THE DELAYED CLOSURE OF CONTAMINATED WOUNDS *

A PRELIMINARY REPORT

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THE CLOSURE of wounds is a technical procedure common to most surgical operations. The ideal toward which surgeons have striven is immediate closure of wounds, to be followed by uninterrupted healing. The primary closure of clean wounds is usually successful no matter what methods are employed, but perfection has not yet been reached since infection and dehiscence still occur in a small percentage of wounds thus closed, no matter what technical measures have been employed.

Many studies have been and are being made on the factors that influence wound healing. Suture material, the nutrition of the patient, allergic reactions, air-borne infection, and operative methods have all been shown to play a part in causing the occasional catastrophe to wound healing, and proper observance of the facts brought out by these studies has further diminished the untoward results.

All wounds probably are contaminated to some degree, due to exposure to the air and to the impossibility of sterilizing the skin; yet, due to the remarkable protective power of most tissues, relatively few so-called clean operative wounds become infected. When infection does take place, it is generally assumed that there has been an error in technic or that an unusual relationship exists between the bacteria and the tissue.

Not infrequently, an otherwise clean wound may become contaminated during the course of the operation because of conditions met in the tissues at the site of the operation. If frank sepsis is encountered and drainage is indicated, the wound will necessarily become infected along the course of the drain. Occasionally a focus of infection such as the interior of the colon may be encountered during operation, in which case drainage is not indicated, and although it is desirable that the wound in the abdominal wall heal without interruption, infection may develop in it to the detriment of the patient. The handling of wounds thus contaminated is still capable of improvement. A method we have used in handling such wounds recently has been helpful to us and will be described.

Infected wounds have always occurred in the human race. The susceptibility of vertebrates to infection increases as one passes up the evolutionary

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scale. This diminution of resistance to infection in the higher vertebrates is paralleled by a progressive loss of the ability to repair tissue damage as compared with the remarkable ability in the lower forms of animal life to regenerate whole limbs and organs.[1]

The closure of frankly contaminated wounds such as those associated with open approaches to the gastro-intestinal tract, especially in its lower portions, such as colostomies, cecostomies, and inadvertent openings into the colon and rectum, has never been entirely satisfactory. Although many successful primary closures of such contaminated wounds have been carried out, the incidence of infection in them has always been high, carrying with it a prolonged convalescence and a higher mortality. Examination of our own records showed about a 50 per cent occurrence of serious wound infection in the wounds contaminated through some contact with the interior of the lower gastro-intestinal tract.

It has been customary in such cases to place a drain in the wound to provide a route of exit for the exudate of infection to pass when contamination passed to infection. Occasionally the drain, thus placed, was effective; more often the infection became so extensive as to necessitate the removal of all sutures and eventually necessitate secondary closure when the infection had abated.

In 1917, the French surgeons[2] developed a method of treating potentially contaminated war wounds, called delayed primary closure. It was applied to all wounds in soft tissue, 15 hours or more old, except those of the scalp, face and hands. The method consisted of the usual careful cleansing of skin and deeper aspects of the wounds; wide débridement; culture of the wound; constant flooding of the wound with Dakin's solution or other antiseptic; and wide packing of the wound with flavine gauze. The patient was then sent to the Base Hospital, marked for delayed primary closure. Within 24 to 48 hours, the bacterial flora of the wound was known, and if streptococci were not present, and if there were less than five colonies per plate, the pack was removed and the wound closed under anesthesia. The method had many advantages in that the Field Hospitals and Dressing Stations were emptied rapidly. The first cultures were available early and infections by the streptococci, which carried the highest morbidity and mortality, could be sorted out and treated more adequately. Finally, the surgeon who closed the wound was able to follow it personally. Fraser,[3] in 1918, reported an incidence of 9.7 per cent failure in 41 cases of primary closure as compared with 4.5 per cent failure in 63 cases of delayed primary closure. He also reported 31 bacteriologically negative wounds from 35 contaminated wounds after 48 hours' treatment by delayed primary closure, employing a flavine pack in the wound. In 1918, delayed primary closure of all soft-tissue wounds, excepting those in the scalp, face and hands, was advised by the surgeons of the American Expeditionary Force.[4] The best results were obtained when the wounds were closed within 50 hours.

The differentiation between delayed primary closure and secondary closure is usually interpreted as one of tissue repair rather than that of time. Pool[5] defines delayed primary closure as the approximation of wound edges without excision, while secondary suture is taken to mean that the epidermis has grown inward over the granulations and must be excised and lifted before good approximation and union can be obtained. In late secondary closure, granulation tissue must also be excised.

During the past few months, a method of delayed closure of frankly contaminated wounds has been carried out that has given fewer infections and a much higher incidence of uninterrupted healing than was secured by the primary closure of such wounds with or without drainage. Its employment has been largely confined to wounds contaminated during operation upon the lower bowel. The method is not in any sense unique, since surgeons have, from time immemorial, packed wounds with various substances with the expectance of closing them later, and it has been a common practice to pack wounds contaminated during appendicectomy without even applying sutures.

This method was first employed by us on a patient with a carcinoma of the sigmoid colon. Previous to his entrance to the University Hospital, he had developed acute intestinal obstruction and an operation had been performed to relieve this obstruction. The cecum had been delivered through a right rectus incision and he still presented most of the cecum in this wound when first seen by us. The original incision was badly placed for resection of the lesion in the sigmoid, so an incision was made through the left rectus muscle and the lesion resected and an end-to-end anastomosis made. There was, unfortunately, some contamination of the field during this procedure. The peritoneum was closed with double No. 000 plain catgut and the fascia closed with interrupted sutures of a No. 30 stainless steel wire. It was certain that the wound was contaminated both from proximity to the cecostomy and because of misfortune during the anastomosis. It was decided to pack the subcutaneous tissue with flavine gauze, but to place fine silk sutures to be tied later since it seemed inevitable that infection would occur. Cultures were taken which showed the usual intestinal flora. The next day the pack was removed, cultures again taken, a biopsy secured from the wound and the sutures tied, thus securing approximation of the wound. The wound healed without event. Later the cecum was closed, returned to the abdomen, and the wound associated with this approximated in a similar manner, again with a good result.

Since then we have employed this method of wound closure, under similar circumstances, upon 21 patients, the details of which are shown in Table I. As can be seen, we have secured uninterrupted healing without infection in all except one instance, in which a small abscess containing about 1 cc. of pus appeared in the wound; this cleared up rapidly following evacuation of the exudate.

In all cases, the wound has been closed as described, namely, with con-

TABLE I

TWENTY-ONE CASES OF DELAYED CLOSURE OF CONTAMINATED WOUNDS

No.	Name	Diagnosis	Operation	Healing
1	A. T.	P.O. carcinoma of sigmoid	Closure of colostomy	No infection
2	J. M.	P.O. carcinoma of sigmoid	Closure of cecostomy	No infection
3	J. M.	Carcinoma of sigmoid	Obstructive resection	No infection
4	A. L.	Carcinoma of sigmoid	Obstructive resection	No infection
5	A. L.	P.O. carcinoma of sigmoid	Closure of colostomy	No infection
6	E. H.	Carcinoma of sigmoid	Obstructive resection	No infection
7	A. H.	Perf. diverticulum	Obstructive resection	Minor infection
8	A. H.	P.O. diverticulum	Closure of colostomy	No infection
9	R. C.	P.O. carcinoma of rectum	Revision of colostomy	No infection
10	A. M.	P.O. carcinoma of rectum	Bilateral herniorrhaphy	No infection
11	L. W.	Ulcerative colitis	Right colectomy	No infection
12	B. W.	P.O. regional ileitis	Closure of colostomy	No infection
13	E. K.	Fecal incontinence	Closure of colostomy	No infection
14	W. K.	Perforated appendix	Appendicectomy	No infection
15	L. L.	Regional ileitis	Exclusion of ileum	No infection
16	W. G.	Biliary fistula	Closure of fistula	No infection
17	I. D.	Fecal fistula	Closure of fistula	No infection
18	M. M.	Ulcerative colitis	Left colectomy	No infection
19	T. G.	Carcinoma of rectum with perforation	Combined abdominoperineal resection	No infection
20	J. S.	P.O. perforated appendix	Excision sinus	No infection
21	M. H.	P.O. carcinoma splenic flex.	Closure of colostomy	No infection

tinuous sutures of fine catgut in the peritoneum and interrupted sutures of stainless steel wire in the fascia. Various ways of applying the silk sutures to the skin and subcutaneous tissue have been tried but the near-far, figure-of-eight method has been found to be the most satisfactory. The flavine pack need be only large enough to cover the denuded areas and is best applied in two portions, one from each end, to meet in the middle, because they are removed more easily than one long pack. The method is shown in Figures 1 and 2.

The patients complain of very little discomfort at the time of the removal of the pack and the approximation of the wound when tying the sutures. When the pack is removed, it has been a uniform observation that the wounds appear dry and there is a certain stickiness to the surfaces that aids the closure. Microscopic study of sections of the wound edges, at 24 hours, shows an exudate which consists of fibrin, in the meshes of which are polymorphonuclear leukocytes, wandering cells, some necrotic tissue and many young fibroblasts. Several wounds have been left for 48 hours before removal of the pack, and sections of the wound at this time show more fibrin, many more leukocytes and a definite increase in the number of fibroblasts. The characteristic reaction seen in the margins of the wound is shown in the photomicrographs in Figures 3 and 4.

Howes, Sooy and Harvey[6] have described a "lag-period" in wound healing, during which time the wound has little if any tensile strength. This period lasts from four to five days and corresponds to the stage of exudative reaction

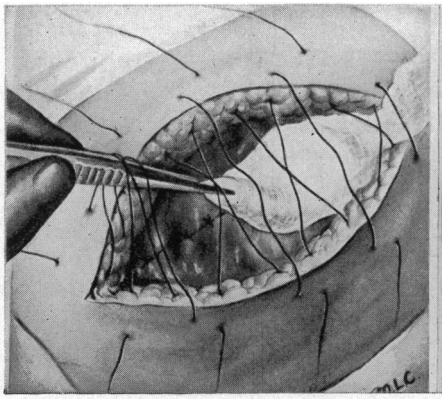


FIG. 1.—Acriflavine pack being placed in wound.

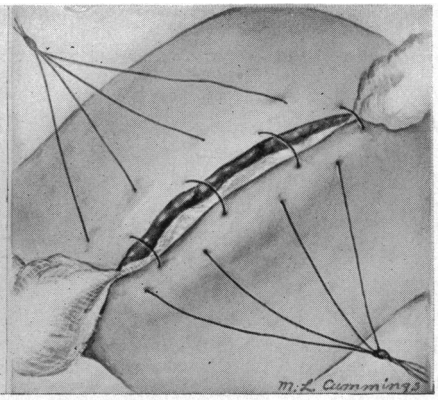
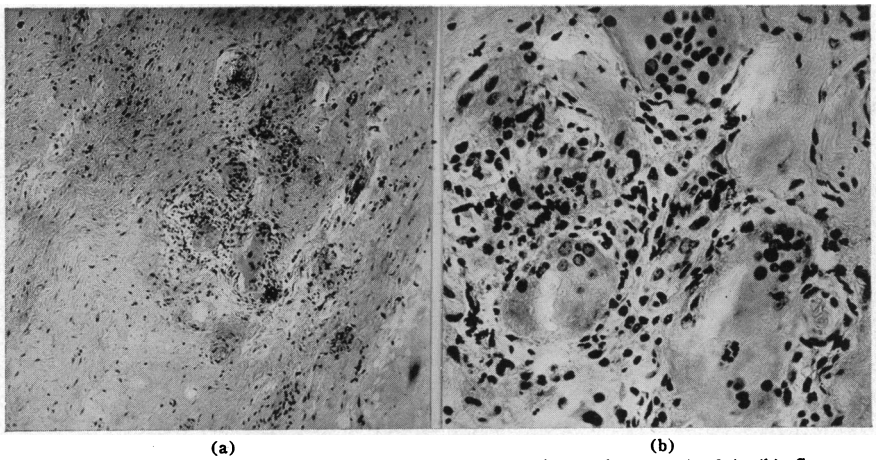
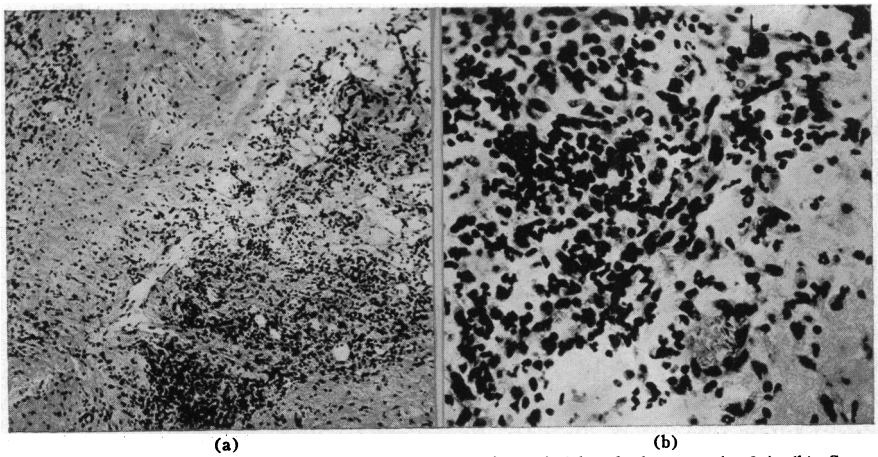


FIG. 2.—Acriflavine pack in place.



(a) (b)

FIG. 3.—(a): Biopsy of wound 24 hrs. p. o. at time of delayed closure. (×185) (b) Same as above. (×750)



(a) (b)

FIG. 4.—(a): Biopsy of wound surface 48 hrs. p. o. at time of delayed closure. (×185) (b) Same as above. (×750)

in wound healing. The critical time for the wound, as far as infection is concerned must occur during the exudative reaction before fibroplasia begins. DuMortier[7] smeared *Staphylococcus aureus haemolyticus* over the suture line of guinea-pig wounds at various time intervals postoperatively, and found that, up to six hours, postoperatively, the wounds were infected in 100 per cent of the cases with many virulent widespread infections of the entire abdominal wall. Twenty-four hours postoperatively, 66 per cent of the wounds were infected; 48 hours postoperatively, 56 per cent infections; four days postoperatively, 10 per cent infections; six days postoperatively, no wound infections; after six hours postoperatively, all wound infections were local and without systemic reactions. It has been suggested that after coagulation of the fibrin occurs, the resistance of the wound is greatly increased because of the accompanying sealing off of the capillary and lymph spaces, tending to keep infection localized or below the clinical horizon. Delayed closure of contaminated wounds, such as described, must, in a similar way, carry the wound through this critical period, probably by aiding coagulation of the fibrin so that when the wound surfaces are brought together a more unfavorable environment is present for the bacteria in the wound.

No additional benefit has been noticed from leaving the pack in the wound for two days; and at present we are removing the pack and tying the sutures 24 hours after operation. Cultures have been taken from the wound at the termination of the operation in ten cases, all of which showed dominantly *B. coli* with fewer *Staphylococcus aureus* and *Streptococcus anhaemolyticus*. Cultures were also taken on the same wounds at the expiration of 24 hours, and these were still positive with the same bacterial characteristics. Consequently, the packing of the wound apparently has no bactericidal effect, although we cannot state that it may not have a bacteriostatic one.

Since the peritoneum and the fascia have been contaminated to the same degree as the skin and subcutaneous tissue and these layers have not shown infection in spite of being closed by sutures, one might assume that they have a higher degree of resistance to infection than has the subcutaneous tissue. This observation and clinical experience suggest that infection in wounds of the abdominal wall frequently begin in the subcutaneous tissue and spread to deeper layers from this plane. The low resistance of fat to infection is well known. It is known that from eight to twelve hours usually elapse before infection supervenes in a contaminated wound, and it is possible that the irritation of the gauze produces an early inflammatory reaction in the subcutaneous tissue that is protective and that inhibits the transition from contamination to infection.

Experimental work to determine this point is under way. We have neither tried the administration of sulfanilamide to these patients, although it may well be useful in those wounds contaminated by the *Streptococcus haemolyticus*, nor have we tried the local use of antiseptics, including washing with soap and water, as suggested by Jackson;[8] therefore, we cannot contrast these

methods with the one described. It is obvious that contamination by certain virulent organisms, or by the common organisms, in patients with lowered resistance may give rise to serious infections if contamination occurs. Judging from this limited experience, we believe that delayed closure of wounds of the abdominal wall may be helpful in the occasional case where contamination has occurred either because of the nature of the surgical problem or because of accidents in technic.

SUMMARY

A method of delayed closure of contaminated wounds has been described with a report of 21 consecutive successful wound closures without serious infection.

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DISCUSSION.—DR. DERYL HART (Durham, N. C.): I will restrict my discussion to the paper of Doctor Walters. First, I want to emphasize that we do not consider contaminated air as the only source of wound infections. It assumes a position of major importance only after other sources such as supplies, instruments, and skin have been eliminated or reduced to the minimum. In our own operating rooms we believe that the air contaminated with pathogenic bacteria given off from the respiratory passages of human beings was the greatest source of danger to the open wound until steps were taken to remedy this condition. Since this hazard has to a large extent been removed, we have had a most striking improvement in our results, as indicated not only by reducing the infection rate in clean primary incisions from 4 per cent to less than 1 per cent, but there has been no serious infection in such wounds, and the patients whose wounds did not show signs of suppuration have had much less local and systemic reaction. The postoperative temperature elevations have been lower and of shorter duration.

There are wide variations in the number and type of organisms found in the air, corresponding to similar changes in the nose and throat flora of the occupants of a given area. We rarely have many carriers of the hemolytic streptococcus, but the respiratory tract carriers of the *Staphylococcus aureus* have varied from 15 to 80 per cent of the general population. On the basis of cultures of the air made in other operating rooms over the country we feel that this distribution of staphylococci must be widespread. Our wound infections were caused almost entirely by the hemolytic yellow staphylococcus, a streptococcal operating room infection being almost unknown. This

might be contrasted with the report of Walker from a teaching hospital in Boston where, during an epidemic of streptococcal sore throats, approximately 10 per cent of their operative wounds became infected with the hemolytic streptococcus.

During the first six years of the Duke Hospital, before instituting bactericidal radiation in the operating rooms there was a total of 15,557 operations. During this time there were at least seven deaths from infections in clean incisions on the general and neurosurgical services alone: three extrapleural thoracoplasties, primary stage; one extrapleural thoracoplasty, secondary stage; two craniotomies; and one radical mastectomy, all caused by the hemolytic *Staphylococcus aureus*. During the next three years, 10½ months, or up to December 1, 1939, out of a total of 23,213 operations, 1,062 clean, primary operations and 105 clean secondary operations (reopened wounds), on the general, orthopedic, and neurologic surgical services, were performed in a field of bactericidal radiation. Even though most of the larger operative procedures such as thoracoplasties, arthroplasties, bone grafts, laminectomies, craniotomies, ventral herniorrhaphies, *etc.*, were included in these groups, not one of these patients died as a result of, or had his life seriously threatened by, an infection in the wound. During this same period one patient having a craniotomy and decompression performed for an inoperable left cerebral glioma, when bactericidal radiation was not available, died of meningitis caused by the hemolytic *Staphylococcus aureus*.

During the 12 months from November 1, 1938, to November 1, 1939, there were over 600 clean, primary incisions made in a field of bactericidal radiation with only one postoperative wound infection of sufficient note to be diagnosed at the time of the patient's discharge from the hospital. This occurred in a patient having a laminectomy immediately following injury, the operation being performed through skin which showed superficial abrasions, and deeper tissues which were contused and infiltrated with blood. In spite of such a condition of the skin, this infection was thought to be hematogenous since it came on nine days after the operation, and five days after a postoperative pneumonia with an associated septicemia, pyelitis, and cystitis, all caused by the hemolytic *Staphylococcus aureus*. On careful review of each of these records there were five other mild, or questionable, wound infections as follows:

(1) Herniorrhaphy—stitch abscess. Maximum temperature 99.5° F.
(2) Craniotomy—stitch abscess.
(3) Open reduction old fracture dislocation of ankle, lengthening tendon of Achilles. Skin necrosis. Infection limited to denuded and exposed area; joint not involved.
(4) Arthroplasty hip—vitallium cup inserted; and superficial drains—postoperative hemorrhage. Infection limited to drainage tract, joint not involved—apparently retrograde infection from skin.
(5) Thoracoplasty; extrapleural—hematoma in incision; drained. Considered not infected by those who dressed it, but a positive growth of *Staphylococcus aureus* was obtained from the draining blood clot. Second stage performed 29 days after first stage.

We feel that by greatly reducing the number of viable pathogenic bacteria in the air about the wound and sterile supplies, we have reduced our postoperative wound infections by over 75 per cent and greatly diminished their severity, at the same time improving wound healing following most of our larger operations.

In regard to the work of Devenish and Miles, it is my opinion that they were dealing with a special condition. Cultures of the skin of one surgeon consistently showed a heavier contamination with a more pathogenic strain of yellow staphylococci than similar cultures taken from the skin of another surgeon and other members of the operating teams. With many punctured gloves, naturally, the surgeon with the more highly contaminated skin had the greater percentage of infected wounds since the hands cannot be completely freed of organisms. When the skin of a patient or his surgeon is known to harbor more virulent yellow staphylococci as indicated by recurring boils, operations of election should be postponed until such a condition can be eliminated.

Whether or not one considers the air to be an important medium for transporting pathogenic bacteria to operative wounds and whether or not one undertakes to remedy the condition, one must not neglect other sources of contamination and must maintain a surgical technic which leaves his wounds in the best condition for the body defenses to handle the bacteria which gain access. Regardless of how aseptic conscious we may be and what measures we may employ, we have not yet attained such ideal conditions that we can operate with assurance that no pathogenic organisms will reach the wound. Fortunately the wound that is in the best condition to handle the bacterial contaminants is also in the most ideal condition for healing.

DR. ROY D. MCCLURE (Detroit, Mich.): I would like to ask Doctor Coller whether or not he made anaerobic cultures in these wounds. Dr. W. A. Altemeier,* of our staff, has been taking both aerobic and anaerobic cultures from cases of peritonitis and wound infection secondary to appendicitis or intestinal surgery. Mixed cultures containing as many as five to seven different species of bacteria were usually obtained by him. The anaerobic organism frequently predominated. He has found the virulence of these bacteria in pure culture to be very low for laboratory animals. Collectively, however, three or more strains have a high degree of synergitic pathogenic action, producing large areas of cellulitis and gangrene when injected subcutaneously.

The treatment of such wounds with zinc peroxide, as advocated by Meleney, has been very successful in our hands, when combined with adequate drainage. Perhaps part of Doctor Coller's success was due to the inhibitory effect of the air upon growth of anaerobic organisms.

DR. HUGH A. GAMBLE (Greenville, Miss.): I have been interested in the work of Miles and Meleney ever since their early reports. Their work certainly merits most careful consideration.

There is one feature in regard to infection of wounds which has not been brought out in the discussion this morning, and that is the prominent part played by droplet infection from talking over wounds during an operation.

Some two years ago, a Vienna surgeon reported a series of 1,000 clean operations without a single infection. He laid stress upon the fact that he felt that most infections of clean wounds were due to inadequate masking and unnecessary conversation over the patient. He instituted, in addition to thorough masking, a non-talking technic applicable to everyone in the operating room, using sign language only, and allowing no conversation. To this change he gave full credit for his excellent results.

Shortly after reading this article we instituted a similar regimen in our services. In the period of time since then, my brother and I have performed

* Altemeier, W. A.: The Bacterial Flora of Acute Perforated Appendicitis with Peritonitis: A Bacteriologic Study Based upon 100 Cases. ANNALS OF SURGERY, 107, 517–528. April, 1938.

approximately 3,000 clean operations and have had three wound infections in that number. We are convinced that elimination of talking has played a major rôle in the reduction of infections of this character. It is a technic easily learned and consists simply of the use of sign language for instruments, sponges, linen, *etc.*

Referring to Doctor Coller's paper upon the method of treatment of wounds, we have advocated a similar procedure both in season and out of season during the last 16 years. First, in 1924, I read a paper before the Mississippi State Medical Association advocating the leaving open of such wounds and also those more virulently infected than the ones Doctor Coller has shown. In potentially infected abdominal wounds, particularly those associated with peritonitis, intra-abdominal abscesses, intestinal obstruction, gangrenous appendices, you are sure to have infections, principally with anaerobic organisms. In the closed wound these infections find an ideal incubator and culture medium and spread in the fascial planes and between the skin and fascia with, at times, most astonishing rapidity and catastrophic results.

Before adopting the open treatment of the potentially infected wound I have seen a number of infections of this character, and reported before the Southern Surgical Association 12 cases of fulminating gangrene of the abdominal wall occurring in the closed or partially closed, potentially infected wounds. Leaving the wound open allows air, which is a specific for this type of infection, to reach all portions of it, and provides for free drainage. Since adopting this plan of treatment for the potentially infected wound, we have had no cases of spreading infection of the abdominal wall.

In the type of case which Doctor Coller reports we feel that he is right in closing it secondarily, but in the type of wound acutely infected with virulent anaerobic organisms, closing the wound after removing the pack is inviting trouble.

As to the manner in which the pack acts in its effect upon the wound it is our opinion that it has: (1) A bactericidal effect; (2) it causes a reversal of the flow of lymph; and (3) it limits the spread of infection by the formation of a barrier of inflammatory tissue.

We are definitely of the opinion that the mortality rate in acute intra-abdominal catastrophes such as ruptured appendices, gangrenous cholecystitis, suppurative peritonitis and intestinal obstruction, *etc.*, is more often due to anaerobic infection of the soft tissues of the abdominal wall and complicating sequelae than to any intra-abdominal pathology. Since adopting the open treatment of abdominal wounds in such lesions, our mortality rate has been lowered to such an extent that we have largely lost the dread of these conditions.

In a recent review of the cases of generalized diffuse peritonitis secondary to appendicitis, 158 in number, treated, since 1924, by leaving the wounds open, our mortality rate has been under 2 per cent.

DR. FRANK K. BOLAND (Atlanta, Ga.): I would like to ask Doctor Elkin whether he has ever made cultures of the catgut used in hospitals. We sterilize everything else, but accept catgut as being sterile. Did he ever estimate the difference in cost between silk and catgut? Silk is much cheaper, which is an important item, especially in a large city hospital.

DR. FREDERIC W. BANCROFT (New York, N. Y.): I think there is another source of contamination of wounds that has not been mentioned. Dr. Kingsley Roberts, on my staff, a number of years ago took cultures of the

peritoneal cavity in presumably clean cases. He would take the peritoneal strip up very gently, cauterize it and put in a small applicator and take a culture. These were presumably clean wounds, but he had a 72 per cent culture growth. It is my impression that nothing is sterile. It is true that 60 per cent of these were nonpathogenic organisms. We must, therefore, consider that contamination may be present, and use gentleness and care as well as all the protective measures we know. These were cases of noninfected, clean celiotomies, such as hysterectomies for fibroids, chronic appendices, *etc.*

DR. WM. H. PRIOLEAU (Charleston, S. C.): I would like to cite briefly my experience with suture material in thyroid operations. For some years I used fine, plain catgut. In a majority of the cases there was a discharge of serum from the wound. Because of this objectionable feature I changed to the use of fine, black silk. With it the healing was far superior, there being much less induration, and only, occasionally, the drainage of serum. However, in one instance of a severe wound infection, there resulted the extrusion of silk knots over a period of months. This forcibly brought to my attention that the satisfactory use of silk was based upon certain conditions over which I did not have absolute control—such as the operating room technic of rotating internes, some with no previous experience, and student nurses being coached by supervising nurses during the progress of the operation. I next tried fine (No. 00–000) chromic catgut, which I have been using with satisfaction for several years. It fills a midposition between silk and plain catgut. There is a moderate amount of wound induration, but only seldom the discharge of serum. In one case there was the extrusion of a few knots. In case of infection, it gives no particular trouble. It is to be avoided subcutaneously as it sometimes forms small nodules, or sterile abscesses.

I have found great satisfaction in the use of fine alloy steel wire in the repair of herniae, and the closure of celiotomy incisions, particularly in the presence of infection. In the presence of wound infection, it is preferable to silk in that the wire does not become extruded, nor does it act as a focus for sinus formation.

DR. W. A. BRYAN (Nashville, Tenn.): It seems that everybody here agrees that we cannot get rid of bacteria. I think everybody understands that. All we can do is reduce them to as safe a minimum as possible. Doctor Elkins, I think, said that the resident who had 82 cases in the hospital at Atlanta must have done something. I am wondering if his result did not come because he did not do something. That is what I would like to talk about. You know that dead tissue is a much better culture medium than live tissue. We know that traumatized tissue is a much better culture medium than nontraumatized tissue, and we know that tissue in which there is poor circulation or no circulation, although it is still alive, is a better culture medium than where the blood is still circulating. Everybody knows that. Wounds of the face get well readily; wounds of the feet and various other parts of the body do not. Some of us were brought up in the country and when we had to tie a pig we tied him tight so that he would not get loose; you had to tie a bag of oats so that it would not leak. Now we brought that idea into the surgical field and in our overanxiety that the wound should hold we tied the sutures in it good and tight, tight enough to constrict the tissues, and still a little afraid, we tied it still tighter and killed the tissues. This offers a field in which bacteria can grow if they get in.

As between catgut and silk I use one sometimes and sometimes the other. I do not know how much difference there is. I do believe there is a differ-

ence between large ligatures and small ones, and also in masses of material introduced into the tissues. If your assistant gets a wad of fat, or tissue, or ligament inside the forceps and you tie it tight enough it leaves a good site for the culture to grow within the wound. I wonder if one of the differences in favor of silk as opposed to catgut is not the fact that silk will not stand the pull. When you tie with silk you cannot bring it too tightly together because it will break. And, in addition to all that has been done toward reducing the number of bacteria so far as possible and doing whatever you please, I think one of the keynotes is handling of the patient's tissues gently and causing as little trauma as possible. Sutures should approximate tissues, not constrict them.

DR. CHARLES C. GREEN (Houston, Tex.): I have a very definite opinion about silk and catgut. " 'Everyone to his own liking,' said the old lady when she kissed the cow." I have lived long enough to see this thing come up and go away and come up again. We have heard the older surgeons tell of the advantages of silk over catgut, then have heard them reverse themselves. You could not make Alton Ochsner use anything but silk, but he has not lived long enough to see it come and go. I think the most convincing argument is to check our own results. I took 100 cases and used silk, and a second 100 cases and used chromic catgut, and in my hands catgut was far superior to silk. You know they tell you: "Oh, yes, you do get a sinus or a fistula sometimes." But they do not tell you they last for three or five or six months—that is passed over quickly. I do not think you can deny the fact that the longer a foreign body stays in the tissues the more trouble it causes. Catgut is absorbed much more quickly than silk, consequently it is much less likely to cause infection, with sinus formation, than does silk.

DR. RUDOLPH MATAS (New Orleans): I fear that what I am about to say will sound like a very discordant note in this discussion. It is the result of a recent experience in the Military Hospitals of Catalonia during the later months of the so-called Republican régime in Spain. I am referring to the method of treating compound war fractures of the extremities which abounded in all the surgical services and in fact had one entire hospital exclusively devoted to their care. I remained in the Catalonian war zone for over two months while being delayed in the securing of passports for relatives whom I wanted transferred to safety in France.

As a nonpartisan American surgeon, concerned essentially in the medical aspects of the war, speaking the language fluently, with many old friends in the medical profession of the country, I was treated with every courtesy and given free access to all the hospitals and medical centers in the war zone.

I saw many practices, especially in the treatment of war fractures, which, in the light of the present discussion on the importance of atmospheric contamination, were amazing as surgical heresies.

I must say that whatever preconceived notions I had of the treatment of war wounds—derived chiefly from the experience of the World War—were completely upset by what I saw in the Catalonian war zone. The military and civilian hospitals in Barcelona alone, where over 5,000 wounded were under treatment; in Gerona, likewise, crowded with wounded who were being rushed in carloads from the battle front on the Ebro and the Segre, provided an inexhaustible clinic for the study of the most varied war wounds.

The patients were all young men, the flower of the youth of the country—battered, crushed or crippled from the effects of rifle, machine gun, shrapnel, shell and aerial bomb explosions—a fearfully tragic sight to contemplate.

My most interesting experience was at Banolas, near Gerona, where an old monastery had been transformed into a base hospital exclusively devoted to war fractures—except those of the skull with brain injury, which were referred to Neurosurgical Services in other hospitals. I never imagined that one could see such an aggregation of fractures as I saw assembled at Banolas. There were great halls in which several hundred fractured men were treated in separate divisions, classified according to the anatomic seat of the fracture. In one ward devoted exclusively to fractured *femurs*, there were 75 or more patients under treatment; as many, or more, in other divisions for fractured legs; and even more numerous in wards for fractured shoulders, arms and forearms. What an incomparable but lost opportunity for the education and training of a school of young surgeons was the thought that frequently recurred in the presence of this immense mass of traumatized bones and joints!

The fractures of the *femur*, all compound (there were no "simple" fractures in warfare), often multiple, and comminuted, with great lacerations of the soft parts, commanded special attention; not only because of their gravity, but as tests of the efficiency of the revolutionary methods of treatment adopted in the Catalonian hospitals in which antiseptics were totally discarded. The Carrel-Dakin treatment had been tried unsuccessfully and abandoned early in the war. With the great crowding of wounded and inadequate trained help, the rigorous application of the method had proven ineffective, especially since the simplified technic based on the procedures of Winnett Orr (of Lincoln, Nebraska) and Lorenz Böhler, of Vienna, enormously simplified the care of the wounded and yielded better results. The only relic of the World War that remained in the practice of this war was *débridement*, which was the initial procedure in all cases, after hemorrhage and shock had been attended to in the casualty stations and field hospitals. The greatest stress was laid upon the excision of all dead, dying or doubtful tissue and the reduction and setting of the fractures under the fluoroscope or by radiographic control, while the limb was kept in complete extension on a suitable fracture table (Putti's, Böhler's, *etc.*) While in full extension, under general or spinal anesthesia, the wound was packed with plain sterile gauze so as to reach and drain every recess or pocket where the wound secretions could accumulate. With the fracture set, the wound packed and the limb in full extension, a plaster encasement was applied in hand-molded gauze-plaster sections (not roller bandage) directly in contact with the skin and the wound without any interposed stockinet or padding of any sort, in order to prevent any possible motion under the plaster. The limb, thus thoroughly encased in a close fitting spica, extended from the foot to the waist, including the pelvic girdle. By this procedure, the plaster received the discharges from the wound directly, and soon became soaked with them, but the plaster dried and was not removed for three or more weeks, unless there was evidence of abscess or spreading infection, or gas gangrene, an extremely rare event. After the second week the patients were encouraged to move out of bed with the help of a walking stick. The number of patients with fractured thighs who were seen walking about the grounds in their full-length plaster spicas, with only the help of a walking stick—all seemingly lively and happy—is one of the strange sights that greeted me on entering the hospital grounds.

There seemed to be universal agreement on *débridement*, reduction under mechanical traction and anesthesia, controlled by radiograms or the fluoroscope, with packing of the wound, free drainage into a completely closed and immobilizing plaster encasement, which was allowed to remain, *in situ without change*, until the healing of the wound had advanced sufficiently to become protected by granulation, against secondary infections.

While the fundamental principles of the fracture treatment were the same in all the Catalonian hospitals, there were differences in the methods of reducing and setting them.

Dr. F. Jiméno, the chief at Banolas, a most devoted pupil of Böhler, of Vienna, and thoroughly trained in his methods, resorted to skeletal traction with Kirschner's wire and stirrup tractors, Schmerz's tongs and Steinman's pins—in fact, his wards could have passed easily for a German military clinic except for the patients, who spoke Spanish. As a rule, he resorted to gradual reduction by skeletal traction before packing and encasing the limb in plaster.

Dr. Joseph Trueta, chief of the State Military Hospital, in Barcelona, avoided skeletal traction and depended, for reduction, on mechanical extension, availing himself of the open wound and débridement to secure the most perfect apposition of the fragments. After packing, the immobilization of the limb followed with the plaster encasement applied during extension. At first, the wound was packed with vaselined strips of gauze as applied by Orr, but the vaseline gave out and the sterile gauze, alone, was used. There were few cases in which primary suture of the wound had been attempted. All wounds, with few exceptions, that were brought in ten or more hours after the injury were enclosed in the plaster encasement without suture, secondary sutures being applied after the wound had become healthy and filled with granulations.

I had an opportunity to see several plaster encasements removed from arms and thighs after they had been *in situ* for from 15 to 21 days. The stench of the soiled encasement was nauseating. A magma or mush of decomposing pus, wound secretions, including sweat and other matter, covered the surface of the wound under the plaster bandage. But after wiping this off with warm water and soap, and when the packs were removed, I was surprised to see the excellent, healthy, pink, well-granulated appearance of the wounds, coupled with a very satisfactory condition of the patients—no fever, no pain, good appetite, *etc.* This was indeed a revelation which I had not anticipated. Why, no acute streptoccocal infections, little or no tetanus, gas gangrene, *etc.,* was indeed an extraordinary fact which many theories attempt to explain, but are too long to occupy our attention now. Suffice it to say that when fresh wounds are relieved of all dead or devitalized tissues, they are, when put to complete rest, quite able to take care of themselves without the aid of antiseptics, which (when truly bactericidal) hinder the normal reproduction of the tissue cells and weaken their defenses. At any rate it would seem that a symbiotic existence is possible between the normal tissue cells and the saprophytic bacteria and other pathogenic organisms that gather under cover of a plaster encasement. In fact, if there was one essential for the successful treatment of fractures, it was plaster of paris. By the close of the war, plaster had risen to the level of an apotheosis in surgical esteem.

While in Banolas, Doctor Jiméno kindly gave me a statistical summary of his experience in 6,000 fractures which had been treated under his direction since the beginning of the war, of which 500 were fractures of the femur, which had been treated with a total mortality of 16, or 3.2 per cent! There were five amputations—four necessitated by septic infection, and one by gas gangrene which had appeared before admission to the hospital.

Doctor Trueta,* in his little monograph on the treatment of war wounds, was the first to formulate the Catalonian method on the basis of Winnett Orr's teachings, which he practiced early in the war with most satisfactory results.

* Joseph Trueta, M.D.: Treatment of War Wounds and Fractures (English version). 1939. Hamilton, Publisher, 90 Great Russell St., W.C., London.

In 1938, he published a record of 605 war fractures, of which 42 were fractures of the femur, without amputations or deaths. In a more recent paper (abstracted in the Lancet, London, December 2, 1939) he states that during the war he treated 1,073 fractures of all sorts by the same principles previously described, with less than 0.75 per cent requiring the premature removal of the plaster encasement because of unexpected complications.

Statistical compilations of the experience of the military surgeons attached to General Franco's armies have not yet been collected in sufficient number for general comparison with the Catalonian statistics, but since the majority of the Spanish surgeons have been influenced by Böhler's teachings, the figures of the Victoria Base Hospital, reported by Captain Arguelles Lopez (Revista Esp. d. Med. y Cirugia de Guerra, 1, September, 1938) are comparable to those of Dr. Jiméno at Banolas. Thus at Victoria (a Franco hospital) there were 252 fractured femurs, with 20 deaths, or a mortality of 7.9 per cent; and amputations 13, or 5.1 per cent.

This experience, I think, is well worth recording, if only as a contrast to the discussion we are now engaged in. Here, everyone is concerned with keeping germs out of wounds, but despite the great progress accomplished, the best minds are still exercising their wits to devise means and methods to keep them out of the atmosphere. There, at the war front, rude experience imposed by necessity seemed to discount the importance of germs, provided the living tissues were allowed to fight their own battle unencumbered by the bodies of dead or dying tissues, and kept undisturbed and protected in the process of repair and reproduction from tempestuous manipulations and destructive germicidal irrigations by absolute fixation in plaster.

It is true that the smell emitted by these patients while their plaster encasements were ripening was somewhat of a shock to sensitive nostrils. But when I saw them get well, with their wounds healed, I realized that "not all cheese that smells bad, is bad."

DR. DANIEL C. ELKIN (Atlanta, Ga., in closing): In answer to Doctor Boland's query as to sterility of the catgut it has been that which meets the requirements laid down by Meleney for sterilization.

DR. FREDERICK A. COLLER (Ann Arbor, Mich., in closing): In answer to Doctor McClure's question whether we took anaerobic cultures or not, I will say that we did not take cultures of this type. The suggestion is an excellent one and it may well be that exposure of the wound to air for 24 hours may play an important part in minimizing or abolishing the growth of anaerobic bacteria.

I am very glad that Doctor Gamble has discussed the paper, as I am sure all of us are indebted to him for the work he has done on the handling of contaminated wounds. For many years, I have followed his advice to leave the wound wide open after severe contamination following operation for acute appendicitis with peritonitis. In the type of wound that I discussed, however, it is highly desirable to preserve an intact abdominal wall if possible and, therefore, we have closed the peritoneum and the fascia, leaving the pack only in the subcutaneous tissues. I wish to emphasize again that we do not feel that this method will be universally successful as it, obviously, will fail in many instances in which the organisms are particularly virulent or in which there is a low tissue resistance. However, we do feel that it may well prevent severe infection in a certain number of wounds that would become infected were they closed in the usual manner.