Chapter XVI

X-RAY TECHNIC FOR TREATMENT OF GAS BACILLUS INFECTION

The technic of x-ray treatment has practically no routine features in dealing with a disease as fulminating, toxic and dangerous to both life and limb as is the usual gas bacillus infection. None of its stages should be treated by routine therapeutic procedure; every case must be individualized.

It seems essential that for prophylaxis one or two treatments should be given each day for three days, starting immediately after the injury. In all cases with definite infection, two or three treatments should be given each day until the toxemia is controlled. In some instances, a suspected case may require only one treatment each day, rarely two. This is a matter for clinical judgment.

Beginning treatment as early in the disease as possible, even treating the suspected stage, will assure a low mortality rate and lessen all complications, including the secondary infections. All areas involved, all suspected of involvement and the adjacent tissues should be treated each time a treatment is given. To treat only a part of the diseased area leaves other areas free to produce toxins, and the patient will not show the progress toward recovery that one expects; even life may be lost.

Sulfanilamide apparently inhibits the action of x-rays in inflammations. The failure to respond when sulfanilamide is given simultaneously with x-rays resembles clinically the failure to improve when an area of infected tissue is not treated.

Kilovoltage must be adequate to penetrate the diseased areas; otherwise the treatment will fail. This fact was impressed on us very early and was mentioned in the first report, in which two patients with trunk involvement died while the six with involvement of an extremity recovered.

It is recommended that no treatment be given without using some filter; the heavier the part treated the higher the kilovoltage, and, as a rule, the higher the kilovoltage the heavier the filter. If there is any cutaneous reaction, x-ray treatments should be stopped immediately. In this type of therapy there

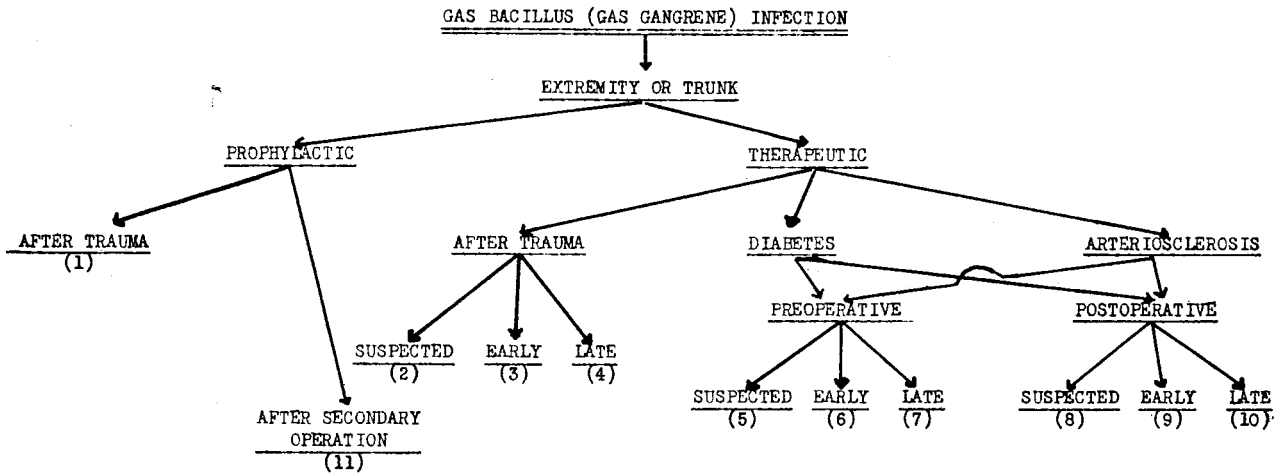

FIG. 48.—Conditions (*1*) and (*11*) require prophylaxis in the usual traumatic case; one treatment each day for three days may be considered routine and adequate. Dose is 60-90 r per treatment. Conditions (*2*), (*5*) and (*8*) are post-traumatic and pre- and postoperative diabetic and arteriosclerotic cases, suspected of harboring organisms in damaged tissue. One treatment daily for three days usually suffices, but such cases should not be considered routine; two treatments daily may be required. Dose is 60-90 r; if there has been considerable irradiation, the dose should be less, possibly as low as 25 r daily. Conditions (*3*), (*6*) and (*9*) are the early gas bacillus infections and require two daily treatments to all involved areas. Dose is 60-90 r. Conditions (*4*), (*7*) and (*10*) are the late cases of gas bacillus infection; if severe, they require three treatments (50-75 r each) for two days, two treatments (50-60 r each) for two days, and probably 25 r for another day or two until the danger is past.

From 60 to 120 r per port daily in one or more treatments is usually adequate for prophylaxis, while 150 r per port daily in divided dosage should be the minimum for treatment and twice this (300 r) in three doses the maximum. For any area which has received 500 r in five days or less, 25 r doses each day thereafter should be the maximum until several days have elapsed (see the discussion on the loss factor).

should be no evidence of local reaction, and if it should appear, a careful investigation of all factors involved and a general examination of all the equipment are indicated.

In any discussion of treatment, a word must be said regarding the patient in whom a reactivation of infection may occur. This includes all cases of ordinary trauma in which secondary surgical repair is necessary within a short time after recovery from the gas bacillus infection and all other cases in which dead tissue is still present after the acute toxic phase of the gas bacillus infection has subsided. In this latter group, one must keep in mind a gangrenous area remaining on one extremity after the other extremity has been removed (see Case 24, Figs. 54 and 55). There has been some question that other causes for lowered resistance as well as a secondary operation might cause a reactivation of infection in these severely debilitated patients, for instance, a severe mental shock in a diabetic patient still having a residue of primary gangrene which harbors gas organisms.

Gas gangrene, as Graham[4] so clearly described it, is a loosely applied term including infections due to one or more of several anaerobes. Other organisms are also found, so that the disease may not be identical in any two individuals. Because of the great variety of conditions which may arise in which the x-ray treatment of either a known or a suspected case seems desirable, Figure 48 is presented. In this diagram, one can see at a glance 11 different clinical conditions in which use of x-rays may be indicated and the estimated range of dosage in r units.

Detailed X-ray Technic for Prophylaxis and Treatment

Kilovoltage and Filter.—A few patients have been treated with x-rays from mobile units having not more than 60 kv. and have recovered, so this minimum kilovoltage is permissible but not advisable unless the area involved is quite superficial. From 75 kv. for extremities to 125 kv. for the trunk infection should be available.

A minimum of 1 mm. Al filter should be used with the lowest kilovoltage, increasing to 3 mm. Al or 0.25 mm. Cu and 1 of Al for the highest kilovoltage in the more prolonged or resistant cases.

A recent review of many cases in which high kilovoltage (200 kv.) and heavy filter (0.5 to 1 mm. Cu) were used on extremities gives the impression that a greater number of r units is required with these factors to obtain the same result that one obtains with a lower number of r units, lower kilovoltage and less filtration, and the response is not as prompt as when lower kilovoltages are used.

Briefly, it appears that the more penetrating type of radiation causes less ionization effect (per r unit delivered) in the tissues than do the less penetrating rays produced by the lower kilovoltages, and as a result less therapeutic effect is evident. However, from the first, owing to the loss of our first two patients with involvement of the trunk, we realized that kilovoltage sufficient to cause ionization in the deeper tissues was necessary if a satisfactory result was to be obtained.

We feel, therefore, that one should not overpenetrate a thin part or underpenetrate a thick part if the best result is to be obtained in the shortest time. Incidentally, it appears that time is a factor in reducing the number of secondary infections which persist after the gas bacillus infection has subsided. This makes it highly desirable that there be early and correct application of x-rays in order to eliminate not only the gas organisms but all other invaders if possible.

Distance.—We designate 40 cm. as the routine distance, but a greater or lesser distance may be employed without any effect on the clinical result if proper compensation is made by changing some other factor.

Size of Port.—We designate 30 × 20 cm. as routine size. The dosages recommended are safe when delivered through this size of port. Smaller or larger ports may be used according to the contour and the area of tissue involved. The principal feature is that a sufficient number of ports is used to cover all of the involved tissue and the adjacent suspected tissues; otherwise satisfactory results will not be secured.

In treating an extremity, only one port, usually anteriorly, is used for one dose; it is seldom necessary to resort to treatment through posterior ports, as the patient recovers before the limit of tissue tolerance has been exceeded through the anterior port. However, in treating the trunk or even a heavy hip region, it may be advisable to turn the patient on his side and give some of

the treatments through the posterior as well as the anterior port. This is especially true if the patient is exceedingly toxic.

Early experiences taught us that when a patient failed to respond promptly, it was because an area of involved tissue was not receiving treatment either because some tissue was not in the field of radiation or because the kilovoltage was not adequate to reach the deeply situated infected tissues. Lately we have learned that certain drugs and chemicals such as sulfanilamide, given simultaneously with x-ray treatments, will also lessen the ionization effect of the x-rays and minimize or even nullify their beneficial action.

In the discussion on kilovoltage and filter we warned against overpenetration and overfiltration in treating the extremities to avoid a delayed or slow response. Therefore if the response is not as prompt as it should be and the patient is not definitely better after the second or at least the third x-ray treatment, one should investigate to make sure that all the area involved is receiving treatment with adequate, but not excessive, kilovoltage and filtration; also, that no drug or chemical which experience has shown to minimize the effect of the x-rays is being administered while the patient is receiving x-ray therapy (see section on sulfanilamide).

r Units per Dose.—Usually 75 r units per day given in a single dose is adequate for prophylaxis, and 150 r units per day given in two or three doses is adequate for an active infection. It is permissible, and might be advisable, to give 300 r units divided into two or three doses on the first day of treatment of a moribund patient in an advanced stage of infection, reducing the dose to 150 r given in two or three treatments on the second day and further reducing the total r units on the third day.

Space Factor.—We still adhere to a program of one treatment per day for prophylaxis and of two or three treatments per day for the active infection. If, for any reason, only one treatment can be given during the day, the entire designated number of r units for a day's dosage should be given. In the acute fulminating toxic infections, frequent administration of a small dose made possible by dividing the day's total number of r units into two or three portions is preferable to giving all the r units intended for that day in a single treatment. For other types of infections, however, a different space factor may be indicated.

We have never stated that one x-ray treatment was all that was necessary. Case 21 is an example of wholly unsatisfactory distribution of x-ray treatments.

Case 21.—V. F., a man aged 21, was injured in a motorcycle accident, receiving multiple contusions and abrasions and a compound

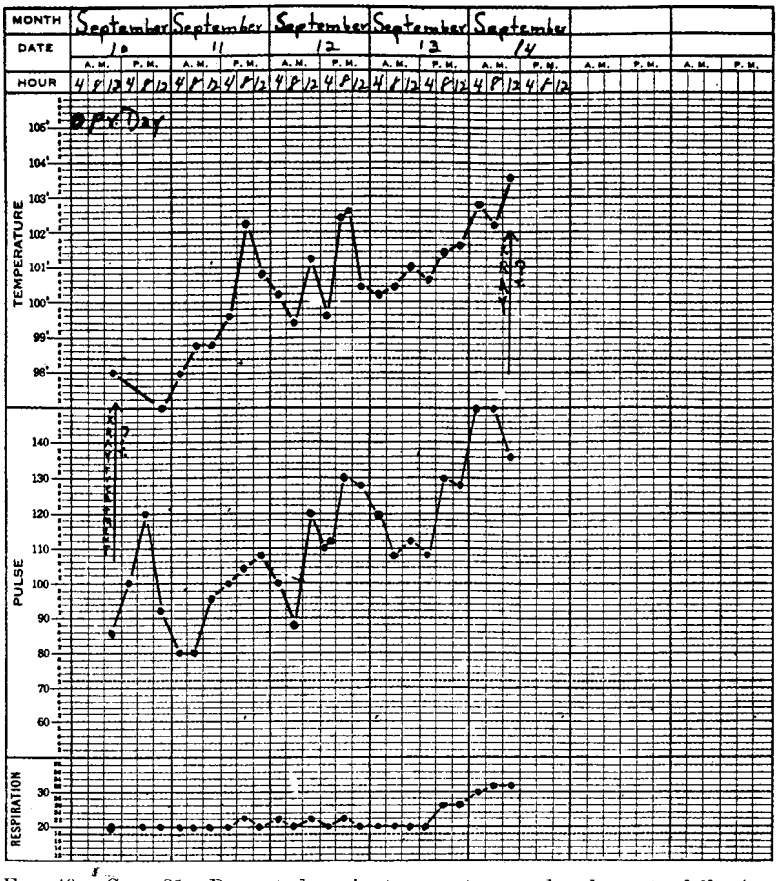

Fig. 49.—Case 21. Prompt drop in temperature and pulse rate following initial x-ray treatment. One x-ray treatment daily should have been given in this case.

fracture of the bones of the left leg. He was given supportive therapy, gas-tetanus serum and one prophylactic x-ray treatment on admission. Open operation and thorough débridement were done. The patient complained of considerable pain in the leg. The temperature reached 102.2 F. the first postoperative day; the next day it reached 102.6 F.

and the pulse rate 130 (Fig. 49). The pain in the leg was severe. On the third postoperative day, the patient's condition continued to become worse. On the fourth day, he became irrational and appeared very ill. The tissues around the wound were crepitant. He was placed in an oxygen tent. He was given 2 Gm. of sulfapyridine by mouth and x-rays to the leg 15 minutes before he died.

Figure 49 shows that after the initial x-ray treatment there was a prompt drop in temperature and pulse rate. But no further x-ray treatment was given until shortly before death. One x-ray treatment daily for three days—*not* one x-ray treatment every three days—is the correct space factor for prevention of gas bacillus infection.

The history in Case 21 suggests lack of familiarity with the proper x-ray treatment of gas bacillus infection and lack of clinical appreciation of the symptom of pain in a potential case of gas bacillus infection. The history of constant pain from a few hours after the cast was applied suggested tissue distention by gas. The importance of pain as a symptom in these cases cannot be overemphasized.

Estimate of Total Dose.—In the estimation of the total dose, one should figure the maximum number of r units permissible if given in a single dose without damage to the skin. If this number is then divided into a three to six day period of treatment, allowing a proportion of the total for each dose according to the total number of doses to be given, proper use is made of the estimated total safe dose for the particular infection. For example, if the area will tolerate 450 r units and one wishes to treat for three days, 150 r units is available each day and may be given in two 75 r unit treatments or three 50 r unit treatments each day. By making due allowance for the loss of radiation effect from the tissues during the period of treatment, one can add some r units to the estimated total dose, since the original total dose has been calculated as if given in a single treatment.

Maximum Intensity Factor.—This is an estimate of the maximum "effect of radiation" absorbed in the tissues at any time during the period of treatment, allowing a 100 per cent effect to be a visible skin reaction. Thus, if 450 r units is considered 100 per cent for the area involved if given in a single dose and it takes three days (giving about 16 per cent, or 75 r, in the

TABLE 20

SUMMARY OF X-RAY DOSAGE

FACTORS	EXTREMITY INVOLVEMENT				TRUNK INVOLVEMENT			
	Prophylaxis*	Suspected	Early	Late	Prophylaxis	Suspected	Early	Late
Kilovoltage	60–100	60–100	60–100	60–100	100–125	100–125	100–125	100–125
Filter	1–2 mm. Al	1–2 mm. Al	1–2 mm. Al	1–2 mm. Al	3 mm. Al or 0.25 mm. Cu and 1 mm. Al	3 mm. Al or 0.25 mm. Cu and 1 mm. Al	3 mm. Al or 0.25 mm. Cu and 1 mm. Al	3 mm. Al or 0.25 mm. Cu and 1 mm. Al
Distance	40 cm.	40 cm.	40 cm.	40 cm.	40 cm.	40 cm.	40 cm.	40 cm.
Size of port	30×20 cm.	30×20 cm.	30×20 cm.	30×20 cm.	30×20 cm.	30×20 cm.	30×20 cm.	30×20 cm.
r units per dose	50–75 r	50–75 r	50–75 r	50–75 r	60–80 r	60–80 r	60–80 r	60–80 r
Space factor	1 daily for 3 da.	1–2 daily for 3–4 da.	2 daily for 3–5 da.	3 daily for 3–5 da.	1 daily for 3 da.	1 or 2 daily for 3–4 da.	2 daily for 3–4 da.	3 daily for 4–6 da.
Estimate of total dose in 3–6 da.	150–225	300†	500†	‡	180 or 240	360†	360†	§
Maximum intensity factor	50%	60%	70%	80%	50%	60%	70%	90%
Loss factor"	X	X	X		X	X	X	
Minimum intensity factor¶	X	X	X	X	X	X	X	X

* See Table 4.

† After 500 r has been put through any port in five days or less, reduce to 25 r per dose and give one dose daily through each port unless urgent.

‡1st day 3×50 r.....150 r
3×75 r.....225 r

2d day 2×50 r.....100 r
2×75 r.....150 r

3d day 2×35 r.....70 r
2×50 r.....100 r

320 r
475 r

4th day and thereafter give 1 or 2 treatments, 25–30 r each

§1st day 3×60 r.....180 r
3×80 r.....240 r

2d day 3×60 r.....180 r
3×80 r.....240 r

3d day 2×25 r.....50 r
2×30 r.....60 r

4th day 1×25 r.....25 r
25 r

5th day 1×25 r.....25 r
25 r

460 r
590 r

" As a rule, favorable response is so prompt that it is not necessary to calculate the loss of radiation effect, since the dosage need not be maintained at a high level over any period.

¶ It is unnecessary to calculate the minimum level of tissue saturation which must be maintained for any length of time.

morning and 16 per cent, or 75 r, in the evening) to give the entire amount, the radiation effect in the tissues will always be considerably below the 100 per cent allowed, owing to loss of radiation effect from the tissues over the three day period required for treatment.

However, the loss factor and the minimum intensity factor are given little or no consideration here since the course of the disease, if recovery takes place, is short, and if death occurs because of gas bacillus infection it generally takes place in the first 72 to 96 hours. In other words, a protracted period of radiation therapy is not necessary, and the lower limit of desirable radiation effect is not essential for success.

Value of Repeated Treatments

Figure 50 shows that in the group receiving only one treatment (29 cases), the mortality rate was 46.4 per cent; in the group receiving only two treatments (38 cases), it was 28.9 per cent, and in the group receiving three treatments or more (288 cases), it was 5.9 per cent. Undoubtedly, some of the patients receiving one or two treatments were so severely injured that they died of the injuries, and an occasional patient, like ours with infection following a hypodermic injection, had such a severe toxemia that x-ray therapy was of no avail; but the majority died because x-ray treatments were started too late in the disease course.

In our first report we recommended that the patient be treated at any time, no matter how hopeless his condition seemed. This did not mean that all kinds of measures be employed until the patient was moribund and that x-rays would then effect a cure.

A suggestion to the radiologist to have courage and treat the advanced case should not be mistaken for an invitation to let all cases advance to a stage of bloated dissolution before using x-rays (see Fig. 49). As a matter of fact, at all times the value of early treatment has been emphasized. It has been recommended that even in the suspected case the condition be considered one of active gas bacillus infection and treated accordingly.

A treatment in the morning and one in the evening for two to four days and a single treatment daily for the next two or three days is adequate for the usual case. Each case, however, must be individualized.

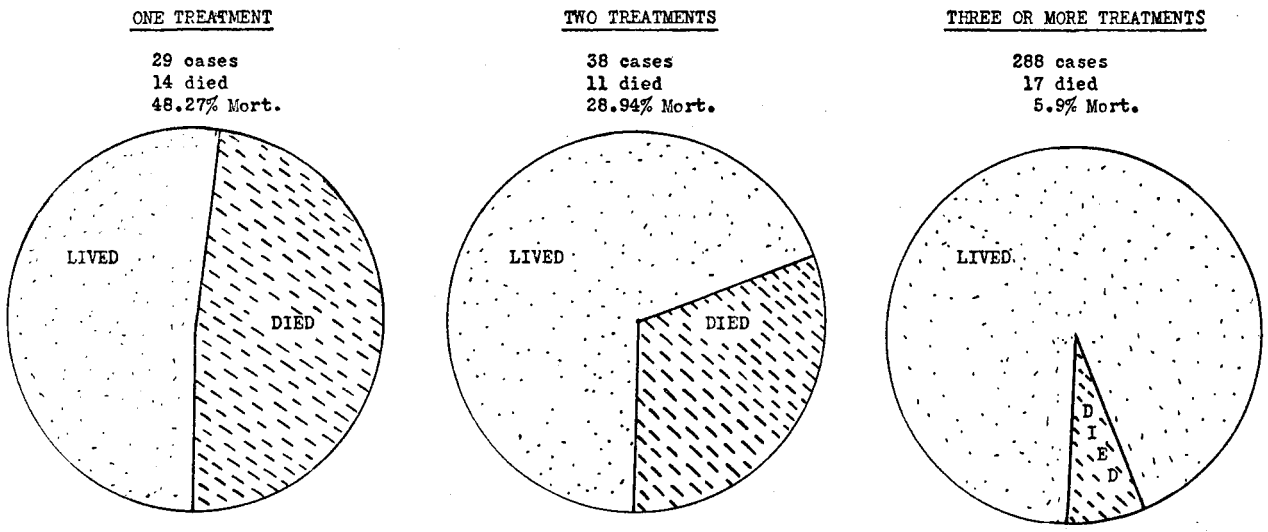

FIG. 50.—Results of x-ray therapy in post-traumatic cases of gas bacillus infection according to the number of treatments. Delay in starting x-ray therapy and failure to repeat treatments are two factors that definitely increase morbidity and mortality. The patient whose treatment is delayed or is not continued throughout the course of the disease has only one-tenth the chance to recover that the patient who receives early and repeated treatments has.

The mortality rate of 5.9 per cent for the cases receiving three or more treatments suggests continuation of the policy of frequent treatments with small doses. This is the lowest mortality rate for any like number of cases of gas bacillus infection treated by any particular method since the disease has been recognized as a distinct entity. By comparison with available reports in the literature, it also proves a definitely lowered morbidity, in that many patients have not lost an arm or a leg. The time has passed when one may boast of a low mortality rate in gas bacillus infections if it has been obtained with a high percentage of amputations or crippling débridement.

Another point is that the correct x-ray technic must be used. An early start with small doses administered frequently is essential if x-ray therapy is to be successful. Use no sulfanilamide.

It must be kept in mind that starting therapy too late permits two changes to occur which can be entirely prevented by early treatment, or their ill effects can be minimized by treatment before the advanced stages are reached: (1) local change, i. e., gangrene of the tissues; (2) distant changes, i. e., toxic action on the heart and other viscera. Another change which may be preventable and is highly desirable, is the prevention of secondary infections. Elimination from the wound of the rapidly growing group of organisms might prevent establishment of the more slowly growing organisms which give rise to osteomyelitis and other complications.

Effect of Multiple X-ray Doses on Morbidity

If the increased number of treatments has so much influence on mortality, what effect will it have in salvaging tissue which has been damaged before treatment is started? Also, what influence does the small frequent dose have on the incidence of secondary infections, particularly osteomyelitis? The relation of the time treatment is started and the onset of the disease may have a greater bearing on this question than the number of treatments given.

Gas Bacillus Infection

Case 22.—H. B., a man aged 23, fell from a third story while on construction work, sustaining a compound fracture of the middle third of the left femur (Fig. 51). The following day, gas bacillus infection

was apparent, and x-ray treatments were given over the proximal end of the thigh and the left side of the abdomen to prevent extension of the infection. The leg was not treated and the patient died.

Since it is the toxemia which kills, all the involved area should be treated, as toxin is being formed in all of the infected tissues. Therefore it is not sufficient to treat only the upper border or

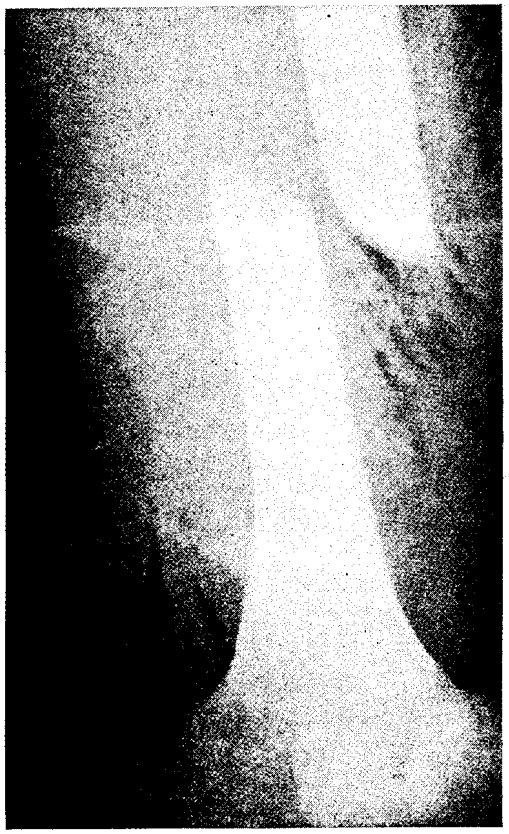

FIG. 51.—Case 22. Compound fracture of the middle third of the left femur, with gas bacillus infection.

just a part of the infected tissue. Treatment must be given above and below the site of injury and wherever toxin formation is deemed possible. In our first report, in 1931, we stated that all suspected tissue should be treated with sufficient kilovoltage to penetrate the area involved and that treatments should be

lus infection and the patient appeared to be in good condition. He died one week later. Postmortem examination showed evidence of active gas bacillus infection which had not been observed by the clinician and had not been reported to the x-ray department.

This is another type of case in which an area of infected tissue is often overlooked. Case 24 also illustrates the necessity of treatment over a long period of time in the diabetic patient because reactivation of the infection may occur. With reactivation, im-

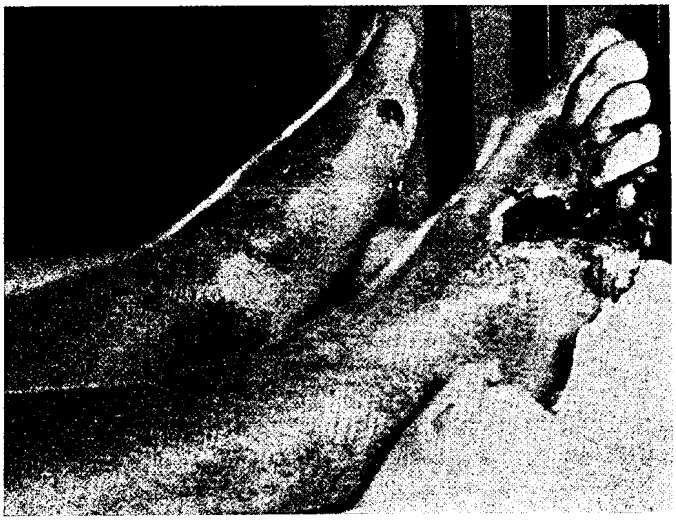

FIG. 54.—Case 24. Typical picture of diabetic gangrenous area on the lower extremity. Gas bacillus was cultured from the wound, but the patient did not become toxic until after amputation.

mediate x-ray treatment is imperative. In the care of these patients, close cooperation of internist, surgeon and radiologist is required, and even then the patient may die. This type belongs in a separate group from those of gas-forming infections following injuries, and its management is much more complicated. One is impressed with the value of x-rays in controlling the toxic condition even though the organisms remain and again become active toxin-producers with each new shock or operation.

Although the mortality has been high in diabetic patients despite x-ray therapy, more experience should definitely lessen this mortality. Because more treatments are required over a long period, the tissues should be protected carefully with adequate filter.

CASE 25.—L. B., a woman aged 47, entered the hospital on January 1, 1940, with a history of diabetes of several years' duration. Blood sugar content was 209.4 mg. per cent. Two months previously, an area of gangrenous tissue had been excised from each foot. The left foot had healed, but the right foot had failed to heal, and on admission the small toe of the right foot was gangrenous and had considerable swelling just proximal to the base of the toe.

X-ray therapy was requested, and two treatments were given the first preoperative day, two treatments on the operative day and one

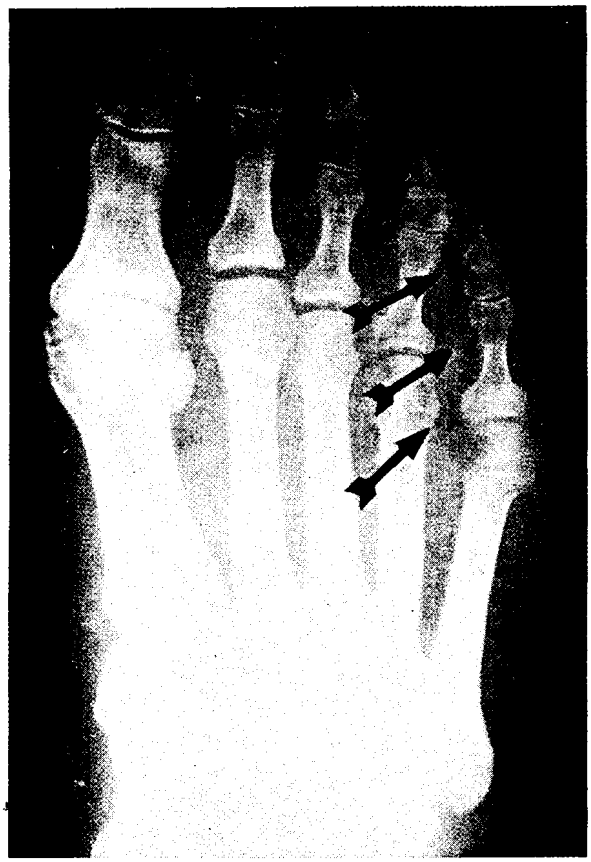

FIG. 55.—Same case as preceding. Small amount of gas in tissues and osteomyelitis of distal end of fifth metatarsal.

treatment daily for the first three postoperative days. The toe was amputated and the pus causing the swelling proximal to the toe was evacuated. The patient made an uneventful convalescence with only low grade fever.

Urinalysis revealed presence of sugar until January 19, two days before dismissal from the hospital. Blood sugar content varied from 266.6 to 123 mg. per cent on January 19. The patient was dismissed on the nineteenth postoperative day with the wound healing well.

This case illustrates the value of prophylactic use of x-rays before gas bacillus infection is evident in a diabetic patient requiring surgery in an infected gangrenous area. X-rays have a definite value in this group of cases.

Probable Changes in Technic

VARIATIONS IN SPACE FACTOR AND DOSAGE

Whether or not it would be advisable to give but one large dose each day and in this way reduce the total number of treatments without reducing the total r units is yet to be decided.

We have data on cases in which, after one prophylactic treatment on admission to the hospital and no further x-ray therapy, gas bacillus infection developed the third or fourth day of hospitalization, with death ensuing the fifth or sixth day. Therefore we feel that one prophylactic treatment with at least 75 to 100 r units is not the proper procedure.

Nevertheless we have records on several moribund patients with fully developed gas bacillus infections who recovered after a single dose of 300 to 500 r units. In that group having but one treatment, all of those who recovered were given more than 50 per cent of the total dose in a single treatment. In contrast, practically all of those in the same group who died received a small dose or less than 30 per cent; some of these undoubtedly died of the injury or were treated too late. Despite this, there is an obvious difference in the results obtained which is to some extent related to the dosage received. In other words, of the 29 who received only one x-ray treatment, 14 died, most of whom received fewer r units in the single dose than did the 15 who survived.

All of the aforementioned cases may be divided into two main groups. Group 1, including those who received one prophylactic dose and died a few days later of gas bacillus infection and those who died after a single relatively small therapeutic dose (less than 200 r), suggests the inadequacy of a single treatment. This conclusion is challenged by the result obtained in group 2, comprised of very sick patients in a late stage who recovered after

one dose in excess of 50 per cent of the total dose. The outstanding difference between the groups was the amount of the dose, those who died receiving a smaller dose than those who recovered. Those who treated patients in group 1 will maintain that one treatment is of no value, while those who treated patients in the second group can maintain that it is not the number of treatments but the amount given that is important and, therefore, that one treatment with a large number of r units is adequate. The questions which arise are: Will one large dose of 60 to 80 per cent do for prophylaxis? Is one justified in giving but one large dose to the patient who has a fully developed infection and giving no additional x-ray treatments? These questions may be answered as more reports appear in the literature and the various factors are recorded with their results. In the meantime, one treatment each day for three days for prophylaxis and two or more treatments each day for three to five days for treatment of the active case is advised because of the excellent results obtained by this technic. There can be no legitimate objection to the administration of numerous doses since the results are so good.

The definite trend toward lower mortality with the increase in the number of treatments is evident in the analysis of all the cases we have on hand (Fig. 50, p. 225), and we intend to use our usual space factors and small doses for both prophylaxis and therapy until some other technic is established.

One hesitates to accept the "high voltage technic" because in a series of cases with involvement of an extremity treated with 200 kv. and copper filter, relatively larger doses (totaling 700 to 1,000 r units) were given before the infection appeared to subside.

The possibility of overpenetration and overfiltration with consequent lessened ionization effect in the irradiated tissues has been our interpretation of the results in this group, but we are not certain of the reason for the slow response. It has, however, been present sufficiently often to attract attention.

In military service or under any circumstances where the time of the next treatment may be uncertain, it is logical to give a larger dose for either prevention or treatment when the opportunity is at hand, attaching some sort of record to the patient, giving the exact day and hour of the treatment and the number of r units given.

With more experience, it is to be expected that there will be alteration of many of the factors now used owing to a better understanding of what dose is necessary under varying conditions of etiology and clinical circumstances.

Summary

One treatment each day for three days is the minimum to be given for prophylaxis. If the disease is suspected or active, the important factors are: (1) two or three treatments each day until the toxemia is under control; (2) treatment of all involved tissues and adjacent tissue; (3) use of adequate kilovoltage to penetrate thoroughly the diseased tissue; (4) use of some filter—the higher the kilovoltage the heavier the filter. If the kilovoltage is too high and the filter too heavy, the response is not so prompt. Finally, one must keep in mind the possibility of reactivation of infection after secondary operations in the ordinary traumatic patient and in all diabetic and aged patients with gangrenous tissue still present after operation, even on the other extremity in the diabetic and aged patient.

The exact details as to kilovoltage, r units, filter and other technical factors for each case can hardly be given; each case must be individualized. Table 20 (p. 223) shows many variations to meet variable clinical requirements. From this one should be able to select an adequate and safe technic. Many of the case histories presented here also include exact data and the technical methods used in treatment; from them additional information about selection of technic is available.

Sulfanilamide is not to be given internally while x-ray treatments are given. If sulfanilamide has been given, x-ray therapy may be started six hours or more after the last dose of the chemical. Serum therapy is not advised for children, aged or diabetic patients.

The foregoing data establish the fact that x-rays present an effective means for preventing and treating gas bacillus infection and provide an almost certain method of treating the condition successfully without any great assistance from other sources. Gas bacillus infection is no longer a disease with a high morbidity and mortality rate, and no longer are any drastic measures or experimental procedures justified for its prevention or treatment in man.

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