

Chapter XIII

SURGICAL TREATMENT OF GAS BACILLUS INFECTION

AMPUTATION

Before going into the details of the x-ray technic for treatment of gas bacillus infection, a presentation of the advantages of x-ray treatment over methods formerly used seems essential. If one is requested to abandon an accepted method of treatment and follow new procedures, the relative merits of all the procedures, old and new, must be carefully evaluated. Since the first report of the six cases reviewed in Chapter XII, over 400 patients with gas bacillus infection have been treated by various combinations of x-ray and other measures, and in some instances by x-rays alone. Therefore the discussion which follows regarding amputation, early radical surgical procedures, serum for prophylaxis and therapy and x-rays as means of prevention and treatment, is based entirely on the records of 400 cases. Thus, the effectiveness of these three methods of prevention and treatment may be compared and evaluated.

No one will attempt to defend amputation as a desirable therapeutic procedure. All admit that it is a drastic and often a tragic measure. Therefore if it is possible to eliminate it through any means whatever, a distinct advance will have been accomplished. This is particularly true if one is able to eliminate it by substituting a simple and easily available method of treatment which in over 400 cases has never given rise to any complications or other ill effects and is, in addition, much more certain to be effective.

As indicated in our early reports, we are strongly opposed to amputation and débridement as they apply to the prevention and treatment of gas bacillus infection. The following excerpt gives our opinion at that time, and nothing has occurred to alter it:

It seems that amputation is definitely detrimental, at least unnecessary, and if unnecessary, who wants to throw an arm away? Often these patients are children; one child 11 and one 12 years of age in

this second series recovered after losing an arm, and both had active gas gangrene above the site of amputation shortly after the amputation was finished, so all the disease was not eradicated by the surgical procedure.

Since many of the cases which had radical surgery still had infected tissue left behind, it raises the question as to what good surgery really does. Then the mortality of the cases operated upon is so terribly high as compared with the cases not operated upon, that again the use of amputation seems to be a distinct disadvantage. Finally, we believe that one should discourage amputations except in those instances in which the tissues are hopelessly damaged by causes other than gas gangrene. The dark appearance of the involved tissues does not indicate a true gangrene, and it clears up following successful radiation. It is probably localized cyanosis.²⁰

We believe that one should perform whatever surgery is indicated because of the injury but that there should be no extensive or major surgery for the gas bacillus infection itself during the acute toxic phase of the disease.

If treated with x-rays, there is no necessity to estimate the extent to which the gangrene will progress during the invasive stage, since the tissue which is destroyed during this time is demarcated as the disease regresses and the hopelessly dead tissue may be removed after the acute toxic stage of the disease has passed. There should not be over 1 or 2 per cent mortality in the deferred amputation group and about the same mortality from the infection itself. Prophylactic x-ray is indicated after the secondary operation if one is required.

Data on the incidence of amputation and the mortality in the different groups of patients with relation to their amputation status are discussed in the following pages.

INCIDENCE OF THERAPEUTIC AMPUTATIONS WITH X-RAY THERAPY

In the 364 post-traumatic cases reported up to May, 1940, there were 303 with involvement of an extremity and 51 involving the trunk; and in 10 the area of major involvement was not determined. The figures in Table 12 become more significant when one realizes that the circle in Figure 18 represents 303 cases of extremity involvement, or 83 per cent of the total post-traumatic group, and that in only 27.3 per cent (66 of 242 cases) was amputation performed as a therapeutic measure. This percentage, one out of four, is far below the usual figure for therapeutic amputations in post-traumatic cases of gas bacil-

lus infection not treated with x-rays; in fact, it is probably just the reverse, and three out of four not treated with x-rays will have an amputation. With x-ray therapy, this high amputation

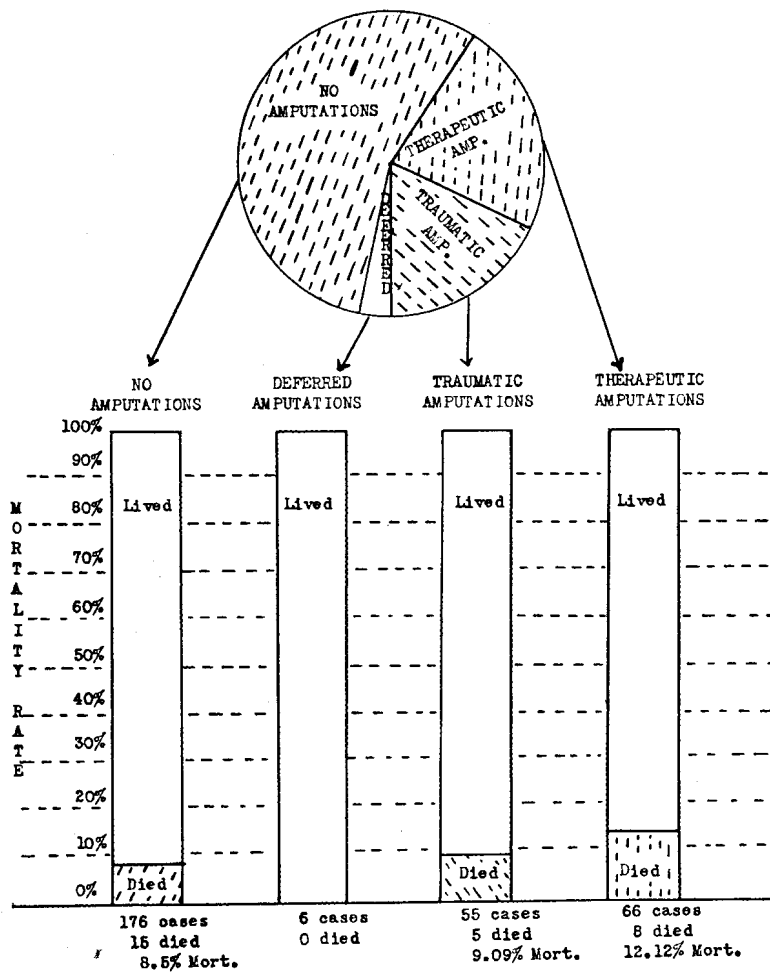


FIG. 18.—Mortality rates with special reference to therapeutic amputations. The circle shows the recent trend away from therapeutic amputations; the pillars show a higher mortality rate in the therapeutic amputation group than in other groups.

rate is unnecessary; this is evident from the fact that the mortality rates for both the amputated (12.12 per cent) and nonamputated (8.5 per cent) groups are also much lower than is usual in

other series of cases not receiving x-ray therapy. Hence, the absence of major surgery has not raised the death rate. Here is the answer of the radiologist to those who claim that without early amputation the patient must die.

TABLE 12
SITE OF INVOLVEMENT IN POST-TRAUMATIC CASES

SITE	CASES	LIVED	DIED
Extremity.....	303	275	28 (9.2%)
Trunk.....	51	37	14 (27.5%)
Undetermined.....	10	10	0 (0%)
Total.....	364	322	42 (11.5%)

The last tabulations of figures (including those in other tables) regarding the status of amputations as a therapeutic procedure are brought up to May, 1940, in Table 13. This includes all the cases at our disposal. Table 14 and the discussion are confined to the cases reported in the literature in detail.

TABLE 13

	CASES	DIED
A. Therapeutic amputations, after trauma (no diabetic or arteriosclerotic cases included).....	66	8 (12.12%)
B. Traumatic or essential amputations (tissue removed immediately because of severity of injury).....	55	5 (9.09%)
C. No amputations after trauma (extremity involvement, no amputation).....	176	18 (8.52%)
D. Deferred amputations (performed after gas bacillus infection had subsided).....	6	0 (0%)

In group A (therapeutic amputations), there is 12.12 per cent mortality and in group B (amputation due to injury), 9.09 per cent mortality. These are higher than group C (nonamputation), with a mortality rate of 8.52 per cent. The fact that none in the deferred amputation group died has great significance. A point to be remembered in consideration of group A is how many of the 58 who recovered had gas above the site of amputation and therefore lost an extremity unnecessarily. From our experience, we estimate that in three fourths or more of patients who recovered after amputation an extremity was sacrificed without any gain. Furthermore, of the eight dead in

group A, we know that a purely postoperative accident after amputation (slipped ligature, emboli) caused the death of some.

Conclusions concerning amputation in diabetic and arteriosclerotic groups cannot be significant since the majority must have amputations because of the primary disease. In these patients with primary gangrene (diabetes, etc.), gas bacillus infection as a cause of amputation seldom enters into consideration. The active gas bacillus infection can be subdued before operation, but cannot be eliminated while the gangrenous areas remain. After being subdued by radiation therapy, the gas bacillus infection becomes active again at the least provocation and continues to do so until all the dead tissue has been removed.

TABLE 14

CASES OF GAS BACILLUS INFECTION REPORTED IN THE LITERATURE IN DETAIL

	CASES	LIVED	DIED
Extremity involved			
Therapeutic amputation.....	12	9	3 (25%)
Traumatic amputation.....	2	2	0 (0%)
Deferred amputation.....	4	4	0 (0%)
No amputation.....	23	22	1 (4.35%)
Total.....	41	37	4 (9.7%)
Trunk involved.....	8	5	3 (37.5%)

The data in Table 14 show that the mortality rate for cases having therapeutic amputation was over five times as great as that for cases not having amputation; and there were no deaths among those in which amputation was deferred until the acute toxic phase had passed. (These figures and all others from the analysis of the cases reported in the literature in detail show no discrepancy from the figures used in exhibits during the past year based on all the cases we have in our files from all sources.) We have insisted for the past several years that amputation is an obsolete therapeutic procedure in the management of gas bacillus infection. The foregoing data sustain our contention.

In 17 of the 23 cases in which amputation was not done *Bacillus welchii* was demonstrated. In the single fatal case, *B. welchii* was not demonstrated, but the patient undoubtedly had gas gan-

grene and the case has been included in our exhibit figures. Of the cases in the therapeutic amputation group (all cases in the literature), eight revealed *B. welchii* and two were fatal. Of the four cases in which amputation was deferred *B. welchii* was demonstrated in three; all patients recovered. In both cases of traumatic amputation *B. welchii* was demonstrated; both patients recovered.

The following cases are of interest in connection with the problem of amputation:

EARLY AMPUTATION

CASE 7.—G. E. L., a boy aged 12, received an injury to the left forearm. Prophylactic and therapeutic serums were administered. Amputation below the elbow was done after diagnosis of gas bacillus infection was made (Fig. 19). The infection extended up the arm into the shoulder and adjacent thoracic area. X-ray therapy controlled this infection and the child made a quick recovery.

This was one of the early cases and served to emphasize the fact that the amputation has no therapeutic value. This boy must go through life without a forearm. Figure 20 shows this boy at 17. Amputation is often necessary because of the severity of the injury, but its use in therapy for gas bacillus infection is poor practice.

CASE 8.—A boy aged 12 received a compound fracture of the left forearm on March 30, 1938. The next day he showed evidence of a gas bacillus infection and was taken to a hospital 350 miles away. On arrival, he was extremely toxic. Crepitation and discoloration extended above the elbow. The x-ray film showed gas in the tissues of the supraclavicular and axillary areas. X-ray therapy was started immediately after arrival at the hospital, and the arm was amputated on the second day. Amputation was necessarily below the highest point of the infection, as gas was present in the supraclavicular and axillary areas on films taken before amputation (Figs. 21 and 22). It is unfortunate that the infection was permitted to become so extensive before the patient received x-ray treatments. He recovered from the gas bacillus infection despite the added shock due to the amputation. It might be well to treat with 50 r units three times each day in preference to 70 r units twice a day in case of such an extensive infection. Frequent small doses must be used, unless a long journey is to be undertaken; then a larger dose, probably 100 or even 200 r units, might be used with advantage.

This case offers a strong argument against amputation as a therapeutic measure in gas bacillus infection. This youngster

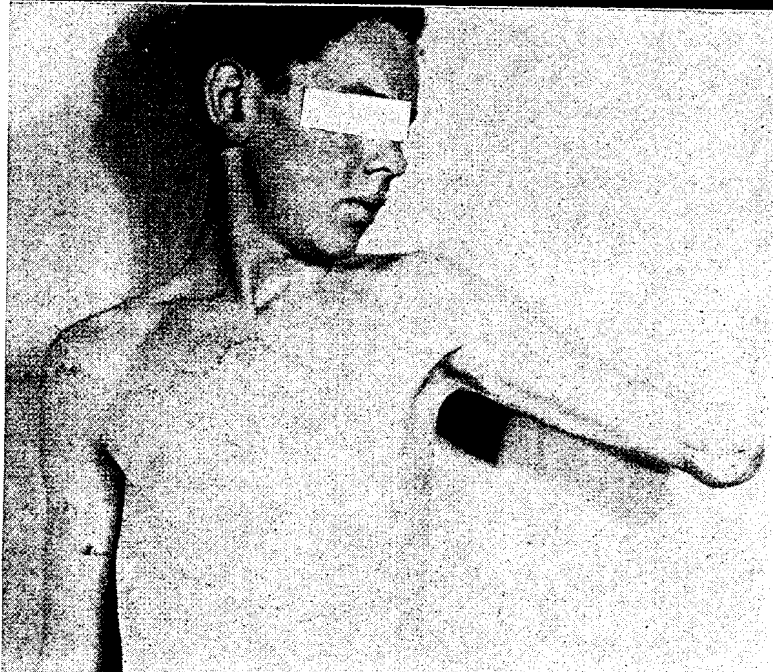


FIG. 19 (above).—Case 7. Elbow area with gas in the soft tissues well above the site of therapeutic amputation.

FIG. 20 (below).—Recent picture of the same patient, seven years after his arm was amputated as therapeutic measure for gas gangrene.

may have needed the amputation because of the delay and long journey to the hospital, but with gas in the axilla and in the supraclavicular space it is obvious that the amputation did not

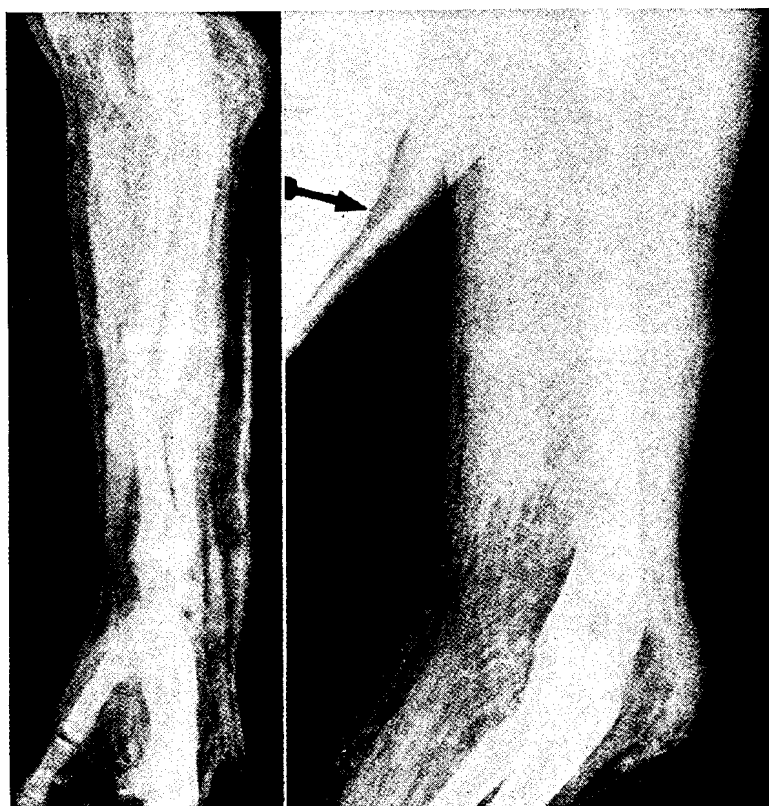


FIG. 21 (left).—Case 8. Fracture of both bones of the forearm. A fracture of this type should rarely result in loss of an arm, even if gas bacillus infection is present, as in this case.

FIG. 22 (right).—Same case. Wide distribution of gas in the soft parts about the elbow, in the arm and under the soft tissues of the axilla. Amputation obviously did not remove all of the infected tissues; however, the patient recovered. Linear distribution of gas is more invasive and probably more dangerous than the saccular distribution shown in Figure 23. A similar linear distribution in another patient proved fatal in a few hours (Fig. 24).

remove the infection. The lad's subsequent recovery was due to therapeutic measures other than the amputation, and despite the amputation which, in our opinion, adds a definite hazard to recovery (see Table 14 and comment).

Before the advent of antiseptics, the history of surgery indicates that a compound fracture usually resulted in loss of the extremity and occasionally of the patient's life. Either of those results should never occur at the present time. However, it took Oliver Wendell Holmes, Semmelweis and a few others over 50 years to induce certain surgeons and obstetricians to dip their hands in an antiseptic solution before operating, and it may take that long to obtain a few units for the injured or infected extremity regardless of how obvious the benefits or how simple the procedure. Emergency x-ray treatment (p. 60) should be given in such cases before a long journey is started. In Case 8, the boy was handled unusually well. Diagnosis was made early,

pathologic involvement to kill him, as shown by involvement of the thorax, but prompt action saved his life. This case brought to our attention the fact that an emergency x-ray treatment should be given before any long journey is undertaken. Although this youngster lost an arm, only a few years ago or with poor management on this occasion he would have lost his life.

DEFERRED AMPUTATION

To expedite a review of the deferred amputation group, the following abstracts of cases are presented. Any points not covered here can be found in the original article. These records support our contention that the proper time for surgical removal of any dead tissue resulting from a gas bacillus infection is after the acute toxic and invasive stage of the disease has subsided and the dead tissue is demarcated.

A white male, aged 8 years, was brought in to the Swedish Hospital by the family physician, on May 28, 1937, with a compound fracture of both radius and ulna above the wrist. The laceration was cleansed and sutured about one hour after the accident, at which time the patient had been given tetanus antitoxin and a prophylactic dose of mixed gas bacillus antitoxin. The swelling and discoloration increased, so at 7:00 A. M. on May 30, 1937, the day following his admission and 36 hours after the original accident, we were called in consultation.

After the cast was removed, we decided that a gas bacillus infection had occurred, which was rapidly extending up the entire arm. By 8:00 A. M. the forearm had become more swollen, all the fingers were markedly distended and were bluish in color. There was a red

area extending from the wrist to the mid-forearm. There was crepitus of the subcutaneous tissues to the mid-third of the upper arm. The previous sutures were removed, gas escaped and the smears of the material showed bacilli typical of *Cl. welchii*.

On May 30, 1937, he was treated with 130 kv. roentgen rays, using a filter of four millimeters of aluminum at 38 cm. distance, and given a total of 50 r to each of three areas extending from the finger tips to the axilla. By 11 o'clock, the swelling was very much more extensive, the hand was cold and bluish black, the red area involved the entire forearm within four inches of the elbow, and there was crepitation in the axilla and chest wall. Additional treatment was given at this time with the same factors. By 1 o'clock, the entire arm was so markedly distended, and the hand and forearm so tense and cold, it was decided that drainage was necessary in order to remove the tension and improve the blood supply to the hand. Extensive incisions of the forearm were then performed. By 6:15, at which time another roentgen treatment was given, his temperature had gone from 105° to 103°, the hand was slightly warmer and his general condition had improved. There was no longer any crepitus in the axilla or chest wall. Roentgen ray treatments were continued at the rate of 100 r to each area involved, twice a day for four successive days. By the third day his temperature had receded to 101°, he was eating well, and looked bright. The swelling in the upper arm had entirely disappeared, but there was an extensive amount of desquamation of the superficial epithelium of the entire lower arm.

On June 7, 1937, the temperature had subsided to 99°, but a sharper demarcated area had appeared at the elbow and all below this region was necrotic and sloughing. By June 12, 1937, it was obvious that the entire lower arm was gangrenous, so he was taken to surgery and an elbow disarticulation was performed, and the wound left wide open. Additional treatment was given the following day and the day after over the stump of the arm with roentgen rays as a prophylactic measure against recurrence of his infection. This patient was discharged from the hospital on June 21, 1937, with the wound practically healed.²¹

Godby reported his experience:

The first patient treated was a miner, who had sustained a compound fracture of the lower end of the left femur. The fracture involved the knee joint. He was admitted to the hospital on July 9, 1938, four days after the accident, in very poor condition, having come by aeroplane from Onslow, a distance of over 800 miles. The wound was filthy. Inspection of both the wound and the surrounding tissues revealed definite gas gangrene infection. X-ray therapy was commenced at once. Serum and "Prontosil" were also given. On account of the splint, the popliteal space could not be irradiated. This omission probably had a great influence on subsequent events. After three days the wound was still filthy, so treatment was given once daily for four more days.

The general condition of the patient was so bad that only very limited local treatment could be given on his admission to the hospital. Twelve days after his admission, his general condition had improved sufficiently to allow of a proper surgical toilet to the wound and of the provision of adequate drainage. During this 12 day period, the tendency of the infection to spread had been checked. At the time of operation, the infection was confined to the wound area only. A gradual but definite improvement now took place; but on August 6, 1938, a brisk secondary hemorrhage from the popliteal artery necessitated amputation of the limb. Further improvement was slow, but uneventful.²²

NO AMPUTATION

CASE 9.—M. H., a girl aged 6, was struck by a car, receiving a severe laceration of the left leg in which her stocking and dirt were ground into the wound. A half-hour later she was admitted to the hospital, where the wound was cleansed and sutured. A prophylactic dose of mixed gas and tetanus serum was given. The child was apparently doing nicely until the temperature rose to 102.6 F. at 3:00 A. M., the third day after the accident. After an x-ray film showed gas in the tissues (Fig. 23), the sutures were immediately removed and irrigations with peroxide were started. A smear of the wound on the next day showed *B. welchii*. The temperature reached 104 F. on the fourth day. She was given one x-ray treatment on the fourth day, two treatments, morning and evening, on the fifth and one treatment on the sixth day.

Amputation was considered in this case, but it was thought unnecessary. Diagnosis was based on an x-ray film taken early, before the disease was demonstrable by any other method. X-ray films should be taken more often in such cases, permitting many early diagnoses. Early diagnosis and early treatment mean early recovery with a minimum of toxic effect.

Case 9 is of interest also because of the queries of parents, other relatives and friends who insisted on knowing at the very beginning exactly what was going to happen and whether or not the child was going to get well. In our opinion, this matter is best handled in plain English with the parents and other doctors in attendance. The chances of prompt recovery following x-ray treatments were probably as good, or even better, than if the leg were disarticulated at the hip or a high amputation in mid thigh were done. But no one can tell exactly what is going to happen in every case, and after the fact is made plain to the parents that the child has a serious infection and that there is an element of danger in any method of treatment, they should be

allowed to indicate their preference. In this instance, they were anxious to accept x-ray therapy and the child made a quick recovery.

CASE 10.—L. H., a young woman aged 20, received a compound fracture of the left femur. Gas bacillus infection was present in 18 hours. X-ray treatment was started the next day, and she received two treat-



FIG. 23.—Case 9. Saccular distribution of gas in deeper soft parts distant from site of injury. Positive culture of *B. welchii*, demonstration of gas in tissues and clinical condition of the child would have resulted in immediate amputation some years ago; amputation was unnecessary and the child recovered promptly with x-ray therapy and serum. Lower arrow, site of injury; upper arrow, gas distant from site of injury.

ments daily for two days and one the third day. The temperature dropped from 103 F., when treatment was started, to normal on the third day, but rose irregularly for some time thereafter. The patient made a complete and rapid recovery, and it was admitted that x-ray therapy prevented mutilating surgery.

Many consider the loss of an arm or a leg solely from its economic aspect. But to us the loss of an arm or a leg in a young person is a serious handicap in other ways. Even its most serious

aspect, the economic one, is probably sufficient to warrant the emphasis that has already been placed on the x-ray in the treatment of a gas bacillus infection. In this case, a limb was saved for a student nurse. She is now a graduate nurse working in her profession, a difficult task if she had an artificial leg.

PRIMARY* PLUS GAS GANGRENE WITH AMPUTATION FOR PRIMARY DISEASE

In patients with primary gangrene (diabetic, etc.), gas bacillus infection as a cause of amputation seldom enters into clinical consideration. The active gas bacillus infection can be subdued before operation, but the infection is not eliminated while the gangrenous areas remain. The gas bacillus infection, after subsiding under x-ray therapy, becomes active again at the least provocation and will continue to do so until all of the dead tissue has been removed. Usually, during the series of operations required the patient finally dies of a combination of factors—hemorrhage, shock and the toxemia incident to the persistent gas bacillus infection.

All future reports on the treatment of gas bacillus infection should carry the figures not only on mortality but also on morbidity. Exact details of the circumstances associated with every amputation should be reported. Whether or not amputation was required by the type of the injury, the destruction of tissues, the gas organisms, a secondary infection or osteomyelitis should be included in the report. The time of each amputation in relation to the onset and course of the disease is also important.

We can say nothing more emphatically regarding our stand on amputations as a therapeutic procedure during the acute toxic phase of gas bacillus infection complicating trauma than was said in one of our former reports: "It now seems that anyone amputating or advocating the amputation of an extremity solely because it is infected with a gas-forming organism or might become infected is definitely out of touch with the proper and conservative treatment for the condition."

CONCLUSIONS REGARDING AMPUTATION

In 1931, the fact was emphasized that amputation for gas bacillus infection is unnecessary; that no patient loses tissues be-

* Primary in this instance means preexisting.

cause of therapeutic surgical procedures; that any tissue is removed because of the injury.

It should be clear from the foregoing analysis of many cases and the consideration of a few cases in detail that when x-ray therapy is used, amputation is unnecessary during the acute invasive stage of the disease. This statement is made in direct reference to the use of amputation for a gas bacillus infection after trauma. It has no bearing on the use of amputation when it is required for any other reasons or for the removal of dead tissue after the invasive and toxic stage of gas bacillus infection has passed. Our opinion was expressed in December, 1940, as follows:

surgery indicated by the initial injury or disease should be performed, but no surgery directed toward the treatment of gas gangrene itself is required with the occasional exception of a few incisions to relieve local tension caused by deep gas pockets or collected serum. Amputation and extensive debridement are now obsolete procedures in the toxic stage of the disease, and have been practically eliminated after the disease has subsided because they are seldom necessary. They should never be necessary, if treatment is started early and has been properly given.

DÉBRIDEMENT

Definition.—Wound excision; a procedure used in treating wounds, consisting in the *removal of all foreign matter* and excision of all the tissues immediately surrounding the wound, *including devitalized soft parts in the vicinity*²³ (italics ours).

In our report of 1938 we made the following statement:

There is no question but that a wound should be *cleared of all foreign material* and *hopelessly isolated fragments of tissue* as a result of severe injury. We do not intend to criticize the surgeon, but we are out thoroughly to discourage the operator who is inclined unnecessarily to mutilate or amputate. In the trunk cases, there was no attempt at débridement, and 14 out of 18 patients recovered, so one can recover without débridement.¹¹

In view of the foregoing definition of débridement and the quotation which follows, it is difficult to see how the opinion originated that we were so completely opposed to débridement. We agreed on two of the three essentials in the definition, but we did not agree on the complete excision of the wound; it is

an entirely unnecessary procedure, and therefore we do not agree to that particular portion of the definition.

X-rays alone (Table 17 and Fig. 50) will prevent or cure gas bacillus infection; therefore any such dangerous or destructive method as wound excision for this purpose is obsolete. On the other hand, if débridement is indicated because of the mutilated condition of the tissues as a result of injury or some cause other than gas bacillus infection clinical judgment is necessary to determine how far surgical intervention is to be carried.

Débridement is simply a localized amputation, and its status, therefore, is essentially the same as that of total amputation or removal of an extremity. It should not be done as a therapeutic

poor surgical judgment to perform a débridement except for gas bacillus infection, in which it was permissible and even indicated because of the seriousness of the disease and because no other conservative method was of any avail.

At this time, we know the x-rays will control a gas bacillus infection, eliminating the reason which permitted such radical surgery under such unfavorable circumstances; consequently, débridement in the presence of a gas bacillus infection is less justifiable today than for any other infection because x-rays more certainly control this infection than any other. We still believe that neither a localized amputation under the term débridement, a complete amputation nor a disarticulation should be done until the toxic invasive stage has passed.

It is not proposed to outline all first aid procedures, for they are better outlined elsewhere. However, it seems that any recent, apparently clean, open wound should have a sterile dressing, applied with pressure, while the patient is being sent to the nearest point where first aid cleansing and repair of any serious damage may be completed at the earliest possible moment. For instance, if tendons, nerves or blood vessels are severed, time is important, and intervention should be accomplished in two or three hours after the original injury if primary repair is to take place. If repair within two or three hours is possible, there is much less chance of infection and, as a result, primary repair is more certain. Some surgeons may not feel that a prophylactic x-ray treatment is indicated at this time, but we believe that it

gives an additional measure of protection against infection and in no way interferes with primary repair.* If first aid surgery is not possible until several hours have elapsed, a prophylactic dose of x-rays every 12 hours for three or four doses may prevent infection and aid in primary union.

One should never probe a recent open wound. This introduces or spreads infection and adds to local destruction which may involve a vessel wall and start a severe hemorrhage. Hemorrhage must be controlled at any time before, during or after any stage of a gas bacillus infection. A dressing with pressure or a temporary tourniquet may suffice, or even suturing may be necessary. A prophylactic dose of x-rays should follow any local trauma to the tissues. If shock is present, the usual measures may be employed with the most suitable variation to fit the case.

Irradiation of an injury in which gas bacillus infection is probable or suspected is done as a matter of prophylaxis, and a gas bacillus infection should not develop in wounds so treated. Observations on patients previously so treated suggest that irradiation prevents other types of infection as well as gas bacillus infection.

It is not intended to leave the impression that bullet fragments, gravel or shreds of torn tissue should be left if they are accessible for reasonable extraction when first aid is given. It seems contrary to the best opinion to attempt to extract inaccessible foreign materials during an early or well developed stage of a gas bacillus infection. The added trauma and disturbance in the tissues are likely to increase the severity and extent of the infection, possibly giving rise to a gas bacillus bacteremia which it might be impossible to control even with irradiation. Such a case requires two or three adequate x-ray treatments daily until the local condition improves and there is little or no danger from the necessary surgery. Each surgical procedure in such an area should be followed promptly by about 25 r units once a day, or more often, depending on clinical indications, to prevent a reactivation of the gas bacillus infection.

* We have been of the opinion for some years that heavy fibrosing x-ray dosage to the skin lessens the tendency to prompt repair and possibly weakens the resultant scar, but the x-ray irradiation we are recommending is not of that variety and we feel that it has no detrimental effect on healing.

EXCEPTIONS REQUIRING EARLY SURGERY

As a rule, then, after the gas bacillus infection has become definitely established, any surgery in that area for at least four to six days is an unnecessary danger; but there are certain exceptions to all general rules. One exception is the case in which a gas bacillus infection has developed in the deeper tissues following a small puncture wound, such as a hypodermic injection (see Case 11). The mortality is so high in this type of case that local surgery may be justifiable to relieve local tension caused by gas distention and the accumulation of fluids. Removal of tissue should not be necessary, but several longitudinal incisions and blunt intermuscular dissection, with care not to disturb important nerves or vessels, may be done in the hope of lessening

a treatment every six hours would do no harm. All the involved tissues must be treated, and in advanced cases some treatment might well be given over distant important viscera, such as the heart, liver, kidneys and adjacent organs, which are badly damaged by the toxins of the gas-forming group if the disease is allowed to progress.

The use of x-rays to prevent the development of infection in the probable and suspected stages and to combat the infection and the toxemia after the infection has reached an early or a late stage, preferably without any additional local trauma or general shock from surgical procedures, seems rational. General rules can be indicated; but, after all, the care of a gas bacillus infection is the practice of medicine, and no absolute laws regarding procedures are infallible. Every case must be individualized, but the mortality and morbidity are consistently lower in all series of cases in the group of cases in which surgical intervention is held to the minimum during the acute invasive phase of the disease. If débridement means excision of the wound and an indefinite amount of tissue adjacent to the wound because of the presence or the threat of a gas bacillus infection before the toxemia has subsided and the infection becomes localized, we are still opposed to it; if it means a conservative cleansing of the wound before the infection is definitely established, it is recommended.

Any tissue which is in a gangrenous state must be removed

surgically, and this form of débridement is essential after the acute toxic phase of the infection has passed. (See deferred amputations.)

GAS BACILLUS INFECTION FOLLOWING HYPODERMIC THERAPY

CASE 11.—H. G., a man aged 27, was given a hypodermic injection of boiled milk for a chronic gonococcal infection. Within eight hours extensive swelling developed with escape of gas at the site of the injection (Fig. 24). The patient was hospitalized, multiple puncture wounds were made, and deep irrigation with potassium permanganate was started. The patient received x-ray therapy, but died the same day.

This patient died only two hours after the first x-ray treat-

given was probably inadequate. He should have received heavier voltage over the thigh and trunk. When gas bacillus infection occurs following a hypodermic injection, the anaerobic conditions may accelerate the rate of toxin production and absorption. In any event, the mortality rate is extremely high. Of four cases reported to us, only one patient recovered. The addition of our own case gives a mortality rate of 80 per cent. The patient who complains of an unusual amount of pain after a hypodermic injection should receive immediate consideration. An x-ray film is easily obtained, and any gas in the deep tissues is demonstrable very early. If gas is present, immediate x-ray therapy is imperative. Pain deep in the tissues where the gas is unable to escape is the outstanding early symptom in gas bacillus infection. Evidences of toxemia out of proportion to the other features of the case should also make one suspect a gas bacillus infection. Crepitation on palpation, discoloration, the escape of gas and the gas odor are later symptoms.

From the work done on the hand by Kanavel,²⁴ his younger colleagues, Mason, Koch and others, developed the present-day principles of aseptic technic for initial care of contaminated traumatized wounds. The following quotation from a recent article by Koch presents what we think is the ideal method for the care of this type of patient. If infection does take place, x-ray therapy, in our opinion, should be added; or, if one wants to be quite certain that no infection occurs, roentgen therapy may be added to the surgical procedure described as follows:

In none of the cases that were seen and cared for immediately after the injury was sustained, and in none of the cases of extensive compound injury which Dr. Mason describes in this symposium, and in which he has obtained such striking results was sulfanilamide or



FIG. 24.—Case 11. Linear distribution of gas through tissues of thigh. This distribution is similar to that in Case 8, Figures 21 and 22, but the latter patient recovered.

any of its derivatives or any so-called antiseptic used at any time during the course of treatment.

The moral, I think, is clear. The most certain way to prevent infection of an open wound is not to fill it with tincture of iodine or sulfanilamide crystals, but to cover it immediately with a sterile dressing and entrust the patient to someone who will give him clean, surgical

care without adding further contamination to the open wound. With increasing experience, physicians are coming to realize that the most important source of contamination of an open wound is not the metal or knife or glass that caused the wound, not the bacteria that may be present on the patient's skin, but the uncovered noses and mouths of excited bystanders, or first-aid workers, or of any one who is attempting to examine or treat an open wound without carefully masking his face, covering his scrubbed hands with sterile gloves and making certain that the instrument and materials with which he is working are sterile.

I would not decry the value of chemotherapy when it is indicated, or deny for a moment that the sulfonamides are of great help in combating and arresting certain types of infection. The point I would stress is that the first line of defense lies in the immediate protection of the open wound so that infection from without is not permitted to enter, and the next line, in simple surgical cleanliness that does not add chemical and mechanical trauma to the fragile, delicate cells of living tissue.

better method than the gentle and patient cleansing with soap and water that I use in the care of an open wound which has just been sustained. Every one has seen the destructive effect of chemical antiseptics, for example, of tincture of iodine, on inflamed and injured tissues.²⁵

From the foregoing discussion it is evident that our position favoring the use of the minimum amount of local antiseptic in a wound is in accord with present-day surgical technic. Furthermore, our attitude toward débridement is not out of line with the accepted surgical procedure of the day, as expressed in the following remarks of Cole and Elman :

Antisepsis is actually best promoted by mechanical cleansing, which is the most effective method of eliminating contamination. Cleansing of the skin around the wound is of preliminary importance in order to prevent contamination of the wound during the operation of closure. It also prevents secondary infection by contiguity in the days following. The cleansing of the skin may be done in a number of ways, including the use of soap and water or benzene. After the skin is thoroughly dried, it is painted with tincture of iodine, which after a few moments is removed with alcohol to prevent blistering. This cleansing is especially important as a preliminary step, if the wound is to be closed under local anesthesia, for it enables the novocaine to be injected through a sterile surface. When general anesthesia is used, the cleansing of both the skin and wound is done after the production of anesthesia. The mechanical cleansing is aided by irrigation with physiological saline solution which is particularly important if the wound contains dirt or foreign material, even in small amounts.

The importance of antiseptics in the treatment of wounds has been greatly exaggerated, particularly because it is only a matter of a few minutes or an hour following injury until the organisms will penetrate the tissues deeply enough to prevent their destruction by the local application of an antiseptic. Most antiseptics also inflict severe damage to the tissue cells of an open wound and in that way interfere with the healing process. Moreover, the application of antiseptics dissolved in alcohol, such as tincture of iodine, produces a very severe burning pain when applied to a freshly inflicted wound. The only occasion when a local antiseptic is of value is in the prophylactic treatment of superficial wounds seen within an hour after injury. Under such circumstances the application of tincture of iodine or acriflavine to the wound, followed by a sterile dressing may be instrumental in preventing cellulitis or lymphangitis. On the other hand, in deep wounds, some of the antiseptic may be retained and may destroy so many tissue cells that more harm than good will result. In punctured wounds, the antiseptic cannot reach the depths of the wound, and its use, therefore, is limited to the prevention of a secondary infection; this, however, is of considerably less importance than the danger of an infection resulting from the initial contamination.

Closure of the wound should be carried out as soon as possible except for the occasional instance when it is not indicated. The decision as to whether a wound is (1) to be closed tightly by primary suture, (2) to be closed around a drain, (3) to be closed later by secondary suture, or (4) to be allowed to heal by granulation without suture depends to a large extent on the presence or likelihood of infection, which is governed by many factors. The most important factor is the *length of time which has elapsed between the injury and treatment*. In general, wounds over 24 hours old are considered too deeply invaded by bacteria to permit primary closure; those under eight hours are nearly always suitable for immediate suture. In wounds between eight and 24 hours old, the appearance and type of the wound, the probable amount of contamination, the extent of the inflammatory signs, as well as the factors mentioned below determine the question of closure and drainage. Another important factor is the amount of traumatized tissues, dirt and debris in the wound. In wounds treated early and effectively, however, the relation of these factors to infections and delayed healing can be eliminated in most instances by debridement. This consists of the excision of all badly contaminated, devitalized, or jagged tissue, and the removal of all foreign bodies by careful and painstaking exploration of the injured tissue. Debridement, however, *often should not be done* on wounds over eight hours old, because the bacteria have already invaded the tissue producing a cellulitis which would be aggravated by the mechanical trauma incident to the operation. In individual cases, however, dependent upon the appearance of the wound and the presence or absence of inflammatory signs, debridement may still be done even though 12 hours or more have elapsed since injury.²⁷

CONCLUSIONS

From the foregoing discussion it is evident that débridement as it applies to the removal of tissue because it might become infected with gas-forming organisms or because it is infected with a rapidly invading toxic gas bacillus infection is definitely contraindicated. We are opposed to such procedures before the infection is present or in its early stages. But débridement, which means the conservative cleansing and repair of the wound during the first few hours following the injury or removal of dead tissue after the toxemia is under control and the infection has become localized, is an essential procedure.

By means of x-ray therapy, infections due to the gas-forming organisms may be localized and the toxic action neutralized. Therefore there is nothing about the situation which requires hasty or drastic measures, and the same surgical rules governing the care of other infected wounds in relation to débridement should prevail. In the past, it was necessary to attempt surgical measures in the presence of a gas bacillus infection because of the seriousness of the disease and because no other treatment seemed to be effective in localizing the process. Since x-rays control the gas bacillus infection, all infected wounds now have the same status regarding débridement, if the term means the "excision" of tissues as indicated in its definition. However, if débridement can also mean "incision" of tissues, we think it might be permissible, or even indicated, during the active stage of the disease to permit escape of deeply trapped pockets of gas or collections of fluid. This applies only to cases far advanced when first seen by the radiologist or to cases in which infection develops after a penetrating type of injury such as a hypodermic injection.