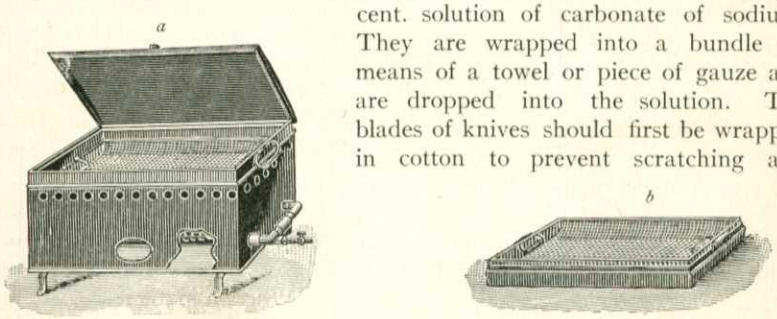

Fig. 19.—*a*, Schimmelbusch's gas-heated apparatus for sterilizing instruments; *b*, wire basket.

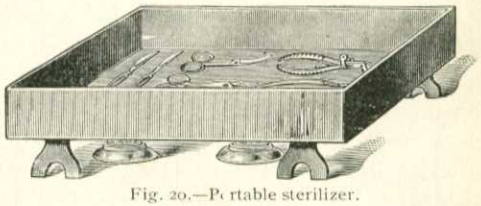

Fig. 20.—Portable sterilizer.

* A review of the literature of disinfection of the hands, by Martin B. Tinker and A. B. Craig, will be found in the Phila. Med. Journal, Feb. 15, 1902.

Preparation of the Patient.—Whenever possible, give the patient some days' rest in bed before a severe operation. During this preliminary rest study the disease, and study the individual in order to learn his tendencies, peculiarities, etc. The condition of the lungs, the heart, the blood, and the kidneys should be accurately determined. The amount of urine passed in twenty-four hours should be ascertained, and the percentage of urea should be estimated from a sample of the twenty-four hours' urine. The urine is carefully examined for sugar, albumin, casts, etc. By the above examinations we may be able to anticipate and provide against certain calamities: We may be led to postpone or abandon an operation, and we will be made able to intelligently select the proper anesthetic. Constipation must be amended by mild laxatives or enemas. The diet should be nutritious but not bulky. The night before the operation give a saline cathartic, and the morning of the operation employ an enema. Emptying the bowels lessens the danger of sepsis after operation. It is desirable that the rectum be empty, because in shock the absorbing power of the stomach is greatly diminished or is even abolished for the time, and we may wish to utilize the absorbing power of the rectum and give stimulants by enema. When a patient is under the influence of an anesthetic, or when he is profoundly shocked, of course no attempt is made to give stimulants by the mouth. Whenever possible, give a general warm bath the day before the operation. The evening before the operation shave the region if hairy, scrub the entire field of operation, as well as the adjoining regions, with ethereal soap and water; wash with ether or alcohol; scrub with hot corrosive sublimate solution (1 : 1000); apply a layer of moist corrosive sublimate gauze, and place over this dry antiseptic gauze, a rubber dam, and a bandage. Many surgeons apply a poultice of green soap for many hours before applying a chemical germicide, in order to separate masses of epithelium and with them many germs. This method is particularly useful in cleansing the scalp. On removing the dressings to perform the operation, scrub the part with soap and water, wash it with sterile water and then with alcohol, surround the field of operation with dry sterile sheets and towels and scrub the exposed area with a hot solution of corrosive sublimate (1 : 1000). Murphy prevents infection from the cutaneous surface by spreading a specially prepared rubber dam over the sterilized operation area. The dam is sterile and sticks to the skin. The incisions are made through the artificial skin of rubber and the dam is removed when the surgeon is ready to introduce the sutures. Thus infection of the wound with contaminated sweat is prevented, for, as Murphy says, this elastic covering is "in reality a non-secreting, sterile, artificial derma, for the period of operation" ("General Surgery," edited by John B. Murphy). The patient must be carefully protected from cold by wrapping him in blankets and often by having him wear specially prepared drawers with feet. After the completion of an operation and the application of the dressings the patient is returned to his room or the ward, care being taken to protect him from cold or draughts. In emergency cases disinfection can only be practised just previous to the operation. Disinfection in such cases can be thoroughly effected by scrubbing with soap and water and then using chlorinated lime and washing soda.

Disinfection of Mucous Membranes.—It is impossible to thoroughly

disinfect mucous membranes. We cannot scrub forcibly, and we must not use powerful antiseptics because they are irritant and also because they may be absorbed. The best that can be done in the vagina is to rub lightly, when possible, with a bit of moist absorbent cotton and irrigate with a solution of boric acid or with normal salt solution. Another method is to sponge the vagina with creolin and Johnston's ethereal soap (1 and 16) and irrigate with hot saline fluid or boracic acid.

The *rectum* is prepared by washing out all retained feces by the use of copious high injections and by irrigating with salt solution or boracic acid.

The *mouth* is prepared by having snags of teeth removed and decayed teeth plugged. For several days before the operation scrub the teeth twice a day with a brush and castile soap; and every three hours, when the patient is awake, rinse the mouth with peroxid of hydrogen and spray the nares and nasopharynx with boracic acid solution.

The *urethra* is prepared by the administration for several days of salol or urotropin and by frequent irrigation of the urethra and bladder with boracic acid solution or normal salt solution or a solution of permanganate of potash (1 : 6000).

Irrigation is often practised in septic wounds, but is not required in aseptic wounds. In a septic wound gentle irrigation with an antiseptic is advisable. It removes bacteria and toxins and antidotes retained toxins. It must never be forcible for fear it may disseminate infection. Among irrigating fluids we may mention corrosive sublimate, carbolic acid, peroxid of hydrogen, boric acid solution, and normal salt solution. Hot normal salt solution is the best agent with which to irrigate the peritoneal cavity, the pleural sac, the interior of joints, and the surface of the brain. This solution contains 0.6 per cent. of sodium chlorid.

Many surgeons employ Landerer's dry method in operating aseptically. No fluid is applied to the wound. As the wound is enlarged gauze sponges are packed in to arrest hemorrhage. On the completion of the operation the sponges are removed, any bleeding points are ligated, and the wound is often closed without drainage.

Ligatures and Sutures.—In using sutures always remember that they must be tied firmly, but never tightly. A tight suture will cut when the wound swells and will thus fail of its purpose; further, it produces an area of tissue necrosis, which is a point of least resistance in and about which, infection is prone to occur.

Catgut.—The favorite ligature material is catgut. Catgut undergoes absorption in the tissues. Years ago attempts were made by Scarpa, Crampton, and Physick to use absorbable ligatures. Sir Astley Cooper tried catgut. These attempts failed because the material employed was septic, suppuration ensued, the wound gaped, and the ligature was cast off prematurely. Surgeons remained content with non-absorbable ligatures of silk or linen. These ligatures were not cut short, but a long end was left to each one, and the ends were allowed to hang out of the wound. The ligatures were lightly pulled upon from time to time, and when they loosened or cut through were removed. Catgut is the submucous coat of the intestine of the sheep, and is the material from which violin strings are made. It was reintroduced into surgery by Lister. It is obtained in the following manner: The small intestine,

after separation from the mesentery, is washed in water, laid upon a board, and scraped with a metal instrument. Thus the mucous coat and the muscular coat are scraped away, and the submucous coat only remains. The submucous coat is cut into strips, and each strip is twisted into a coil. Raw catgut is an infected material. It is difficult to sterilize it, because in the twisting many organisms get into the interior of the strand, where it is difficult for antiseptics to reach them. Raw catgut obtained from animals dead of splenic fever contains spores of anthrax. If not thoroughly disinfected, catgut is dangerous, and some surgeons consider its cleanliness always a matter of grave question and will not use it. Surgeon's catgut can be bought from the dealer in skeins containing thirty yards. It should be rough and yellow. The smooth white variety should not be gotten. It has been rubbed smooth with a piece of glass and bleached with a chemical, and in consequence is weak and unreliable. The smallest size is known as double zero, then come single zero, No. 1, No. 2, No. 3, and No. 4. The usual ligature size is No. 2. Nos. 3 and 4 are only used for tying thick pedicles. Nos. 1 and 2 are used for suturing the dura and peritoneum, and for tying small vessels in the brain. McBurney and Collins state that when catgut is used to tie delicate tissue (omental masses, intestinal surfaces, etc.), it must first be softened by immersing for half a minute in normal salt solution. If this precaution is neglected and wiry catgut is used, the ligature or suture will cut and hemorrhage will occur.*

If catgut is thoroughly freed from bacteria, and the wound in which it is used is aseptic, it is a most satisfactory ligature material, is absorbed in the wound after being cut off short, and produces no trouble although it does increase slightly wound secretion. The smaller sizes are absorbed in four or five days, No. 2 lasts from nine to ten days, Nos. 3 and 4 from ten days to three weeks.

One of the following methods of preparation may be used: The catgut is soaked in ether for twenty-four hours to remove fat. It is then wound on glass spools, transferred to alcohol, and boiled under pressure. The boiling is conducted in a heavy metal jar with a well-fitting screw-top. The jar is half filled with alcohol. The spools of catgut are placed in the jar, the lids screwed down, and the apparatus is immersed in boiling water for half an hour. The gut is kept in this jar until needed. Fowler's catgut is prepared by boiling in alcohol. It is placed in hermetically sealed U-shaped glass tubes. Each tube contains alcohol and twelve ligatures. The alcohol is boiled *by immersing the tube in* boiling water. The cumol method is employed by Kelly in the Johns Hopkins Hospital, and is known as Krönig's method. Cumol is a fluid hydrocarbon which boils at 179° C. Catgut is wound upon spools of glass, and these are placed in a beaker glass, the bottom of which is covered with cotton. A bit of cardboard is placed on top of the beaker, and through a small perforation in the cardboard a thermometer is introduced. The beaker is placed in a sand-bath and the bath is heated by means of a Bunsen burner. The temperature is gradually raised to 80° C., and is kept at this point for one hour, in order entirely to remove moisture from the gut. Cumol, at a temperature of 100° C., is poured into the glass, and the heat is increased until the temperature of the cumol is a few degrees below its boiling-

* "International Text-Book of Surgery."

point (165° C.). For one hour this temperature is maintained. Then the cumol is poured off and the catgut is allowed to remain for a time in the sand-bath at a temperature of 100° C., in order to dry. It is transferred for keeping into sterile glass jars or test-tubes.*

The formalin method is advocated by the elder Senn. The catgut is wound on glass test-tubes, and is immersed in an aqueous solution of formalin (2–4 per cent.) for twenty-four to forty-eight hours. It is placed in running water for twelve hours to get rid of the formalin. It is boiled in water for fifteen minutes, is cut in pieces and tied in bundles, placed in a glass-stoppered jar, and is kept ready for use in the following mixture: 950 parts of absolute alcohol, 50 parts of glycerin, and 100 parts of pulverized iodoform. Every few days the mixture should be shaken.

Senn's process is a modification of Hoffmeister's. Even sterile catgut contains a toxic substance which increases wound secretion, has a poisonous effect on body-cells, and favors to some extent limited suppuration. Senn maintains that to counteract this influence gut should not only be sterile, but should be antiseptic, to inhibit the growth of pyogenic organisms which reach the wound from without during operation or subsequently by the blood.

Boeckman wraps catgut in paraffin paper, seals it in a paper envelope, puts it in the sterilizer, and subjects it to dry heat. For three hours it is heated to a temperature of 284° F., and for four hours to a temperature of 290° F. The envelope can be carried in the pocket or the instrument bag. When the gut is wanted the end of the envelope is torn off, an assistant with sterilized hands unwraps the paraffin paper, and the gut is dipped for a moment in sterile water to make it pliable.†

A method which has been largely used is to take raw catgut, keep it in ether for twenty-four hours, soak it for twenty-four hours in an alcoholic solution of corrosive sublimate (1 : 500), wind it on sterilized glass rods, and place it for keeping in ether or in alcohol.

Johnston's quick method of preparing catgut is as follows: Place it for twenty-four hours in ether; at the end of this period place it in a solution containing 20 grains of corrosive sublimate, 100 grains of tartaric acid, and 6 ounces of alcohol. The small gut is kept in this for ten or fifteen minutes, the larger gut from twenty to thirty minutes, but never longer. It is placed for keeping in a mixture containing 1 drop of chlorid of palladium to 8 ounces of alcohol. This gut is strong and reliable. At the time of operation the gut is placed in a solution one-third of which is 5 per cent. carbolic acid solution and two-thirds of which is alcohol.

Chromicized catgut is absorbed less rapidly by the tissues than ordinary catgut. It is used to tie thick pedicles and large arteries, to suture nerves and tendons, and as a suture material in the radical cure of hernia. Chromicized gut, No. 3 and No. 4, will remain unabsorbed in the tissues from four to six weeks. The gut should be soaked in ether for twenty-four hours, and placed for twenty-four hours in a 4 per cent. solution of chromic acid in water. The gut is then dried in a hot-air sterilizer and disinfected by one of the several methods. The cumol method is satisfactory.

*See McBurney and Collins, in "International Text-Book of Surgery," and Clark, in Johns Hopkins Hospital Bulletin, March, 1896.

†James E. Moore, in Phila. Med. Journal, June 22, 1898.

Catgut is tied in a reef knot (square knot) and distinct ends are left on cutting. The second knot, if pulled too tightly, may break the ligature. Moist catgut is slippery and is hard to tie. If a large vessel is tied by catgut, a third knot should be used and the ends cut close to the knot.

Kangaroo-tendon is obtained from the tail of the great kangaroo. This material is especially useful for buried sutures in hernia operations; it will be absorbed in the tissues, but only after a long time (sixty to seventy days). Kangaroo-tendon is not grossly infected as is catgut. The material is obtained from a recently killed animal and is promptly dried in the sun. This suture material was introduced by Dr. Henry O. Marcy. It can be prepared in the same manner as the chromicized catgut, and it ought always to be chromicized. Marcy's plan of preparation is as follows: Soak the dried tendon in a solution of corrosive sublimate (1 : 1000) and separate the individual strands. The individual strands will be of equal diameter and from 10 to 20 inches in length. The diameter depends on the size of the animal. Dry each strand in an antiseptic towel. Chromicize the tendons and keep them until needed in boiled linseed oil containing 5 per cent. of carbolic acid. Before using the strands take them out of the oil, wipe off the oil with a sterile towel, and immerse the tendon for half an hour in a 1 : 1000 solution of bichlorid of mercury. This immersion does not make them swell and soften and does not weaken them as it would catgut.

The following method of preparation is recommended by Charles Truax ("Mechanics of Surgery"): Soak the dried tendon until it becomes supple, in a 1 : 1000 solution of corrosive sublimate. Separate the material into individual tendons, place them lengthwise between two towels; dry them; make them aseptic by soaking in a solution of formalin, as we would do with catgut (see page 51). After washing out the formalin chromicize the tendon by placing it in a fresh 5 per cent. solution of carbolic acid containing 1 : 4000 parts of chromic acid. When the tendons become "dark golden brown" in color, they are removed from the chromic acid solution, dried between sterile towels, and placed for keeping in 10 per cent. carbolized oil. When wanted, they are removed from the oil, and wiped with a sterile towel saturated with bichlorid solution (1 : 1000). Kangaroo-tendon is tied in a reef knot.

Silk.—This material can be used for both ligatures and sutures; many sizes should be kept on hand. White silk may be used, or black silk, which is more easily visible. Silk is encapsuled in the tissues. It is not absorbed at all or only after a very long time. It is not a good material for buried sutures, as in the long run it may form a sinus. Sutures of silk should be boiled for half an hour before using, in a 1 per cent. solution of carbonate of sodium. Some surgeons keep the silk after boiling in sublimated alcohol (1 : 1000) or carbolic solution (5 per cent.), but it is better to prepare it just before using. A convenient method of preparation is to wind the silk on a glass spool, place the spool in a large test-tube, close the mouth of the tube with jewelers' cotton, introduce the tube into a steam sterilizer, and subject it to a pressure of ten pounds for twenty minutes, repeating the process the next day. These tubes are carried in wooden boxes sealed with rubber corks. Silk is very strong, soft, extremely supple, and does not swell or irritate. It can be tied into very firm knots. Ordinary surgical silk is a form of twisted silk—that is, several or many strands are twisted into one.

Cable twist or Tait's silk is very strong and is used for tying large pedicles. Braided silk is extremely strong and is made by plaiting together several strands of twisted silk. Floss silk is "a straight fiber slightly twisted" (Truax). Silk is usually tied in a reef knot, but occasionally in a surgeon's knot.

Horsehair.—This is used for effecting very neat approximation where only light sutures are required; for instance, in wounds of the face. Its chief use is for capillary drainage. It is prepared by washing and then boiling for fifteen minutes in a 4 per cent. solution of carbonate of sodium. It is kept until needed in sublimated alcohol (1 : 1000).

Silkworm-gut.—This material contains fewer bacteria than catgut and does not swell when introduced into a wound. It is strong, solid, smooth, non-irritating, and can be drawn through the tissues with slight force. The designation silkworm-gut is a misnomer; the material is not gut at all. It is obtained by killing the silkworm when it is just ready to spin the cocoon, and drawing out the fiber. It is a very valuable suture material, but is not used for ligatures. Silkworm-gut is prepared by placing it in ether for forty-eight hours and in a solution of corrosive sublimate (1 : 1000) for one hour, or it can be boiled in plain water for half an hour. It is carried in a long tube filled with alcohol. A few minutes before using the gut is placed in carbolic acid and alcohol (one-third of the solution is a 5 per cent. solution of acid, two-thirds of it is alcohol). Silkworm-gut is tied by the surgeon's knot.

Celluloid thread is warmly advocated by Pagenstecher. He calls it celluloid yarn, and prepares it from English gray linen thread. I have used it with much satisfaction. It is strong, smooth, flexible, and the knot holds firmly; it can be sterilized by any method used for raw silk, and sterilization by dry heat actually increases its strength. Its one disadvantage is that it absorbs about 40 per cent. of fluid, but does not soften. The celluloid is added after the thread has been boiled in a 1 per cent. solution of carbonate of soda wiped or wrapped in a sterile towel and dried in hot air or steam. It is then dipped in a solution of celluloid heated in a hot-air sterilizer, and packed in sterile boxes (Schlutius, in "Pacific Med. Journal," Jan., 1900; Keen and Rosenberger, in "Phila. Med. Journal," May 10, 1900). Celluloid thread can be used for sutures or ligatures.

Silver wire is prepared by boiling. It is a very useful suture material, as it can be thoroughly sterilized and has an inhibitory effect on the growth of bacteria. Some surgeons use it for buried sutures, but many are opposed to using it thus on the ground that it is apt to lead to sinus-formation.

Most wounds are closed by interrupted sutures of silkworm-gut, but silk, catgut, chromic catgut, or silver wire can be used. The old continuous suture (glovers' stitch) is rarely used. An admirable closure can be effected by Halsted's subcuticular stitch, and scarcely any scar results. Marcy's buried tendon sutures are very valuable, especially in hernia operations and in various operations upon the abdomen.

Dressings are made of cheese-cloth. In order to make *antiseptic gauze* the cheese-cloth is boiled in a solution of carbonate of sodium, rinsed out, and dried; it is then soaked for twenty-four hours in a solution containing 1 part of corrosive sublimate, 2 parts of table salt, and 500 parts of water. It is placed in clean jars with glass lids, and it may be kept moist or dry.

Sterilized or aseptic gauze is prepared by boiling in carbonate of sodium, etc., as described under Antiseptic Gauze. It is wrapped in a towel and is placed in a steam sterilizer for an hour (Fig. 21). It is kept in sterile glass jars with glass lids. The pads for sponging are made by rolling up portions of sterile gauze. Ashton's abdominal pads are made by taking several layers

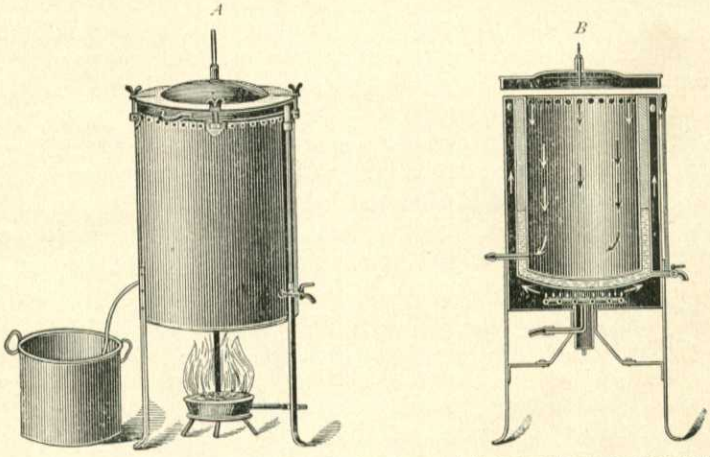

Fig. 21.—Lautenschläger's steam sterilizer for dressings: *A*, Exterior view; *B*, cross-section.

of sterile gauze, each piece about six inches long and four inches wide, running a stitch around the margin, and sewing a piece of tape into one corner.

Sterile absorbent cotton is prepared in the same manner as gauze. Cotton is useful as a dressing to supplement gauze, being placed on the outside of the gauze. It absorbs quantities of serum, but will take up very little pus.

Iodoform gauze is very useful for packing in the brain and abdomen, for packing abscesses and tuberculous areas, and for dressing foul wounds. It is prepared as follows: Make an emulsion composed of equal parts by weight of iodoform, glycerin, and alcohol, and add corrosive sublimate in the proportion of 1 part to 1000 of the mixture. This mixture stands for three days. Take moist bichlorid gauze, saturate it with the emulsion, let it drip for a time, and keep it in sterilized and covered glass jars (Johnston).

Lister's *cyanid gauze* (double cyanid of zinc and mercury) is not certainly antiseptic, and must be dipped into a corrosive sublimate solution (1 : 2000) before using. All forms of gauze can be bought ready prepared from reliable firms.

Some surgeons place *silver foil* upon a wound before applying the gauze (Halsted, page 29). Small wounds in which drainage is not employed may often be dressed by laying a film of aseptic absorbent cotton over the wound and applying, by means of a clean camel's-hair brush, *iodoform collodion* (grs. xlviij of iodoform to ℥j of collodion). Among other materials sometimes used for dressing wounds the following should be mentioned: Wood wool, absorbent wool, moose pappe, oakum, jute, peat, and sawdust.

Protectives.—A protective is a material placed directly upon wounds to shield them from irritation and infection and outside of dressings to diffuse and prevent the escape of discharge. The commonly used protectives are Lister's

oil silk protective, gutta-percha tissue, rubber dam, waxed paper, paraffin paper, mackintosh, and silver foil. Undoubtedly, many antiseptic agents destroy young cells and in this way hinder repair. The same is true of certain rough dressings.

R. T. Morris maintains that gauze and particularly cotton are injurious to a healing wound. A non-irritant protective laid directly upon a wound may be useful.

Among the best protectives in common use are Lister's protective, gutta-percha tissue, and silver foil. Morris condemns gutta-percha tissue as irritant. He uses thin gold-beaters' skin made from the peritoneum of the ox, which material he calls Cargile membrane, after an Arkansas physician who introduced it into practice. The advantage of this material is that moisture cannot penetrate and new cells do not adhere.

Silver foil, Lister's protective, and gutta-percha tissue are laid directly upon a wound, the dressing being placed above it. Silver foil comes in books and is sterilized by dry heat. Gutta-percha tissue is sterilized by washing with soap and water, rinsing in sterile water, and soaking in a solution of corrosive sublimate. Lister's protective is employed to save the wound from the irritation of carbolized dressings. In the United States, if it is desired to place an impermeable material over a dressing, a rubber dam is usually employed. A rubber dam before being used should be washed with soap and water and soaked in a solution of corrosive sublimate.

The use of a protective over a dressing is not nearly so common as formerly. In an aseptic wound dry dressing uncovered by rubber is the most useful. When a dressing is covered by an impermeable material it becomes wet, acts as a poultice, and the discharges on the dressings may undergo decomposition.

Drainage.—Drainage is obtained, when needed, by rubber or glass tubes, by strands of horsehair, silkworm-gut, or catgut, or by pieces of gauze. Rubber drainage-tubes (Fig. 22, *B*) are prepared by boiling in plain water. They are kept until wanted in a mercurial solution. This solution should be changed every few days, because the mercury is apt to be precipitated as sulphid. Glass tubes are prepared by boiling. A bit of rubber tissue is sometimes used for drainage. Gauze, catgut, etc., are known as capillary drains. When moist they drain serum excellently, but pus very badly or not at all. Drainage-tubes or strands are brought out at a portion of the wound which will be dependent when the patient is recumbent. Drainage is used in all infected wounds, in most very large wounds, in wounds to which irritant antiseptics have been applied, in cases in which large abnormal cavities exist in very fat people, and in individuals with such thin skin that we dare not apply firm pressure.

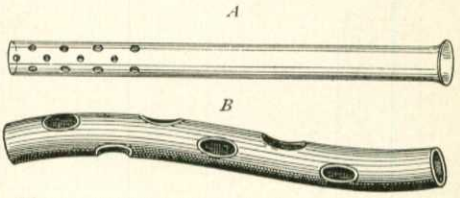

Fig. 22.—Drainage-tubes; *A*, Glass; *B*, Rubber.

Change of Dressing.—Dressings must be changed as soon as soaking is apparent, or if constitutional symptoms of wound infection arise, and the change must be effected with all of the aseptic care employed in the operation.

Removal of Stitches.—Stitches may usually come out from the sixth to the eighth day, although if there is much tension on the edges of the wound they are allowed to remain several days longer. In large wounds, half of the stitches are taken out at one time, the remainder being allowed to remain for a couple of days longer. When a stitch begins to cut, it is doing no good, and it should be removed, no matter how short a time it has been in place. If it is allowed to remain, it will cut into the wound, make a stitch-abscess, and cause an irregular suture-line.

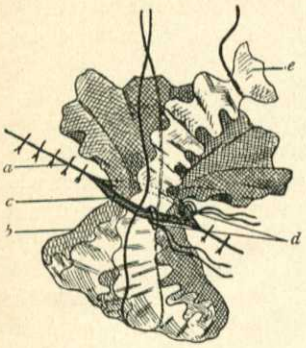

Fig. 23.—Mikulicz's bag; *a*, Abdominal sutures; *b*, gauze bag; *c*, abdominal wound; *d*, loops in the abdominal wall; *e*, gauze strip.

Artificial Sponges.—Bits of gauze should be used, each piece being thrown away as soon as it is soaked with blood or tissue fluid. Gauze pads can be used, soaking them in an antiseptic solution and squeezing them from time to time during an operation.

Preparation of Marine Sponges.—Marine sponges are rarely used. Gauze pads are preferred. Marine sponges absorb admirably, but they are hard to clean when new and cannot be certainly sterilized in their interiors after becoming infected. They may be prepared as follows: Beat out the dust; place them for forty-eight hours in a solution of hydrochloric acid (15 per cent.); wash them with water; place them for one hour in a solution of permanganate of potassium (℥ij to 5 pints of water); soak for four hours in a solution containing 10 ounces of hyposulphite of sodium, 5 ounces of hydrochloric acid, and 3 pints of water; wash with running water for six hours. Keep the sponges in a jar containing corrosive sublimate solution (1 : 1000). After using, wash in hot water, soak for half an hour in a solution of sodium carbonate (1 : 32), wash again in hot water, and replace in corrosive sublimate.

Senn's Decalcified Bone-chips.—Take the shaft of the tibia or femur of a recently killed ox, saw it into portions two inches in length, remove the marrow and periosteum, and place the fragments of bone in a 15 per cent. solution of hydrochloric acid. Change the solution every twenty-four hours. In from two to four weeks the bone will be decalcified. Wash in distilled water, place the pieces of decalcified bone for a few minutes in a dilute solution of potash to neutralize the acid, and then immerse for twenty-four hours in distilled water. The portions of bone are cut into strips in the direction of the long axis of the segments. Each strip is three-quarters of an inch wide and should be sliced into bits one millimeter thick. These chips are kept in an alcoholic solution of corrosive sublimate (1 : 500).

Bandages.—For retaining dressings upon wounds the muslin bandage may be used, but in most cases the gauze bandage is employed. The gauze bandage soaked in corrosive sublimate solution is antiseptic; it does not partly seal the dressing and act like protective; it can be applied firmly, evenly, and rapidly, and is very comfortable.