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SURGERY OF DIABETIC GANGRENE *

By Eldridge L. Eliason, M.D.

of Philadelphia, Pa.

Diabetic patients with gangrene are bad risks and need exceptional care and attention because of their advanced years, susceptibility to infection, delay in healing, and liability to acidosis. The present series of cases is no exception to that rule. In fact, this, perhaps, more than any other reported series, represents the worse risks possible, in that all of them were patients in a large city hospital, namely, the Philadelphia General Hospital, were of typical ward type, and most of them long unrecognized or untreated cases of diabetes before admission. The surgery was performed chiefly by four of the General Surgical Services.

An attempt is here made to give a statistical review of those cases of gangrene occurring in the diabetic patients in the Metabolic Wards of the above hospital, describing the treatment before, during and after operation. In 1926, the writer, together with Dr. V. W. M. Wright, reported fifty cases of amputation for diabetic gangrene, and at a later date, 1930, added 103 cases to this number. In the present article, further data are given on sixty-seven more cases of amputations. Consideration is given to the infections incident to the vascular disease, the precautions to be taken before and after operation, the type of anæsthesia employed, the specific surgical indications, the mortality, morbidity, and economic results as far as the patients' finally becoming useful citizens.

Incidence of Gangrene.—In the last three years, of 1,305 diabetics admitted to the Philadelphia General Hospital, 175, or 13 per cent., developed gangrene requiring surgery, a high incidence when compared with Allans' figures for the year 1931 at The Mayo Clinic where of 684 diabetic patients only seventeen were operated upon for gangrene. Records are available at the University of Pennsylvania Hospital on 355 diabetics before the year 1923 and before insulin therapy. The per cent. of gangrene in this number was 2.5. In 845 diabetics treated in the same hospital since 1923, the occurrence of gangrene was present in 6.2 per cent. The sex distribution in the above 175 cases was about the same. The ratio of occurrence in the white and Negro patients in this series was as 4 to 1. Fifty per cent. of the patients did not know they had diabetes until admitted to the hospital with gangrene; 96 per cent. of the gangrene occurred in the lower extremities. The average age of these patients was sixty-five years. General statistics throughout the country reveal that 20 to 25 per cent. of diabetic patients die of gangrene.

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Our own follow-up figures show that 58 per cent. of diabetic patients suffering with gangrene are dead within one year. These figures show the reason for the interest in diabetic gangrene, the seriousness of the condition, and why meticulous attention must be given all patients suffering with the condition and all diabetic patients who are apt to develop it. The age of the diabetic patient with gangrene determines to a great extent the prognosis. Gangrene seldom occurs in a youthful diabetic except as an embolic affair. Gangrene is a condition resulting from an inadequate blood supply which is usually the result of endarteritis obliterans.

Every untreated diabetic patient develops arteriosclerosis by the fourth decade. Arterial disease has been shown in diabetics under twenty years of age. Elsewhere it has been shown[1] that the diabetic form of gangrene occurs ten years earlier in life than does the senile form. Autopsies and operations on patients suffering with diabetic gangrene of the lower extremities show that the sclerosis is general, affecting particularly the coronary arteries, which condition is responsible for many of the deaths. Table I shows the comparative age of occurrence of gangrene in the present series and that of six

TABLE I

Occurrence

Status	Year	30–40 %	40–50 %	50–60 %	60–70 %	70–80 %	80–90 %
Occurrence.....	1926	1.8	5.5	52.7	29.1	11	...
Occurrence.....	1929–1932	1.2	8.6	22.0	46.0	18.4	1.8

Note the shift to the right after sixty years of age.

years ago. The vascular condition is the underlying and determining factor in the cause of diabetic gangrene. Joslin, in 1923, found the average age for the development of diabetic gangrene to be sixty-one years. In 1926, we found it to be 59.2 years in ward cases. McKittrick and Root, in 1928, found the average age to be 64.1 years. In 1931, we find that gangrene has been delayed to the average age of 69.9 years. This represented a postponement of gangrene for more than ten years, a distinct advance in the welfare of the diabetic patient. Unfortunately, the figures dropped back to 61.6 in 1932, making an average of about 7 years. While improved results in the treatment of diabetics have of late been justly attributed to insulin therapy, modern surgical principles especially applicable to the diabetic have improved the mortality and morbidity results, as far as diabetic fatalities are concerned. There has been little change in the surgical results. (Table II.)

TABLE II

Age and Incidence of Gangrene

Author	Year	Average Age
Joslin.....	1923	61.0 years
Eliason and Wright (50 cases).....	1926	59.2 years
McKittrick and Root.....	1928	64.9 years
Eliason and Wright (103 cases).....	1931 (1st series)	69.9 years
Eliason (67 cases).....	1932 (2nd series)	61.6 years

The age of the patient should ever be borne in mind in the surgical treatment of these patients. The fact that insulin and other factors have advanced the age of occurrence of gangrene seven years indicates immediately that we are dealing with a worse risk than formerly and therefore must be more radical than ever in its treatment. Temporizing methods are dangerous where tissue resistance, the vascular system, the heart, lungs and the metabolism are in such a state that they easily develop myocardial failure, hypostatic congestion, pneumonia, uræmia and septicæmia, when procrastinating and insufficient surgical measures are adopted. The older the patient and the worse the risk, the more radical must be the surgery if life is to be saved and healing of the wound is to be obtained. Operations should be performed early, quickly, and at a sufficient high level to obtain good blood supply.

Susceptibility to Infection.—Diabetic patients are particularly prone to develop infections, and, what is more to the point, they never bear it well. This is especially true when the infection is closed and undrained. Infection in a diabetic spells hyperglycæmia, acidosis, a poor response to insulin and metabolic therapy, and coma which often results in death. Procrastination in seeking surgical advice or delay in operating in such cases increases the mortality. A diabetic patient with moist gangrene, cellulitis, gas-bacillus or other infectious process, immediately becomes a serious case. Previously easily manageable, he now becomes much more difficult to diet regulation and insulin therapy. In such cases operation is necessary. Once early drainage, excision or amputation of the offending infectious process is accomplished, the temperature, pulse and respiration, acidosis and insulin therapy drop to normal standards.

Because the diabetic is more prone to infection, bears it poorly and responds immediately to the elimination of it, his advisor should be on the watch for early infection and immediately seek the advice of a surgeon acquainted with and interested in diabetic surgery. Such team work results in the best possible management of surgical diabetes. Under these circumstances it can readily be seen that prevention of infection before surgery is necessary and will lower the mortality and morbidity. With this in view, the Metabolic Division has only especially trained nurses in the wards whose business it is to see that their patients have the best of hygienic care, especially of back and feet; when gangrene threatens sterile precautions are applied to that particular part. In addition, a chiropodist is on duty to care for corns, calluses, *etc.*

Conditions Demanding Operation.—From the standpoint of gangrene alone, the conditions demanding operation are, in priority of importance; gas gangrene, gangrene with cellulitis, moist or open gangrene, and dry gangrene. An analysis of our recent cases of gangrene shows that 87 per cent. entered the hospital with moist gangrene or developed it while there. This justifies consideration. Moist gangrene is potentially infected and is soon

followed by local pus and rapidly spreading cellulitis and lymphangitis. Dry gangrene should be kept so.

Gangrene which is demarcated and without visible or clinical signs of infection may be treated conservatively (electric-light cradle or dry dressings). Moist gangrene, however, deserves careful attention as far as antisepsis, and supportive measures (dry heat, dry dressings, or electric cradle) prior to amputation. Since moist gangrene is often followed by cellulitis, it behooves the observer to be on the watch for lymphangitis and cellulitis and to immediately seek early and adequate drainage or high amputation above the line of infection. Procrastination and conservatism are the pitfalls of internists and operators.

Occasionally, gas-bacillus infection enters the picture. Here no delay can be tolerated by the patient. Immunizing treatment and immediate excision or incision must be resorted to within a period of minutes or hours. Speed in the treatment of this dread infection cannot be overemphasized. Disproportionate pulse hurry with either a slight recognizable foul odor or slight subcutaneous crepitations, and with or without the usual late signs of typical discoloration and frothy discharge indicate immediate opening of the wound, or incision, excision and complete drainage of the suspected area. The condition has a high mortality despite the best efforts in treatment.

Preparation of Patient for Operation.—In comparison with past surgical treatment of the surgical diabetic patient, the patient now arrives in the operating room as nearly balanced metabolically as it is possible to make him. Carbohydrate, fluid and insulin requirements have been adjusted as far as possible to lend the patient the reserve, physiologically, that a normal patient has to possess for an operation. Operation is deferred until the metabolic needs are taken care of or improved. A few hours are usually sufficient in which to prepare the patient.

As this part of the care of the patient is entirely in the hands of the metabolist, Dr. Edw. S. Dillon, chief of the department, has kindly outlined the following:

Pre- and Post-operative Care of Diabetic Surgery.—The principle upon which all pre- and post-operative care in diabetes is founded is to see that the patient receives three carbohydrate meals equal to the prescribed amount of carbohydrate in a twenty-four-hour diet. If this is done, and enough insulin administered to keep the blood sugar normal, the patient will not develop ketosis.

Of necessity, during so crucial a time in the diabetic's life, the diet must be light and easily taken. In many cases a concentrated liquid diet will suffice, but in more extreme cases the diet must be administered by tube, hypodermoclysis, or even intravenously.

The Choice of Anæsthesia.—It is a well-known fact that certain anæsthetics tend to produce acidosis. This is a factor in the order of choice of

anæsthetics to be used and the anæsthetics in order of their desirability are as follows:

(1) Local Anæsthesia: Produces no changes in metabolism and is to be preferred in all cases where minor operations are performed and other cases that would not stand a general anæsthetic.

(2) Spinal Anæsthesia: Also causes no disturbance in metabolism and is the anæsthetic of choice born of necessity in operations on the lower extremities, perineum and lower abdomen, providing there is no contra-indication due to the patient's general condition.

(3) Nitrous Oxide Oxygen: Does not tend to produce severe metabolic disturbance unless unduly prolonged. Not a good anæsthetic, however, when relaxation is desired.

(4) Nitrous Oxide supplemented with Ether: Produces better relaxation, more apt to cause acidosis, due to the ether.

(5) Ether: If prolonged it is certain to be followed by acidosis, as indicated by fall in the carbon-dioxide combining power. It can be used, however, if this fact is borne in mind and the necessary post-operative measures taken to combat acidosis.

(6) Chloroform: Produces an extreme acidosis and is mentioned only to be condemned. It should never be used on a diabetic.

As a routine on all surgical diabetics a blood-sugar and carbon-dioxide combining power should be performed on all patients prior to operation. If the CO_2 shows any appreciable drop below normal operation should be deferred until the acidosis has been treated. This is an inviolate rule, even if the operation is designed to remove the cause acting to produce acidosis. A patient will survive the operation, but very often will not survive the acidosis following the operation. On the other hand, if the acidosis is treated first, he will survive them both. A routine blood sugar and CO_2 should be performed within five hours after operation, especially if anæsthetics in groups of 3, 4, and 5 are used.

Insulin.—Granted that the patient has been well standardized before operation, we continue his required dose, increasing it as required when the blood sugar tends to rise. For this reason it is necessary to have daily blood sugars or even sugars at twelve-hour intervals in the more severe diabetics.

Indication for Operation.—In general, it may be stated that the indications for operation are identical with the non-diabetic. The presence of diabetes is not a contra-indication for any operation, providing the pre- and post-operative care can be supervised by one familiar with metabolic treatment. In fact, there are some cases in which the presence of diabetes more strongly indicates prompt operation. Any collection of pus, as the result of infection in a diabetic, demands prompt incision and free drainage, and this is a motto in diabetic surgery. A diabetic's life may be lost in deferring a leg amputation twenty-four hours. The absorption of the products of an infection is attended with decreased carbohydrate tol-

erance and a resulting tendency toward acidosis. Experimentally, pus can be mixed with insulin and injected into a laboratory animal with no hypoglycæmic response, showing the neutralizing effect of pus upon the insulin in the diabetic's body.

In operations upon extremities, incision and drainage of abscesses, the patient receives an enema the night before. In amputations of the lower extremities, spinal anæsthesia is generally used, whereas in the other operations, local or short nitrous oxide oxygen anæsthesia is required. All cases of amputation receive a prophylactic dose of 25 cubic centimetres perfringens antitoxin before operation. The morning of operation the patient receives orange juice, enriched with glucose, with the usual dose of insulin. This is given in the morning at 6 A.M., in order to allow its passage through the stomach, and thus diminish the danger of vomiting when nitrous oxide and oxygen are used. The patient, of course, receives pre-operative morphine and atropine. If not nauseated and vomiting following operation, patient is allowed orange juice. Very often it is advisable to pass a gastroduodenal tube immediately upon the patient's return to the ward, and administer orange juice, glucose and fluids by this route. Of course, if the patient is nauseated and vomiting, the carbohydrate must be administered in saline, either hypodermically or intravenously. Nausea and vomiting should be treated by passing a tube and lavaging the stomach with warm 2 per cent. sodium bicarb.

Fluids.—Fluid intake before and after operation is even more important in diabetic patients than in others. In the latter, one can be content with a daily intake after operation of 2,400 cubic centimetres, but in the diabetic, 3,000 cubic centimetres, or more, are needed during the twenty-four hours preceding and following operation. This avoids dehydration. To accomplish this, a charted amount is administered by mouth, Jutte tube, under the skin or intravenously, and a daily intake and output chart kept as long as needed. Saline or tap water may be supplied by bowel also, but glucose by bowel has been discarded by the author as unreliable in supplying a desired caloric requirement. Blood-sugar determinations before, during and after the administration of glucose by bowel in a series of diabetic cases attest the conclusion that it cannot be relied upon to supply caloric needs.

Specific Treatment.—The local and general care of gangrene depends upon its type and extent as well as upon the general condition of the patient. Dry gangrene, moist gangrene, gangrene complicated by cellulitis or frank pus and gangrene with gas-bacillus infection require different treatment. Temporizing or conservative measures may be adopted with the first, but not with the latter. The author is generally in favor of high (mid-thigh) amputations, but does occasionally perform the Stokes-Gritti and other lower amputations by request or where special circumstances indicate that a low amputation is justifiable.

Dry Gangrene.—Dry gangrene is never considered a condition requiring immediate operation. Because of this, conservative treatment is given.

This consists of an electric-light cradle over the foot of the bed to keep the area dry, maintain warmth, promote good circulation and avoid pressure over the affected part. Simple dry dressings may be used if desired or proved to be more practical. Conservative treatment in these cases permits sufficient time to standardize the patient's metabolic requirements and for the formation of a line of demarcation in these few cases where a low or leg amputation is to be considered.

Moist Gangrene.—Eighty-seven per cent. of the 170 cases were of the moist gangrene type. This figure is entirely too high with our present early detection of diabetes. Advice should be given all diabetic patients, and physicians as well, to avoid moist dressings and ointments at the first sign of an infection or early gangrene. Heat and moisture together are not borne well by diabetic tissues and often an infection or threatened gangrene is made worse by maceration through the popular treatment of hot salt-water dressings or the sealing in of infection by an unguent.

In comparison with the dry form of gangrene the moist type is usually attended by lymphangitis or some cellulitis. Because a diabetic cannot handle infection well it is customary to operate upon these cases as emergencies. Invariably they are operated upon at least within twenty-four hours. Simple dry dressings or the electric-light cradle is used temporarily to treat the condition locally and the extremity is elevated. The patient is fairly standardized by morning as a result of the metabolic treatment previously outlined. All cases of this type should be drained as the stump above the level of gangrene is traversed by lymphatic vessels and veins which have been carrying infection upward. A split tube in the depths of the wound before closing will usually insure adequate drainage. The drain is removed within twenty-four to forty-eight hours. If infection makes its appearance, the wound is opened freely.

Infected Gangrene.—Gangrene complicated by cellulitis or frank pus is a serious condition and should be treated as an emergency. This condition is often the result of neglected moist gangrene and is another indication for early operation in such cases. A diabetic patient with infected gangrene usually presents a high temperature, pulse, respiration, acidosis or impending acidosis, delirium and toxicity. They respond poorly to insulin and metabolis measures. These are the cases that respond so rapidly to incisions, judiciously timed and placed, or high amputation with drainage or the stump left open. It is unwise to wait, here, for standardization of the patient's metabolic condition. One can only delay a few hours to prepare the patient as well as possible for an immediate operation. We only delay if laboratory examinations how the presence of severe acidosis. Then alkalies are administered, glucose and insulin are given in extra amounts until the patient's CO_2 is within or near normal limits. First, a blood-sugar and CO_2 determination are made. This indicates the amount of glucose and insulin that should be given to temporarily tide the patient through the operation and prevent further acidosis. Glucose is given intravenously, insulin

hypodermically and a Jutte tube is passed and left in place for immediate post-operative introduction of lactose and fluids. As these patients, are often delirious or semicomatose, fluid and carbohydrate intake are assured by administration of the same through the tube. When the cellulitis has extended high up the limb, a guillotine amputation left open is indicative.

Gas-bacillus Infection in Gangrene.—Within the last two years we have encountered fourteen cases of gas-bacillus infection in patients with diabetic gangrene. Owing to the susceptibility of diabetic patients to infection, the presence of gas gangrene is even more dreaded than in other patients. Ten of our cases were post-operative complications. Immediate wide excision and drainage or higher amputation must be performed. Where a stump has become infected, it is best to immediately cut all sutures, lay the wound wide open, débride all questionable tissue and irrigate frequently with peroxide or Dakin's solution. Even with the best of treatment the mortality in gas-bacillus infection in diabetics is extremely high. Perfringens antitoxin should be given intravenously and intramuscularly in twenty-five to fifty cubic centimetres doses and repeated as indicated depending upon the individual case. Repeated excision of chocolate-colored and frothy muscle or high amputations may be necessary. The treatment of gas-bacillus infections in diabetics has been extremely disappointing in our hands. The fact that 78 per cent. of our cases with gas infection have died indicates why we feel the way we do. Our present feeling is that, if properly immunized previously, a diabetic stands a fair chance toward recovery. If, on the other hand, he has not been immunized against it, his poor circulatory and physiological condition precludes the results often observed in non-diabetic patients in whom the mortality is not nearly so appalling. During one period when perfringens serum was available, thirty-three of forty-three cases obtained it before amputation; in this number four developed the infection, of which two died.

Operative Consideration.—In considering what operation to perform upon a patient with diabetic gangrene, less consideration should be given as to where and how much gangrene is present, than to how old is the patient, with regard to the vascular disease how old is the gangrene, and how much infection is present. The immediate condition and result should not necessarily take precedence over the future result. Rather should the latter be considered first and then the proper procedure be determined upon. A patient with dry gangrene, in the forty to fifty decade, can often suffer an amputation of a toe and have no further trouble for a number of years. Another, of the same age, with cellulitis and lymphangitis, or still another who is sixty years of age, but with dry gangrene of the foot or ankle will do better, in the long run, with the high amputation. Local and general conditions must be weighed in every case and each should be treated individually, but under broad general and basic principles. Experience shows that, as a general measure, high amputations are preferable. Various statistics and immediate results are often misleading. Careful consideration of post-operative and end-

results frequently shows that preconceived and hoped-for results are not borne out. For example, in amputations performed below the knee the hospital mortality (thirty days) was 56 per cent.; in amputations of the mid-thigh area, the mortality was practically the same, 55.8 per cent. These figures constitute only immediate results and banish the fear that the thigh amputation gives a greater surgical mortality rate. End-results showed, moreover, that none of the high amputations required further surgery, but that in those with operations performed below the knee, multiple surgical intervention was necessary with an increase of 15 to 20 per cent. unfavorable results. It is of interest to note in Table V that in the series of twenty-five deaths, eleven of the cases were noted to have had extension of the gangrenous condition as a causative factor in their death. This, of course, is indicative of poor blood supply at the operative site. If above the knee, it indicated a hopeless situation; if below the knee, it probably meant too low an operative level. In a previous article we have shown that re-amputations or multiple surgical procedures are attended by an increased hospital mortality of 15 per cent. in comparison with primary high amputation. In our recent cases with improved care, the futility of conservative and procrastinating surgery is clearly shown. In selected cases conservative operation is justifiable. As a workable thesis we believe that the lower the amputation the higher the mortality and conversely, the higher the amputation the lower the mortality. In fifteen cases where procrastinating surgery had been performed, there was a mortality of 66.6 per cent. (in comparison with 55.8 per cent.) and 86.5 per cent. unfavorable results, resulting in thigh amputation finally.

Anæsthesia.—Selective spinal anæsthesia is used routinely in gangrene of the lower extremities. Eighty per cent. of the cases were operated upon under spinal anæsthesia, 17 per cent. under local and only 3 per cent. had gas or ether. Spinocaine and novocaine were the agents generally used. By selective spinal anæsthesia is meant the selecting of the level of operation and the placing of the level of anæsthesia to a point just above the operative site instead of the routine administration of trunk anæsthesia. With rare exceptions all thigh amputations had spinal anæsthesia.

When operations are performed with a low blood-pressure, many bleeding vessels are not visualized at the time and consequently are not ligated. This low pressure can be prevented by ephedrin given twenty to thirty minutes before the anæsthesia is administered. When the fallen blood-pressure returns to normal later on, hæmorrhage occurs, and the wound has to be opened or it will often become infected. Local anæsthesia has a tendency to traumatize and so further devitalizes the already weakened tissue; gas anæsthesia is not a safe anæsthetic in old patients with high blood-pressure and arteriosclerosis.

Operative Technic.—After pre-operative consideration, operations should be performed quickly, neatly and thoroughly. Teamwork is essential. A mid-thigh amputation can be performed in a very few minutes. Under low

spinal or a short gas anæsthesia, there is hardly any reason why almost any properly prepared diabetic patient cannot be relieved of a menacing gangrenous limb.

Without a tourniquet the limb should be removed by the transfixion method. Care should be used in not making long and thin antero-posterior flaps. It is best to make the flaps as short as the condition of closure will permit. The transfixion method is much quicker and less traumatizing than the dissecting and prosthetic method. The Gritti-Stokes operation is sometimes used. Rigid hæmostasis is required to prevent hæmatomas that lead to infection. Hot saline irrigations prior to closing both remove all blood-clots and stimulate muscle ends made cold by air exposure. No attempt is made to suture individual muscles to each other, thus avoiding constricting muscle sutures that result in necrosis. Muscle bundles are, however, approximated by fascial sutures and wound compression. Interrupted mattress sutures of iodine catgut insure contact and allow for wound tension. Drainage is inserted and the skin edges are approximated by interrupted silk sutures. The latter have the advantage that if a localized hæmatoma or infection occurs, the wound can be opened at that point by clipping a single suture without detriment to the rest of the wound. A large dressing of loose gauze is then applied to the stump and the operation is completed.

Drainage and Post-operative Dressings.—Infection, latent or present, is often not suspected. Especially is this true in diabetic patients. Since a drain causes no harm and is an excellent insurance if infection be present, it seems desirable. In some cases a drain has been placed in the depths of the wound reaching down to the bond end. This is withdrawn in twenty-four hours if no infection appears. Laterally, however, we have introduced a drain designed to meet physio-anatomical requirements with happy results. This consists of a drain inserted through a stab puncture, before the wound is closed, in such a manner that the tube drains postero-laterally at a point opposite the bone end. As the most comfortable stump position is slight flexion, this method of draining permits postural drainage, comfort and freedom from excretory soiling. Table III shows the incidence of wound infection and the reason why drainage is desirable. In badly infected cases, with cellulitis and lymphangitis, the guillotine operation is employed and no suture used.

TABLE III

Wound Complications

Closed Wounds	Cases	Per Cent.
Clean	49	44.1
Type A (Serum)	13	11.7
Type B (Stitch abscess)	2	1.8
Type C (Break down)	47	42.3+
Totals	111	99.9

NOTE.—Type *C* is the only serious complication jeopardizing wound, increasing hospital stay or endangering life.

Type of Operation.—Seventy-six per cent. of the amputations were in the thigh, 10 per cent. were primarily leg amputations which required a higher operation later, only the lower operation being permitted by the patient or family at first. Minor operations comprised 14 per cent. of the cases which were either too ill or permission was not obtainable for a higher removal. Five of the 175 refused treatment.

Delayed Healing.—Clean wounds in diabetics do not heal as kindly as in non-diabetics. Because of the increased susceptibility and the decreased resistance of the diabetic patient, wound complications in the diabetic occupy a higher ratio than in others. This is a result of local tissue changes which may be divided under the head of altered vascular and metabolic function. Forty-two per cent. of the amputation wounds showed some form of infection resulting in a severe diffuse suppuration. This is a vastly higher incidence of wound infection than occurs in general surgery where it runs from 4 to 6 per cent. Since wound infection has such a high incidence, it behooves us to drain all cases to obtain a dry wound free of blood and serum. From time to time cases are cited that heal perfectly when closed "tight." All too often this does not occur. A small drain to the cut end of the bone does much good and no harm in its twenty-four-hour stay. Experience and statistics bear this out in the present series, but it is only fair to state that other writers close all such wounds with reported good results. These figures are very bad and could be charged possibly to poor technic, but the reader will recall that 87 per cent. of these cases were primarily infected, and hence probably had cellulitis or at least lymphangitis at the site of operation before the incision was made. Studies instituted since this was written have shown in some instances that cultures taken at the time and site of operation have revealed organisms present there similar to the organisms found in the lesion lower down.

Of the serious wound infections (pus) forty were cultured. Table IV shows the prevailing organisms. The high incidence of gas-bacillus infection is attributable to a certain brand of catgut on the market as was proved by laboratory cultures and controls of used and unused material. An occasional case of gas-bacillus infection may be encountered in amputation cases where the patient is incontinent, delirious, or where for other reasons the contents of the intestinal tract have soiled the amputated area before or after operation.

TABLE IV

Type of Wound Infections

Organisms	Cases	Died	Mortality %
B. Welchii	14	11	78
Hæm. Strep.	13	8	60
Strep. Viridan	3	2	66
Staph. Aureus	5	1	20
B. Proteus	3	0	0
B. Diphtheriae	1	0	0
B. Coli	1	0	0

The hæmolytic streptococcus and the *streptococcus viridans* seem to be the organisms most generally dangerous to the diabetic patient. Leaving the incidental gas-bacillus infections out, these two organisms represent 47 per cent. of all infections and are concerned in 95 per cent. of the mortality in the infected cases.

Operative Complications and Results.—Previous to 1927, 37.5 per cent. of the diabetic gangrene patients died of diabetes. This was due partly to the prevailing treatment. Surgical diabetics were admitted directly to the surgical wards and received varying types of surgical and medical treatment. The surgical condition usually received early operative intervention, which was often performed under ether anæsthesia, and starvation before and after operation, which practice only tended to increase acidosis and mortality. The metabolic requirements of the patient were injudiciously handled by a surgeon or an occasional visiting medical consultant. In other words, the surgical condition was treated first and the metabolic condition secondarily, and often inadequately. Neither is sufficient without the other.

The present series of cases represents an entirely different method of treatment. This group was admitted to the metabolic ward, treated there for their diabetes and operated upon after surgical consultation. In the past the surgeon has erred as far as adequate metabolic treatment is concerned. Now that diabetics reach the medical man first, he must not err, as has the surgeon previously, to seek early consultative advice. Whereas teamwork always works for the best, here it is imperative. Procrastination or independence on the part of either the surgeon or metabolist works for only one end-result—increased mortality.

Operations under the older form of surgical treatment (routine starvation before and after operation, ether anæsthesia, low fluid and carbohydrate intake afterward) have been superseded by the elimination of starvation, dehydration and acidosis through proper preliminary standardization, caloric and fluid requirements, spinal or gas anæsthesia and proper metabolic treatment immediately after operation. The latter method makes for a lower incidence of acidosis and of complications, and for better operative results.

Results.—In comparison with results of five years ago, today's results are both disappointing and pleasing. Immediate operative results are no better, but end-results seem to be a little better. Improved metabolic treatment, better preparation of the patient for operation, and improved anæsthesia technic have worked for a much lower mortality due to diabetes *per se*. The reason for poor end-results is accredited to the patient's age. In 1926, the average age of individuals developing gangrene under the then existing form of treatment was 59.2 years. Now that improved metabolic treatment has advanced the age of occurrence of gangrene to 65.6 years, we have a more diseased patient to cope with. Not only is his diabetes in a more advanced stage, but his kidneys, heart, lungs and tissues are much weaker than a decade previously. Added to this (which is the most important) his arterial tree is far more sclerosed than before. As gangrene depends upon inade-

quate circulation and its prognosis upon the arterial tree above, it is obvious that we are dealing with a worse risk than previously.

An analysis of the last five years shows that 42 per cent. of diabetic patients with gangrene died in the hospital and that 55 per cent. were dead within a year. The higher per cent. figures are those including ten cases of gas-bacillus infection. Surely this is not very cheering. Despite these gloomy figures, though, the diabetic patient with gangrene is better off today than five years ago as he lives about seven years longer before gangrene appears.*

Causes of Death.—As stated above, the commonest cause of death in these cases is myocarditis with coronary thrombosis. Many other contributing factors are usually concerned in each case, so that three and four—sometimes five—diseases will appear on their post-mortem sheets. Table V lists the conditions and the frequency of their occurrence in twenty-five deaths as entered on the death certificate.

TABLE V

Causes of Death (25 Consecutive Cases)

Disease	No. Cases
Diabetes	25
Myocarditis	17
Infection (including gas and streptococcus)	8
Gangrene (extension of original process)	11
Sclerosis (advanced)	6
Toxæmia	4
Senile dementia	4
Pneumonia	4
Miscellaneous (decubitus, senility, *etc.*)	8

It will be seen that in eleven of the twenty-five cases, extension of gangrene in the stump was noted. The anterior flap was the one chiefly involved, meaning that this flap had the poorer blood supply. This bears out the observation of the writer made at the time of operation, namely, that more ligatures are necessary in this flap. The literature confirms this in the finding of increase in the size of the arterial trunks in the sciatic tree. This increase is very marked in the supply of the sciatic nerve itself.

Follow-up and Economic Considerations.—In 1926, our operative mortality (twenty-four hours) was 3.6 per cent. and our hospital mortality (thirty days) 43.6 per cent. We had no follow-up at that time. With improved metabolic treatment, anæsthesia and operative technic, we naturally expected a vast improvement. Actual figures, however, show that in 1929-1932 the

* Figures obtained from the University of Pennsylvania records show that the average age at death of all diabetics before insulin in 1923 was thirty-seven years and since the advent of insulin, the average age at death has been fifty-one years, an addition of fourteen years to the diabetic's life. One can easily appreciate when comparing these figures, fourteen with the seven at the Philadelphia General Hospital, the difference in the character of the material at these two hospitals. In both hospitals the post-mortem reports show that circulatory disease has been by far the most pronounced cause of death.

operative mortality is 3.5 per cent. and the hospital mortality (thirty days) is 41.8 per cent.; but the follow-up mortality for one year is 55 per cent., as against 61.1 per cent. years mortality two years ago. The one-year mortality figures include the operative as well as the hospital mortality. (Table VI.)

TABLE VI

Mortality Figures

Year	Operative (24 hours)	Hospital (30 days)	1 Year
?–1926 (50 cases)	3.6%	43.6%	61.1%
1929–1932 (170 cases)	3.5%	41.8%	55.0%

The very nature of our follow-up problem in this class of patients with frequent change of address, many of them foreigners, the wide area of the entire county of Philadelphia to be covered and ofttimes the difficulty of location and time consumed in long distance calls, hampers the collection of data. In the last eighteen-month period (January, 1931 to July, 1932) of sixty-seven cases operated upon, thirty-four cases left the hospital alive, and of these twenty-eight have been followed. (Table VII.)

TABLE VII

Mortality Figures (Continued)

No. Cases	Months after Operation	% Living
28	1– 6	100.0
20	6–12	71.0
8	12–18	28.5
3	18–24	10.4

It is seen from this limited number that only 10.4 per cent. are alive after eighteen months.

Joslin has remarked that a gangrenous diabetic toe costs some one (patient or taxpayers) $500. Conservative treatment and multiple operations with increased mortality and funerals are apt to double this figure to $1,000 without any attending gain of any kind. Logic, it would seem to us, should point out that we must give the subject of diabetic gangrene a careful thought when treating this condition. At the risk of being regarded as radical, the writer wishes to reiterate that in his opinion the best form of treatment in ordinary diabetic gangrene (favorable selected cases excepted) both as regards the immediate and end-result, is an early, high, quick, and drained amputation. Past experience has proven this. In those cases surviving operation the average hospital stay was 62.2 days. The average hospital stay of the entire group of 170 cases was 36.5 days.

The writer is in favor of high amputation. Seventy-six per cent. of the cases were mid-thigh amputations. The reasons for this attitude are (1) multiple operations make for increased mortality; (2) it is generally hopeless to amputate a foot or a leg when the arteries immediately above it are hopelessly diseased and incapable of supplying good circula-

tion; (3) from an economic and functional point of view a thigh stump is preferable. In addition the majority of these patients, because of their advanced years, diabetes and attending complications, rarely do anything in the way of a useful occupation afterwards. Saving them a few inches of extremity, which they will probably never use, at the expense of further operations and increased hospitalization and mortality, seems to be an unwise procedure.

Insulin therapy has been accredited largely with the improved results obtained in the treatment of diabetes and diabetic gangrene. This is possibly only one of several factors which should receive credit. Earlier recognition of diabetes and consequent earlier treatment have improved the status of the diabetic patient immeasurably. This has been brought about by widespread publicity through the radio, newspapers, magazines, health programs, industrial and insurance examinations, and an awakening interest in the public at large in yearly examinations. Because of this the surgeon will see more cases of diabetes in the future demanding his advice. Physicians likewise have been aroused to the benefits of proper dietary régimes and insulin therapy.

All diabetic patients should be warned against infections, cutting corns, calluses, *etc.* Physicians should now be warned against three different things concerning diabetic patients: First, never apply hot wet dressings to gangrenous or infected toes—the poor or absent circulation often results in blisters, infection and moist gangrene; second, never apply ointments to an infected wound in a diabetic—ointments are not necessarily sterile, in fact are most often the reverse—dry dressings and mild dry heat are best in either of the above conditions; third, never fail to call in a surgeon for consultation when infection or possible gangrene threatens.

Many surgeons in the past have erred in the proper medical treatment of surgical diabetics in inadequately caring for their metabolic needs. Now that these patients come to the medical man first and the surgeon only sees the patient when an operation is decided upon, better results should be obtained. Occasionally, the surgeon is called after semisurgical care has been carried out for days or weeks and finds a hopelessly infected case with acidosis. The surgeon and the internist should work hand in hand. Happily, this is the method of treatment at the Philadelphia General Hospital. All patients are admitted to the Metabolic Division and a request for a surgical consultation is immediately answered whenever a condition suggesting surgery appears. The patient is treated pre- and post-operatively in this department where especially trained assistants, a private laboratory and a special diet kitchen are ever waiting to supply his metabolic requirements.

Summary.—A group of 170 diabetic cases operated upon for gangrene has been analyzed. Gangrene affected 13 per cent. of the diabetics in the Philadelphia General Hospital.

Over 95 per cent. of gangrene was in the lower extremity.

Fifty per cent. of the 170 gangrene cases did not know of their diabetes until gangrene occurred.

Open gangrene with infection is the commonest and gives the poorest results, 87 per cent. of this series.

Infection played a part in 95 per cent. of the fatal cases; *B. welchii* and *streptococci* being the chief offenders.

Early surgery in properly prepared diabetics is essential. Pre-operative insulin, carbohydrates, fluids and perfringens antitoxin are necessary.

High amputations (mid-thigh)—76 per cent. were mid-thigh and single—with drainage in infected cases, gave the best results. Transfixion and guillotine methods were the rule without tourniquet. Spinal anæsthesia was used in 80 per cent. of the cases; local in 17 per cent.

Diabetics with gangrene have had seven years added to their lives by modern method of treatment. Operative mortality (twenty-four hours) was 3.5 per cent.; hospital mortality 41.8 per cent.; one year mortality, 55 per cent., in last sixty-seven cases a slight improvement over the previous series.

Hospital days of the entire 170 was 36.5; of the survivals 62.2 days.

Only 10.4 per cent. of these last sixty-seven cases are alive after eighteen months.

Education of the patient, the physician and the surgeon all working as a team is essential for the best results.

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