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Acute hematogenous osteomyelitis

Keith F. Krausnick

University of Nebraska Medical Center

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"ACUTE HEMATOGENOUS OSTEOMYELITIS"

KEITH F. KRAUSNICK

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"ACUTE HEMATOGENOUS OSTEOMYELITIS"

In view of the fact that acute hematogenous osteomyelitis is a clinical entity, and that the treatment of this condition is subject to a great deal of controversy, a study of the subject seems desirable.

This, of necessity, will eliminate all of the chronic osteomyelitis cases, Tuberculous osteomyelitis, and all cases of osteomyelitis following compound fractures.

The number of cases of acute hematogenous osteomyelitis that later develop into chronic cases, with long continued draining sinuses, growth deformities, and bony destruction is appauling. The poor results, in treated cases of acute osteomyelitis, seen on our streets every day is a fact that should stimulate our desire to study more closely and more carefully the causation of this unfortunate condition.

There must be some cause; be it lack of knowledge of pathology, etiology, diagnosis or treatment. The most logical mistake, in these cases, must lie either in the lack of knowledge in diagnosis or treatment. To me the gravest error lies in the methods of treatment. However, it must be remembered that diagnosis is important, and signs and symptoms that make for correct early diagnosis must be understood, before
correct treatment can be instituted.

In this paper I shall attempt to bring out all the important features in the various methods of treatment and evaluate their importance. A relatively short time will be allotted for definition, etiology, pathology, signs and symptoms, diagnosis and complications.

Because many of the bones are near the body surface, infections in them have been seen and discussed from the beginning of recorded surgical observations, and many famous names are associated with the progress of understanding of the various phases of acute osteomyelitis. However, in spite of the great mass of literature dealing with all phases of bone infection, acute osteomyelitis still remains a disease that is usually diagnosed too late to be treated promptly enough to prevent a high mortality rate, long illness, serious complications, permanent deformity and great economic loss. (38)

In view of the fact that an early diagnosis is rarely made in cases of acute osteomyelitis, and that recognized treatment of this condition in the early stages is open to question, it seems desirable that the subject should be reviewed. (40)

When Sir Joseph Lister undertook to apply the discoveries of Pasteur to surgical practice fifty years
ago, he had one definite idea. His idea was that if fermenting micro-organisms could be excluded from wounds and if their activity could be inhibited by antiseptics, putrefaction, pyemia, and the long train of wound complications could be avoided. Time and clinical evidence have proved that he was right. Lister departed from the use of carbolic acid and searched for a universal antiseptic. His second choice was boracic acid.

Since the time of Lister, the usual conception of wound treatment has been that infection must be met and defeated by antiseptics. It should be remembered that infections of all kinds had been successfully overcome long before the time of surgeons or antiseptics. A study of the fossil remains of pre-historic animals reveals the presence of healed lesions of bone and joint infections of many kinds. Out of our present day notion as to the importance of antiseptics, there have developed certain errors in surgical practice for which it is desired to propose a remedy.

Lanfrank, in the 14th. century, had formulated quite definite and fairly successful methods of dealing with simple and infected wounds. He advocated and employed compresses, sutures, and special dressings. He quoted both Galen and Avicenna to emphasize the point that no attempt must be made to close septic wounds until they had been cleaned up.
Lanfrank reports a case in which primary healing occurred and says: "I found the wound and the vein all healed and the father and all the neighbors had great wonder".

It has somehow become a notion prevalent among the laity, as well as current in the profession, that a certain amount of treatment with poultices, packs, irrigations, or antiseptic powders or pastes is necessary to persuade a wound to heal. The healing of a wound without any of these things is usually looked upon as an interesting and unusual phenomenon. The important factors in securing such results are primary asepsis or antisepsis when required, adequate drainage, immobilization, and protection of wound against disturbance and reinfection.

Dr. Singer, in her life of Pare', directs our attention to the methods of wound treatment worked out by Pare' and by his predecessor, Joubert (1570). Joubert was a skilled medical botanist and a learned physician. Toward the end of his life, he employed pure spring water only as his dressings for wounds. Commenting upon this, Pare' said, "As for some empiricks who cure simple wounds merely by application of linen, either dry or soaked in water, and sometimes cure them, it is not necessary to believe there is enchantment, or a miracle, as do idiots and the populace,
but merely in the beneficent action of nature, who cures wounds, ulcers, fractures, and other ills. For the surgeon does no more than aid her by removing the hinderance, as pain, flexion, inflammation, and infirmity or other things that cannot be moved by nature alone .

By the work of Hilton (1807-1878) and Thomas (1834-1891) we are taught the control of inflammatory processes by methods designed to conserve body resistance. Hilton and Thomas, better than any others, have demonstrated the tremendous ability of the body forces to deal with infection. Hilton showed the value of rest in combating chronic or low grade infections. He proved that prolonged rest was the therapeutic agent of importance. Following Hilton, Thomas was the first to work out a satisfactory method and appliances by which rest could be obtained. With the advent of Pasteur and Lister, we had the opportunity which has never been taken advantage of, to apply the principle of rest to the treatment of the more acute and more severe infections. Lister certainly showed us the way to the prevention and to a certain extent, the control of putrefactive and parasitic processes resulting from the invasion of wounds by septic micro-organisms.
It must be understood that Lister conceived of antiseptics as a means of preventing rather than controlling putrefaction. Lister says, "for it is hardly needful to point out that neither the spray nor the carbolic acid externally, nor the oiled lint inserted in the outlet to serve as a drain could correct putrefactive fermentation once established in the abscess cavity. Here, as in the antiseptic treatment generally, the means are calculated to prevent, not to correct, putrefaction". (32)

Acute hematogenous osteomyelitis is a local manifestation of a blood stream infection which is usually transient. (26)(13)(15) The skeletal manifestation is always secondary to a remote infection, the source of which is usually the integument or the mucous membrane of the upper respiratory regions. A bacteremia usually precedes the localization of the infection in the osseous system.

The first skeletal manifestation of the disease is constantly localized in a single metaphysis of one of the long bones of the extremities or in the juxtaepiphyseal region of other bones of the growing skeleton. The primary bone involvement is not in the medullary cavity or cortex of the main shaft. However, it may spread to the neighboring joint and the medullary cavity may be involved. (23)
The condition which we call osteomyelitis is essentially an inflammation of all the structures of the bone, and really should be designated as a peri-osteomyelitis. It seems incredible that an acute infection could be limited to the cancellous bone or to the periosteum, in view of the easy access and free communication between these by means of the Haversian canals and para-epiphyseal line.

Wilensky (43) divides the disease into four groups.
1. Disappearing lesions (a) Uncomplicated.
   (b) With metastasis.
2. Cases in which blood infection is a paramount factor.
3. Cases in which general infection becomes controlled and the outcome depends on the local condition or the intercurrent complications.
   (a) Fatal cases because of complications and
   (b) Cases in which both factors are controlled and recovery follows.
4. Cases in which general infection becomes controlled and the end-result depends entirely on local lesions in the bone. (43)

Crossan quoting Coheur gives this grouping: (8)
1. Septicemic cases in which the patients die in from 3-5 days.
2. Cases with grave pyemia.
3. Benign cases of septic pyemia.
4. Localized osteomyelitis with large sequestra.
5. Localized osteomyelitis with small sequestra.
7. Non-suppurating osteomyelitis.

The most accepted order of frequency of involvement of the metaphysis and juxta-epiphyseal cancellous bone of the growing skeleton is as follows: proximal end of tibia, distal end of femur, distal end of tibia and fibula, proximal end of femur, illeum, proximal end of humerus, distal end of radius, and distal end of humerus. No bone, however, is exempt. (40)

The lesions of acute hematogenous osteomyelitis are, in the large majority of cases at least, due to the presence and action of the pyogenic cocci, the Staphylococcus pyogenes and the Streptococcus pyogenes, and in many of its forms may be regarded as one of the phases of septicemia. (9)

The condition may be "so-called primary or spontaneous", beginning with pain and fever, preferring younger individuals, especially children, often when they are anemic, and when their bony growth is not as yet completed. When the surgeon speaks of acute osteomyelitis, he usually means this "spontaneous" form arising during childhood.

Not rarely these "spontaneous cases", may show
some minor primary condition in another part of the body, such as a furuncle, a panaritium, a phlegmon, an angina, which is the portal of entry of the bone infection.

In other cases, the disease is notoriously secondary to pyemic and infectious disease, is therefore a metastatic inflammation or a pyemic metastasis in the ordinary sense; these infections are particularly scarlet fever, measles, typhoid fever, recurrent fever, small pox, pneumonia, gonorrhea etc. (44)

Among the bacterial inflammatory irritants, the pyogenic cocci merit first consideration.

Particularly in primary spontaneous acute osteomyelitis and periostitis, pyogenic cocci should be suspected; in these conditions, as a rule, the Staphylococcus pyogenes aureus, or the albus, can be found in foci of the bones, and occasionally in the blood. (22)

Kaufmann states that Muller and Klemm believe the classical picture of osteomyelitis is produced only by the Staphylococcus, inasmuch as infection with Streptococci, Pneumococci, and Typhoid bacilli, produce changes in the symptom-complex. Klemm holds that Streptococcic osteomyelitis is less severe, more apt to have cortical foci, or foci in the epiphysis or the epiphyseal borders, so—that loosening of the epiphysis
and exudation into the joints are frequent. The neighborhood of the parts is edematous and shows a tendency to undergo gangrenous destruction, whereas in Staphylococcus infection the tendency is more toward suppuration. (22)

The organized causes of inflammation enter the blood stream and are deposited in the marrow or the periosteum. The passage of bacteria into the blood from primary portal of entry may occur without fever; in fact, the portal, a panaritium, or a furuncle, may even be healed by the time the bone metastasis has manifested itself clinically. From this it can be concluded, that bacteria reach the blood stream and the bone marrow quite frequently even from mild localized infections. In fact, it is known that bacteria enter the blood occasionally through intact external skin, intact mucous membranes, (gums, tonsil, pharynx) and through the intestines, probably only when they are very virulent. For the production of suppurative foci in the bone, the bacteria must have a high degree of virulence, and be present in large numbers; otherwise they are removed. (22)

Trauma and infections are frequently mentioned as predisposing and precipitating factors. Pyrah and Pain (34) in 103 cases, found that 78 had a history of injury within two weeks of the onset. Green and
Shannon (13) found 17% of patients had a history of local injury and 55% had preceding infection and half of the latter were in the respiratory tract. Coheur found a history of trauma in 15 of 19 cases, and in an additional 20 cases there was preceding infection. (8)

Previously it was thought that trauma played a great part in helping to localize the infectious organisms in the bone. Experimentally, osteomyelitis can be produced by subcutaneous injury of a bone, or after ligation of an extremity in young animals, an simultaneous injection of microorganisms of various kinds in the blood stream, particularly the ordinary pyogenic cocci with their metabolic products. (35) The fact that the lower extremity shows a higher percentage than the upper, and the neighborhood of the knee the greatest of the lower extremity, strengthens the view that trauma is important in reducing the bacteriadicidal ability of the tissues, so that bacteria already present or brought there shortly after the injury, are able to multiply vigorously. (22)

As predisposing causes must be considered any factors that have a tendency to lower the resistance of the individual, such as diabetes, nephritis, or exposure to cold. (26)

Trauma plays an important part in the localization of the infection. It lowers the vitality of the patient
and especially that area which becomes the focus. The infection occurs most frequently as a local focus in those areas which are subject most frequently to trauma.

Acute bone infection is pre-eminently a disease of children. It is rare to find the acute process in the adult. The most common age is 2-10 years. (26) But according to Trendel, the curve of frequency increases to the seventeenth year, and then falls rapidly; most of the individuals attacked were between the thirteenth and the seventeenth years. The male sex being much more frequently the victim, possibly because of the trauma factor and frequency of skin infections, percentages for boys 62.3% and for girls 37.7%. (26)

In osteomyelitis there is a tendency to formation of bone abscesses in the early stages, and thickening and sclerosis with the formation of sequestra in the later stages. Porosity may be present, but is not characteristic, and results from non-use. (4)

Acute hematogenous osteomyelitis begins with hyperemia of the marrow, finally accompanied by hemorrhages, and quickly followed by the formation of inflammatory foci, most numerous around the diaphysis, and the zones around the epiphyseal ends; from here it spreads into the shaft, the epiphysis and into the
joints. (9)(22)(36)

At first the exudate is serous or fibrinous, but it soon becomes purulent, the foci taking on a cloudy yellow or green color, while their surroundings become intensively red. When the organisms are less virulent, circumscribed abscesses are formed, which may become encapsulated. Otherwise the suppurative inflammation takes the form of a phlegmon, more infiltrating than liquefying, and spreads quite diffusely. Complete obstruction of the vessels produces necrosis (central necrosis), or (perhaps from toxin effect), (36), sequestra of the marrow, which may lie in the phlegmonous marrow, or in pus cavities. In severer infections the suppuration spreads quickly from the marrow through the Haversian canals of the cortex, to the periosteum. This is then infiltrated with pus and separated from the bone, the subsequent course of events being as in primary periostitis. If the marrow and the periosteum are both diffusely involved (panostitis), total necrosis of an entire bone may occur without actual endostitis. (9) When the epiphysis of young bones are particularly full of foci, or when the diaphysial foci reach the epiphyseal border, the diaphysial cartilage is destroyed, and the epiphysis itself is lifted off, even in a few days. (22)

This loosening of the epiphysis is possible until
about the twentieth year; after this, the cartilage between the diaphysis and the epiphysis disappears since it is no longer necessary for the growth in length of the bones. Shortening and abnormal mobility are the results of this loosening.

Very frequently a sero-fibrinous exudation takes place into the neighboring joints, but if pus accumulates, severe and permanent changes may be produced in these structures. (22)

In the severer cases, which are often called, malignant osteomyelitis, par excellence, the changes may be very rapid and destructive. The medulla is disintegrated and gangrenous; the joints are soon involved; necrosis of large portions of the bone, sometimes the whole shaft, occurs, the periosteum and surrounding parts become gangrenous; the veins contain thrombi, and pyemic infarctions and abscesses may form in various parts of the body. (3)

Starr (40) believes that the firm attachment of the periosteum is a safeguard against direct extension into the joint. It is to him most unlikely that infection will travel through the epiphysis and articular cartilage direct into the joint, and that the joint infection is more often secondary to operation, than as a result of primary extension.
Inasmuch as trauma is one of the deciding factors in location of the disease, the disease is essentially one of an age at which the epiphysis is still unfused.

The history usually, by diligent and patient investigation, reveals, a definite history of injury to the joint or its region. There is usually an interference with function - a limp, for example - which may last for hours or even days. After recovery the patient feels well until local symptoms occur at the site of the trauma.

It may happen that an abrasion is produced at the same time the injury occurs. It is not uncommon for this abrasion or cut to become infected. A very common lesion is a blister on the foot. It is clinically noted, that the bone infection does not manifest itself when the superficial infection is at its height; rather it becomes evident when the superficial lesion is healed or well on the way toward healing. If there has been no skin abrasion, there may have been a fur-uncle.

This type of skin lesion is practically constant in cases of Staphylococcus osteomyelitis, but the lesion may not have been noticed by the patient or his friends, so that a careful investigation must be made for such wounds. In the absence of such wounds, one must
continue his investigation to the mouth, throat and mucous membranes. It is probable that the Streptococcal infections find entrance to the blood stream in these regions.

The first symptom of the infection in the bone is stiffness. This stiffness is interpreted as being in or concerning a joint, and soon reaches the stage at which there is definite pain. This advances to a point where movement of adjacent tissues produce pain, and a rigidity is imposed upon the part, and function is abandoned. At this time general reaction begins to manifest itself by elevation of temperature, by nausea and restlessness. Within twelve hours the pain will have become so severe that sleep is precluded. Temperature and pulse have risen to a considerable height, and the part is guarded against trauma and any movement. There is no remissions of the pain in the first few days. Tenderness is definite. Difficulty in examination makes it difficult to illicit. Early diagnosis depends upon this examination. One must exclude arthritis, rheumatic or septic. In either of these conditions there is synovial involvement, with all its symptoms. In osteomyelitis there is no synovial change in twelve hours. Tenderness is a definite point, and may be demonstrated over the
metaphysis of a bone. This area may be no larger than a five cent piece but it is definite and unchangeable.

During the second twelve hours all symptoms have increased and added to those already present and one may find beginning local change in the soft tissues overlying the involved bone. This local change is first an edema which later becomes reddened, as the infection spreads out to involve the subperiosteal area and the periosteum. In some cases it does not appear until as late as thirty-six hours. Once it is observed it is found to progress towards the shaft of the bone and away from the joint. Without intervention, this progress continues until the entire diaphysis is surrounded by pus, the periosteum being lifted and the epiphysis loosened from the shaft. This is the outcome of an infection of ten days duration or more. (35)

In acute osteomyelitis the onset is sudden sometimes followed by such rapid progress of the disease that delerium and coma may supervene before localizing signs and symptoms are evident. This is not usually the case, but in children it may be the course. Sometimes the onset is much like pneumonia, beginning with a short period of malaise, followed by a chill with high fever, rapid pulse and rise in the leukocyte count. The face is flourid and there is profuse sweating, restlessness, and anxiety. The outstanding symptom is
local pain which is continuous, deep, boring, and severe, and the outstanding sign is exquisite tenderness on pressure over the bone, with increase in discomfort by tapping along the shaft of the affected bone. (38)

In acute cases after twenty-four hours there will often be some edema and tenderness in the soft parts over the involved bone, and suppuration will usually develop in soft tissues if not treated. It is not uncommon to find, after the first twenty-four hours, other bone lesions. Multiplicity of lesions occur in over seventy-five per cent of cases. (38)(35)

If the patient complains of pain over end of bone and is loath to move the limb, if there is tenderness on deep pressure over the bone, as well as signs of acute infectious disease, if the onset of these signs and symptoms has been abrupt and if evidence of infection are rapidly on the increase there will be signs of toxemia, dry tongue, headache, sometimes vomiting, with a pulse rate as high as 120 or 130, a temperature of 103 or 104 degrees F. and a marked leukocytosis as high as 25,000 or 30,000; then a diagnosis of acute osteomyelitis should be made. (16)(38)(40)

In addition to the symptoms described in the previous literature there are the following important signs:
1. Hart speaks of lipuria, known as Hedris' sign. (16)

2. From Dillehunt, (10) "if a child under 13 years is seized with pain in the extremity and he shows loss of function, rise in temperature, and leukocytosis, that child has acute osteomyelitis.

3. Platt designates pain over the metaphysis and intermittent limp. (34)

4. Green and Shannon are of the opinion that x-ray will show rarifaction sooner in infants than in adults. (13)

5. Halderman says that within from 5-7 days the x-ray will show rarifaction if the film is compared to one of the opposite side. (15)

In making a diagnosis, the history is of great importance, and a careful examination of the patient must be made to find out whether or not there is a skin lesion which is just healing or has just healed. In the typical case the patient has sustained an injury which has caused what may be called a sprain, with soreness in the region of the joint for a day; the patient then apparently recovers, but some days later stiffness returns to the joint, and the acute reaction begins. The patient may have injured the metaphysis which was already "seeded", or he may have caused an injury to the metaphysis which later became "seeded". Therefore, in the diagnosis of this condition, one must look for tenderness at the part of the diaphysis that
has been most liable to strain. (36)

In general there should be no delay in beginning treatment as soon as the diagnosis is reasonably established. It is better to expose a bone end and find no infection present than to wait until the involvement of the soft parts or roentgen examination makes the diagnosis more certain. Treatment is directed at two separate points of attack—to drain the site of the infection and to combat the symptoms and support the body of the patient in the fight against infection, an infection which may become a septicemia.

There is a marked difference in the handling of these cases. Drainage is evidently the best type of treatment. The literature presents treatment varying all the way from a purely expectant method, in so far as operative interference is concerned, to the gouging out of a large portion of the covering of the medullary canal or even complete subperiosteal excision of the infected bone.

Most surgeons are neither so conservative nor so radical as this in the treatment of the disease in the early stages. The problem is one of drainage, with as little destruction of bone as possible, and with the saving of periosteum, because it is from the osteogenic layer of the periosteum that most of the repair is to come. The medullary canal is involved later than
the cancellous bone and the periosteum should not be opened unless it is already infected, since exposing the medulla to infection may lead to extension of the infection along this canal.

If the patient is young and the epiphyseal line is involved, it is most important to safeguard the limb against pathologic epiphyseal separation, as this mishap causes deformity and complicates the entire problem of treatment and convalescence.

Treatment does not end with drainage of the infected bone. The limb must be safeguarded and cared for and the patient treated through a long convalescence. The length of time that elapses before recovery is complete varies from a few weeks to many years; this is determined by a number of factors, early diagnosis followed by prompt and efficient drainage being most important. (38) Thus, it is readily understood that surgery is the type of treatment to be used.

The history of surgery divides itself naturally into two periods at the point where Lister adopted the discoveries of Pasteur and devised methods for their application to surgery. A study of the labors and writings of Lister will show that the ideal in his mind and in his work was that of excluding septic infection from wounds.

Osteomyelitis as a clinical entity was first described in about 1854 by Chassaignac, but it had been
mentioned earlier in the United States by Nathan Smith in 1789 and by his son, Nathan R. Smith, in 1834. Heister, in 1739, refers to the incompatibility of fracture immobilization and daily wound dressing.

John Hunter was the first to recognize, in what might be called a scientific way, the marvelous recuperative and reparative powers of nature. It is interesting to compare the folded cloth of Hunter with the eighteen tailed bandage of the ancients; a rather less efficient device than the older one with the same object—easy access to the compound fracture wound.

Ambroise Pare' in the sixteenth century must have had a similar conception in mind in the employment of his celebrated phrase, "Je le pansay. Dieu le gaurit", but he must have had great faith also in some of his fantastic and frequently applied dressings even after having abandoned the boiling oil of his contemporaries.

A recent writer, Myers, calls attention to some of the historical references to devices dealing with compound fractures and infected wounds.

"Infrequent dressings is a corollary of that fundamental principle of absolute rest during the healing process. This principle is not new, for Bellaste, in 1707, said: 'I only dress a wound infrequently convinced that we must give nature leisure to act in re-establishing wounded parts in their former state.' The elder Larrey shows how far he carried the principle of immobility and how little he cared to examine and dress wounds in soft parts by his treatment in the following case: 'This soldier whose arm I amputated
at the shoulder joint, during the terrible battle of Moscow in 1812, at my request set out immediately on his journey homewards, without ever having the stump dressed, in accordance with the assurance that I had given him at his departure that he would not need it.

This brief review of certain phases of surgical practice is not intended in any sense as a history of surgery before Lister's time; it is designed to bring out but one principal point only; this is, that rest has always been considered to be an important factor in the treatment of injuries and inflammations, particularly those of bones and joints. The employment of rest will be found to be referred to in the writings of most of our best surgical writers throughout the entire history of surgery. Methods for the application of rest have always varied, however, and, as has been pointed out, have been subject to modification or discontinuance in the presence of acute infection. Then as now, activity rather than rest has always been the practice whatever may have been the rule.

During the entire pre-Listerian period, that is, up to the middle of the nineteenth century, surgeons exercised very little control over infection in osteomyelitis, compound fractures, and other wounds. Occas-
Even those patients who recovered after long periods of suppurating wounds and with extensive scar or with deformity and disability, were considered to have done well. In spite of the use of oils, balsams, and other antiseptics, hospital gangrene, erysipelas, and other forms of local and general infection prevailed wherever wounds were made or surgical operations were attempted.

It is important to observe that before Lister's time nearly all of these infections and infection complications occurred primarily. That is to say, the infection was introduced at the time of injury or operation. In our own time it has become the custom to do clean operations and to produce infections secondarily at the time of doing so-called antiseptic dressings. Compound fractures then usually led to amputation and amputation very commonly to a fatal termination. Surgical operations for these conditions and for other deformities of the extremities were attempted only rarely and even then were often followed by infection and fatal septicemia.

This was the state of surgery at the time when Pasteur came forward with his announcement in regard to organisms; the discovery which paved the way for Lister's remarkable and valuable contribution to surgical technic.
Pasteur brought forward his discoveries in regard to fermentation and the organisms concerned in this interesting process about 1860. Lister had spent some years already in his study of the factors involved in inflammation and putrefaction in wounds. In his search for an agent that might influence the putrefactive changes in wounds he was directed to the work of Pasteur.

The importance of Pasteur's work was appreciated by three men in particular, Jules Lemaire recognized in some measure the value of carbolic acid as an antiseptic, but his sense of judgement failed to see its limitations. It became to him a panacea for a great diseases. He advocated its use in such a variety of ills that ridicule was poured upon both the substance and its sponsor, and the idea was killed so far as Lemaire and his associates were concerned. Spencer Weil used Pasteur's work and its relation to surgery as the theme for his address at the meeting of the British Medical Association in 1864, but we have no evidence that he carried his ideas, pregnant with possibilities though they were, beyond the stage of hypothesis. The way in which Joseph Lister used the knowledge is a matter of history.
There was great opposition, however, from contemporary surgeons to the methods proposed by Lister. Some refused to accept the germ theory, some claimed equally good results from ordinary cleanliness and many resented the criticism of their methods implied by Lister's teachings. Others soon departed from this teaching, and, whether they influenced Lister's practice or not, the accounts of his work seem to be influenced by this practice on the part of others.

Mr. Rutherford Morison, one of his old assistants, describes the technic employed in the clinics at Kings College about that time:

"One or more large drainage tubes were placed in every wound, catgut ligatures and silk soaked in 1 in 20 carbolic lotion secured the blood vessels and closed the incisions. A strip of green protective dipped in carbolic lotion covered the wound to prevent irritation from the antiseptic in the dressings; over this was placed a pad of carbolic gauze, and covering all was a large dressing of eight layers of carbolic gauze, with a sheet of jaconet between the seventh and eighth layers to prevent blood or discharge from coming directly through the dressing. A bandage of the same gauze, sufficiently adhesive to prevent its slipping, and safety pins, completed the dressing."
"Dressings were changed at once if blood or discharge came through. If not, they might be left on for two or three days. During the time of my service only one wound suppurated. The patient, a man, had had parts of his scapula excised for sarcoma. At the operation the spray broke down and this explained the failure."

Following Lister, especially in America, came the fad for washings, irrigations, and packs with antiseptic solutions. Rubber tubes, wicks, and drains were put in and rivers of bichloride, permanganate, and other antiseptics began to flow. The Carrel-Dakin method, the latest and perhaps the last, the most highly technical and the best of the irrigation methods, has suffered in a manner similar to Listerism from enthusiastic but inefficient and misapplied methods, so have our modern Carrel-Dakinites applied Dakin packs, poultices, and fomentations to wounds only to have them become ineffective and even harmful in a short time because they comply with none of the technical requirements of the originators of the method.

In so far as wound treatment is concerned, the period from Lister to the Great War was devoted to a search for the ideal antiseptic; that is to say, an antiseptic that might inhibit germ growth without
damaging the tissues. It is hardly necessary to say that the search has failed. Not only so, but, as has been pointed out, the attempts to sterilize and disinfect wounds have led to undue disturbance and infection, loss of position in fractures, numberless contracture deformities, and disability beyond computation.

Among those who followed Lister rather more closely than the average in these respects was Dr. F. S. Dennis of New York. In 1884 he reported a series of compound fractures with a high percentage of recoveries. Some of these were fractures of the skull and of the jaw. If we select those which more nearly illustrate the point we now desire to discuss, we find that he had sixty-one cases of compound fracture of the leg and of the thigh.

Dr. Dennis has shown us in many ways that he was a surgeon of exceptional skill and industry. In these compound fractures he not only did what we now call primary debridement and employed antiseptics in his preliminary operation, but he place the injured limbs in plaster-of-Paris casts as an immobilizing dressing. His instructions to his ambulance surgeons were that these patients were to be irrigated with antiseptics and dressed before being lifted into the ambulance from the place of injury. Of the sixty-one cases which Dr. Dennis reported in this manner three patients died, twelve were amputated, and five had been under treatment for less than one month at the time of making his report. This
gives us forty-one cases in which we know patients recovered.

In applying the plaster-of-Paris casts Dr. Dennis left large windows with the wounds entirely open so that drainage was allowed to flow freely out of the wound and out of the window in the cast without any interference by pads, packs, tubes, or dressings. It was Dr. Dennis' opinion that a freely suppurating surface was a better protection for the patient against the invasion of new infection than dressings in the manner that was then employed. If the granulations were weak and flabby he employed flaxseed and carbolic poultries and afterward stimulating dressings such as Balsam of Peru, iodoform, bismuth, and oxide of zinc. Around the edges of the window in the cast he packed cotton which was changed as occasion required. The limb in the cast was suspended in a Fluhrer swing, a device not very different from our modern Balkan frame. Frequent changes in the cast were made as seemed to be necessary on account of swelling or inflammatory complications. It is quite apparent that Dr. Dennis maintained for his patients a much more efficient plan of immobilization than the average surgeon even at the present time. It seems to be that this had more to do than anything else with his rather remarkable success in such cases. We have observed that immobilization,
even in the presence of active infection and suppurating wounds, will contribute much to the union of fractures and the healing of the wounds. This was a point which was frequently emphasized by the present writer in dealing with compound fracture patients who in 1918 were being dressed for transportation from France to the United States.

Before the introduction of the Lister antiseptic treatment, the death rate in compound fractures was reported to be all the way from 26 to 68%. In a later report in 1886, Dennis reported a series of 500 cases with still no deaths from septic infection. It is important to note, however, that the percentage of amputations were very high. From reading the details of some of his individual cases one must infer also that disability and deformity were of rather frequent occurrence. If we are able to show, that adequate splinting and protection of the wound are the matters of primary importance, rather than provision for dressings regardless of the fracture, we shall then be in a position to urge all of our surgeons to make that definite provision for position, traction, and immobilization which are the fundamentals of fracture treatment.

In the field we speak of as aseptic surgery, the
teachings of Lister have been excellently applied. Except in the hands of inexperienced and unqualified surgeons our clean operations are really clean and primary healing is the rule. In the field of antiseptic surgery, however, the story is an entirely different one. If an operative wound becomes infected, or if we have to do with a septic wound from the beginning, even the best surgeons or their assistants have carried into the wounds every variety of secondary or mixed infection under the pretext of doing antiseptic dressings. The infected wound requires protection, no less than the primary aseptic one, from soiled fingers, instruments, and dressings, a rule that up to now has been honored far more in the breach than in the observance.

It would seem that the success of the Lister method should have led us earlier and more completely to depend upon the natural defenses of the body to take care of the certain amounts of infection. It is quite obvious that Lister's method could do no more than to exclude a certain amount and not all of the infection. If Lister's immediate followers had concentrated as he did upon the problem of excluding infection rather than upon that of attempting to sterilize the wound, or clean up infection by means of antiseptics, it seems quite certain that we
should have progressed further than we have in dealing with these conditions.

The time may come, of course, when we shall have methods for measuring the amount or the virulence of infections and our capacity for resistance. Until that time it seems important for us to adopt every expedient that offers to close the avenues by which infection may get into our bodies and to increase our resistance by all the methods with which we are familiar.

One of the important points to bear in mind in connection with Lister's contribution to surgery is that while all of his work was done around a single point—namely, the exclusion of septic organisms from wounds—he had not failed to be impressed with the importance of the employment of rest in surgery also. It may be said that if the ancients had possessed the information to enable them to keep infection out of wounds, their methods of rest would have been sufficient to secure the same excellent results that Lister obtained.

Immediate "reduction" of the fracture and the adjacent soft parts and adequate immobilization of all the parts in correct position are the primary essentials in compound as in simple fractures. In fact, not even debridement or drainage operations should be done until such reduction and immobilization have been accomplished.
Then, with the parts in correct position and at rest, the operation required may be carried through with a minimum of further damage, and without any further change or loss of position the immobilizing device which is to carry the patient through to recovery may be put on.

The "bismuth paste" methods of Beck and Morison were early signs pointing in the direction of the new era in the treatment of osteomyelitis. They had already led us to a considerable modification of antiseptic wound technic when the apparent breakdown of all antiseptic methods led to their general rejection. There were also a few cases of bismuth poisoning to suggest again the inadvisability of direct chemical applications to wound surfaces. Custom bound us, however, to the use of chemical antiseptics in the wounds and usually frequent dressings. The suggestions of both Beck and Morison are entitled to the greatest respect because they served to remind us of Lister's teachings as to the importance of bacterial exclusion. Now we have found that a non-antiseptic mass will serve as well to keep out infection and that immobilization and protection for long periods may be added to contribute to the patient's comfort and recovery.

The "Bipp" method of Morison was described as follows:
"The bismuth paste treatment gives remarkable success in cases of wounds which are not associated with deep cellulitis. In the case of a ragged deep lacerated wound, the patient is given a general anesthetic; the skin is sterilized; the wound is freely opened so as to expose all of its recesses, all bleeding is checked and all foreign matter is removed; the wound is thoroughly washed with hypochlorite solution, followed by normal salt solution, or, better, it is simply mopped out with a paste of bismut subnitrate (1 part), iodoform (1 or 2 parts), and enough liquid paraffin to make a thick paste, having the consistency of soft butter.

"The paste is spread over the wound surface and made to fill every crevice. Over the wound a dry gauze dressing is applied and held in position by adhesive plaster and bandage. No change of dressing is required for several days or a week. The dressing may remain sometimes two or three weeks without changing, the discharge should be wiped from the skin with alcohol, some more of the paste applied to the skin, and a fresh covering of gauze put on. The past is called "Bipp".

Even at the present time, new substances are being heralded as the final and most perfect chemicals for antiseptic wound treatment, but until we can poison the germs without poisoning the tissues, traumatize the
wound surface without injuring the patient, and disturb the injured part without interfering with position for fracture repair, present methods of antiseptic wound treatment will do more harm than good.

In the above references are found a considerable number of the suggestions and methods that indicate the approach of a new era as well as a number of others before the war period indicated a trend away from the antiseptic method and toward the new era. The modification of the Lister method already described and our experience during the Great War were quite sufficient to indicate that satisfactory results with the antiseptic method for infected wounds were not being obtained.

In compound fractures as well as in other forms of osteomyelitis it was plain that much damage was being done by the over-zealous use of complicated technical methods. Adequate drainage had been sufficiently urged and by all our best surgeons was being properly employed. The Carrel-Dakin method was offered during the early part of the war as a solution of the difficulties that had been experienced in the employment of active antisepsis. This highly technical method certainly had the effect of cleaning up wounds and saving lives. As a method of active antisepsis the Carrel-Dakin method
justified itself even in spite of its technical difficulty. To one trained in orthopedic surgery, however, the experience of this entire period indicated that the principle of rest was being disregarded to too great an extent in this method as well as in some of the less efficient methods of the employment of antiseptic solutions, and in actual practice they all violated the teachings of Lister.

One of the most striking and most important steps taken in the direction away from the antiseptic method was the more extensive adoption during the war period of the method of primary closure. It had long been known that certain types of compound fractures might be dressed splints and permitted to heal primarily, just like simple fractures. It had been assumed that in these cases little or no infection had been introduced, and that antiseptic treatment could be omitted. From this to the method of debridement and primary closure was a short step and a considerable number of successful cases began to be reported.

The underlying features of a successful treatment are, first, keep the main portions of the injured bone in correct position; second, to remove all infected foreign bodies as far as possible, all grossly infected tissues; third, to counteract any infection which has
already occurred and to prevent fresh infection. It is from this last position that we make our departure in the Orr method of treatment. We do not try to "counteract any infection which has already occurred" or arrange the parts and the splint so that we can "make frequent changes and dressings" or employ "frequently repeated or continuous methods which remove septic discharges", having shown that these things are not only unnecessary but harmful. Neither primary nor secondary closure are appropriate or suitable for a large percentage of compound fractures, and seldom or never for osteomyelitis. One of the points particularly emphasized in the Orr Method is that pockets of pus or infection should never be covered over so as to become enclosed and make trouble later on. What we have done in our method is to take the next step for wounds that obviously cannot be closed by primary methods and perform what may be called an artificial closure of a septic wound by a sterile non-absorbent pack that permits healing from the bottom toward the surface without enclosing infection or interfering with drainage until healing has occurred. In our own experience, therefore, to find a more satisfactory method of treatment than by active antiseptics, we continue to use plaster-of-Paris, taking more pains
than before to apply efficient, well fitting comfortable casts. By employing such methods we found that our patients were doing better, not only as to the fractures but in respect to the wounds as well. From this point gradual progress has been made in the development of our method which is to be described.

The method, often called the Orr Method is one of drainage and rest. The details are as follows:

1. As a preliminary to any operative procedure we immobilize the patient on a traction table with all of the injured parts in as nearly as possible correct anatomical position. For fractures or old contracture deformities this may call for preliminary manipulative correction or skeletal traction or both. The patient is so arranged that, good position having been obtained, the operation may be carried through and plaster-of-Paris applied without motion of the injured or inflamed parts, and so that the position obtained will not be disturbed in any way during the post-operative care.

2. The entire infected area is opened up and drained by a suitable operation. Foreign material and dead or dying tissue are removed. As part of the debridement or drainage operation the wound may be wiped out at the end with iodin (pure tincture) and
alcohol, or some other efficient antiseptic.

3. Protection of the wound and permanent drainage are provided at the same time by a non-absorbent, non-irritating vaselin pack which will keep open all parts of the wound covered by flaps, sutures, or other devices.

The vaselin pack must not only be carried to the depths of the wound, but it must flow over the edges at the top to a distance of an inch or so around the wound, and the wound dressing completed by a dry sterile absorbent pad bandaged firmly over the entire area.

4. The affected part is enclosed in a well fitting plaster-of-Paris cast, or some other efficient immobilizing device. In case of fractures or other conditions in which highly efficient traction and fixation are desired, moleskin adhesive plaster, ice tongs, Steinman pins, or pins directly into the fracture fragments are inserted and the ends included in the cast for better control of the part and the patient. Casts must be well fitting and sufficiently extensive to overcome, once and for all, muscle spasm and irritative motion of all kinds.

5. Finally, no post-operative dressings in the usual sense are done. If immobilizing devices become
inefficient, if discharge is profuse, or if odor (because of mixed infection) becomes unendurable, dressings are changed usually in the operating room without disturbance of the part and with a minimum of damage to the wound surface.

THE ORR METHOD IN OSTEOMYELITIS, COMPOUND FRACTURES AND OTHER INFECTIONS.

Outline.

1. Immobilize patient in best position on operating table.
2. Do a thorough debridement or drainage operation.
3. Pack entire wound open with vaselin gauze, using no suture or drainage tubes.
4. Apply extensive well fitting plaster-of-Paris cast.
5. Do not disturb the wound or the part except for definite complications.

Preliminary.

a. Secure best position possible by traction, manipulation, etc.
b. Use the simplest and least possible number of movements.
c. Employ moleskin traction, pins, or ice tongs if necessary and include them all in the cast.
d. Do not remove bony or soft parts that may contribute to repair.
The Operation.

a. Make an incision or opening that will thoroughly uncover (saucerize) the infected area.
b. Remove as much foreign material and dead or dying tissue as possible.
c. Do not curette or damage healing and protective portions of the wound cavity.
d. Do not remove bony or soft parts that may contribute to repair.
e. Wipe out with iodine and alcohol.

The Closure.

a. Fill entire cavity with vaseline gauze pack from the entire depths to the surface of the wound. Pack gently but firmly.
b. Use no drainage tubes or other mechanical irritants.
c. Use no chemicals as a dressing.
d. Do not suture or cover any infected areas with flaps.
e. Cover with a dry, sterile, absorbent pad.

The Splint.

a. Immobilize the affected part in such a manner that no muscle spasm or contracture can occur.
b. Plaster-of-Paris, well fitting and extensive, has been found to be most satisfactory.
c. Moleskin adhesive straps or skeletal fixation devices to be included in the cast will insure fixation.
The Dressing.

a. Plaster-of-Paris casts are applied so as not to be fenestrated or split. In this way the temptation to inspect or dress the wound is prevented.

b. Secondary dressings, when done, should be done in the operating room and aseptically.

c. The injured part is not to be moved nor the wound surface to be damaged.

d. Do not hesitate to employ anesthetics for secondary dressings.

e. Make late dressings as infrequent as early ones.

Dr. Orr found that a distinction between the present and the long standing cases was of less importance than it seemed at first. The only really important point is that those patients who can be operated upon before mixed infection has occurred recover more readily and with fewer complications than those who must be treated later. If the patient has survived the first acute attack, however, even if secondary mixed infection has occurred, adequate drainage, protection of the wound and immobilization of the parts will often lead to very early and very complete success in obtaining healing. (33)
Kulowski (25) writes that an analysis of the "Orr Method" of treatment in 130 cases of osteomyelitis has proved conclusively to him to be the method of choice in the treatment of osteomyelitis. The Orr method may be accurately called the gospel of adequate drainage and adequate immobilization. This is surgically accomplished after the diagnosis is made. Technically it means an adequate approach to the bone, saucerization, and removal of all the involved portions of bone; the insertion, lightly of a generous vaselin pack; and the application of a cast, in a neutral position of the limb, which immobilizes the joints below and above the involved area.

To prevent secondary infection is the second great aim of this treatment. This is successfully accomplished by the principle of non-interference with the post-operative wound.

There should be no hesitancy or timidity in the prolonged use of plaster immobilization. The excellent end results, the absence of post-operative pain and temperature, overwhelmingly overshadow the occasional atrophy and stiffness that may result.

Of 130 unselected cases, ninety-nine completely healed. The general average time of healing was seven and fifty-eight hundredths months. Those patients
who were operated on primarily by Orr method healed in six and twenty-one hundredths months. Those cases treated secondarily by the Orr method healed in eight and ninety-five hundredths months.

The Orr method is recommended as a routine procedure in the treatment of osteomyelitis because:
1. It is based on the principles of adequate drainage and adequate immobilization.
2. It is painless, economic, universal method, applicable in any stage of the disease.
3. Hospitalization is greatly decreased.
4. Transportation of the patient is simplified.
5. It prevents sequestration.
6. The general condition of the patient is improved.
7. Good functional end results are obtained.
8. Minimizes loss of limb by amputation.
9. Death rate is insignificant.
10. It is the only treatment that satisfies all the tenets of Orthopaedic surgery.
11. It is a procedure suitable for the rank and file of the profession.
12. Shortens post-operative course which previous to Orr method was in many cases intractable.

Hobart and Miller (18) compiled from Cook County Hospital cases of acute osteomyelitis that were treated by the Orr method. Proper drainage and rest were the
important principles as basis for the treatment. The cases were opened widely and debrided, but cautiously with an attempt to prevent further extension into the normal bone. Petrolatum packs were inserted loosely and a cast applied. The cast was left on until healing occurred, but occasionally a new one is put on. Sinuses of the soft tissues were curetted and allowed to heal from the bottom.

Although the number of reported cases is relatively small, the end results of this method were gratifying. It was difficult to judge the healing powers of the various bones, the period of convalescence in healing and the general response of the patient because of the variability of technic, the period of operability and the virulence of the organisms in the production of osteomyelitis. All that can be said is that this method has given 62% symptom-free cases, with about 20% fail. Those cases treated by some other method or modification gave only 12.5% cures.

In conclusion to their study of the Orr Method Hobart and Miller decided:

1. The Orr Method of treatment still remains the treatment of choice for osteomyelitis.
2. Hematogenous osteomyelitis shows no great advancement of cure, whereas direct osteomyelitis responds well.
Dr. Fraser B. Gurd (14) of Montreal Canada during the World War made extensive studies on the treatment of compound fractures and osteomyelitis. He finally, after much controversy, came to the conclusion that the following method of treatment would give the best results.

For the prevention and elimination of infection and cellulitis, he employs a technique, in the hope that the following desiderata may be obtained:

1. Avoidance of Suitable Pabulum for Bacterial Growth.
   a. Excision of devitalized tissue.
   b. Prevention of accumulation of exudate and blood.

   a. Avoidance of interstiteal tension.
      1. Incision of skin and fascia.
      2. Evacuation of exudate and transudate.
         a. Obliteration of dead spaces.
         b. Curtain drainage.
   b. Rest—fixation.
      2. Splints.
      3. Tractor.
   c. Posture—gravity to assist venous and lymphatic drainage.
Ill. Chemical Inhibition of Bacterial Growth.
   a. Saprophytic bacteria.
      1. Iodoform.
      2. Bismuth.

   b. Pathogenic bacteria.
      1. Iodoform.
      2. Bismuth.

IV. Stimulation of Tissue Reaction—Serous and Cellular.
   a. Iodoform.
   b. Bismuth.
   c. Liquid Paraffin.

Since his studies during the war Gurd (14) has used essentially the same technique as above for his cases of acute hematogenous osteomyelitis. The essential features of his technique are:
1. Incision of the tissues beyond the site of manifest inflammatory changes.
2. Adequate exposure of all suppurative loculi and interstices in the tissues.
3. Careful and complete removal of all dead or devitalized tissue.
4. Proper bipping (use of bismuth, iodoform, and paraffin paste), of the wound and careful packing with liquid paraffin soaked, bipped gauze.
The paraffin packing is introduced in such a way that all deep-seated cavities are brought into communication with the surface.

Such a method of treatment results in lessening of pain and discomfort; the number of dressings, required is reduced; and since the dressings are carried out under anesthetic, there is less suffering on the part of the patient and more adequate treatment of the wound.

It has been taken for granted that dehydration, shock, etc., has been treated either before or at the same time as operation. (14)

Since 1923 when the Orr Method of treating wounds of the skeletal system became known there has been a great many attempts to modify and improve this method, as yet there seems to be no better method that gives such a remarkable percentage of cures.

In view of long continued search it seems scarcely possible that a method of wound treatment, which may completely revolutionize all our previous concepts, could be devised; yet the bacteriophage seems to be just such a method.

Osteomyelitis is one of the most common types of bone infection encountered by the surgeon today. Nearly everyone is familiar with treatment of this condition as proposed by Orr. Soon after the operation the patients
temperature dropped to normal, and upon removal of the cast, the wound was found to be covered with red healthy granulation tissue. Orr explained his startling results on the basis of rest, immobilization, and avoidance of reinfection by repeated dressings.

However, to Albee (1), this explanation did not seem to entirely account for the marked success of the treatment. Some unusual phenomenon must be taking place. D'Herelle of Yale had in 1921 discovered a microscopic parasite which appeared spontaneously and killed the bacteria. This he called the "bacteriophage" because it lived on the pathogenic bacteria and completely lysed them.

This phenomenon had, it seemed a similarity to the processes occurring in Orr's treatment of osteomyelitis.

D'Herelle demonstrated by laboratory experiment that these bacteriophages appeared spontaneously and that there was several varieties or races of the phage, for each type of bacteria.

When one closes up the wound with paraffin vaselin and plaster it is infected and discharging pus. When one removes the dressing eight weeks later, the wound is clean and healthy. Whatever agent clears out the offending infection appears spontaneously. Is it not logical to assume that the phage principle has been
working in the wound, that a native bacteriophage has multiplied and become active under the long-continued dressing? (1)

With this hypothesis, Albee (1) started to use this treatment in all cases of osteomyelitis. It was established, by laboratory and clinical tests that a specific phage did appear in 34% of cases. In three of the remaining six percent the laboratory furnished the necessary phage. In the other 3% no specific phage could be produced. However, with perfection of laboratory methods and technic, it may be possible to isolate races of phages specific for all bacteria in all cases.

In cases of osteomyelitis, the method followed in treatment is as follows:

Alcohol or iodin is not used, lest it interfere with the development of the phage or with the specific laboratory phage after its introduction.

The usual sequestrectomy and saucerization are completed, and a culture is taken. (If a specific phage has already been found, two-thirds of a test tube of phage is poured into and over the wound, so the whole surface is bathed.) The wound is packed with a paraffin and vaselin mixture, usually 75% paraffin to 25% vaselin; or in cases where the wound is deep and made through heavy muscle, 90% paraffin to 10% vaselin. The mixture
is poured in as a liquid or a syringe is used to force the material into the innermost recesses of the wound.

One end of a rubber catheter is inserted through the paraffin-vaselin mixture to the bottom of the wound. Thus, if a laboratory phage is produced it can be injected into the wound in 10cc amounts twice a week. In large wounds several catheters can be used. The phage will, because it is a multiplying organism, spread over the wound surfaces.

At the end of eight weeks the cast is removed and the wound dressed, being careful not to traumatize the granulating surfaces. The wound edges are gently wiped off and cleaned with benzin.

If the wound is not entirely healed the treatment is repeated for a second eight week period. A culture is taken to determine if bacterial flora has changed, or if a more specific phage can be obtained.

A statistical study of 100 consecutive cases treated by this method, show the average healing time for osteomyelitis to be about six months. Three casts are applied at eight week intervals, and after removal of the third, weekly dry dressings are done until skin healing takes place. The Staphylococcus was the most prominent organism. The flora changed in 23% of cases, usually to a more favorable type of organism, resulting in rapid healing. (2)
Those cases in which a native phage develops usually do very well without the insertion of a laboratory-bred phage. However, it is wise to inject periodically a race of phage of highest potency, in order to have at work for the maximum period of time a phage of the highest specificity. In this way, any possible decrease in potency of the native phage, is offset.

Summary of advantages of this treatment.
1. Simple in application, requiring a minimum amount of labor on the part of surgeon and staff.
2. Does not interfere with immobilization of the part.
3. Does not offer frequent and possible injury to granulation tissue.
4. Avoids reinfection to large extent.
5. Method favorable for appearance of native phage and introduction of laboratory phage.
6. Requires short hospitalization period.

The bacteriophage will eventually become one of the surgeons important weapons against infection. Its potency has become so widely recognized that India and Brazil have passed laws that it be kept constantly on hand for use in certain diseases. This phase of bacteriology will have a profound influence on the future treatment of surgical infections. (1)(2)
The principle argument advanced against conservative treatment is the theory of the pathology of the disease. It is alleged that all these infections arise in the metaphysis, from which points, because of compression by the rigid bony cortex, there is spread throughout the medulla. Emphasis is placed on the dissemination because it destroys bone and also as the pus tension increases with the spread, sepsis will be multiplied. The choice between radical and conservative treatment will depend to some extent on the validity of that theory.

Crossan (7) believes that location of pus should be good evidence as to the origin of the pus. In 117 cases recorded at Episcopal Hospital there was only 12 that had a record or a solitary intraosseous collection. In a total of 24 cases there was pus in the medulla but in all of these there was also pus in the subperiosteal space. That now leaves 81 cases; pus was found in the subperiosteal space in all of these cases. In 42 of these, for one reason or another, the bone was not opened. In the other 39 cases the medulla was exposed and no pus found. These 39 cases furnish evidence that many cases of acute hematogenous osteomyelitis start outside the cortex. To summarize; 81 cases just discussed plus 24 previously mentioned makes a total of 105 cases out of 117 studied, in which
there was pus beneath the periosteum. If this be not an argument against intra-osseous origin of the infection, then it does become evident that the pus finds an exit, that decompression occurs, and that spread of the infection can be limited without surgical intervention.

In four cases which were operated on within 48 hours of the onset of symptoms, and in all four there was no pus in the medulla though there was pus in the subperiosteal space. Thus, again pointing to extracortical origin of pus.

The origin of the disease is of importance in the determination of spread of infection. In those cases where the pus is formed outside the bone, there will not be any rapid spread within the medulla. Not quite so obvious, it is equally true that there need be no wild-fire contamination of the medulla in every case where the pus is within the bone and confined in it. It seems that spontaneous decompression of the bone is an actual occurrence and that it can thereby limit spread of infection.

These arguments offer evidence that many infections in acute hematogenous osteomyelitis do arise outside the medulla—thus, the basis for radical treatment in every case of the disease is not a sound theory.
The proponent of conservative treatment must discredit the basis for radical treatment but must also show that it is harmful. (7) That it could be dangerous where there is localized subperiosteal pus needs no argument since exposure of the medulla would carry infection from the contaminated area into clean tissue. From a study of the 39 cases where exposure of the clean medulla was done through subperiosteal pus, there was a mortality of 40% after drilling and 35% after guttering. Contrast these figures to the 5% mortality in the 42 cases where operation was limited to incision, where the medulla was not exposed after finding pus. There can be little argument that exposure of the medulla through pus is a hazardous procedure.

Here are some facts gathered by a study of these cases:

1. The immediate operation mortality rate was 26% compared to 15% mortality for the delayed operation. (The term delayed operation means an operation any time after the first day in the hospital).

2. The early operation when performed within four days of the onset of symptoms had a mortality of 35%.

3. The operation done in the first week of symptoms (still early operation) failed to save 35% of cases.

4. In the second week of the disease the operative mortality was 3%.
5. After the second week of the disease the mortality rises to 15%.

These facts show the mortality in the early operation is twice as high as the late one. The mortality in late cases was too high and it becomes obvious that the rate might have been improved by operation in the second week of the disease, which showed only a 3% mortality.

Consider the patient for a moment. Usually he is very ill, suffering excruciating pain, has lost sleep, has had fever. The patient's margin of reserve has been strained by suffering, insomnia, and dehydration. Then there is the element of fright in transfer to the hospital and preparation for operation. In short, the uncorrected shock of infection is augmented by shock of operation. Wouldn't it be better to first build up the patient and strengthen his depots of local defense.

Let's further study and support the conservative treatment by a study of the temperature range, and analyze the mortality as affected by the early operation.

1. There were 34 patients with a temperature above 102 who were operated within seven days of the onset; 53% died after operation. In the same temperature range, but operated after seven days of the disease, there was a mortality of 25%.
2. Between 103 and 105, there were 26 patients with a 61% mortality, for early operation, and for operation after the first week in the same temperature range the mortality was 37%.

3. There were no cases with a temperature over 105 operated upon after seven days on onset but there were seven early operations with 6 deaths. The mortality rate of 86% could hardly have been worse if operation had been delayed a week.

The sicker cases died in the early operation, but they not only because of the severity of the illness, but also due to the fact they were operated when they were so ill.

Thus we come to the first regulation of the conservative treatment in acute hematogenous osteomyelitis, delay operation until the patients resources have been repaired by rest, transfusions, infusions; give the patient ammunition he cannot supply. The second desideratum is, do not operate until the local battle has been confined, and that is apparently in the second week of the disease. The third measure is, limit the operative procedure to incision only—do not decompress at the first operation.

Following are statistics arguing for incision against bone decompression:
1. 47 cases of evidement or guttering, mortality 29%.
2. 32 cases of drilling, the mortality 31%.
3. 42 cases of incision, mortality 5%.
4. Guttering and drilling were accompanied by 100% mortality if the temperature was over 105.
5. The only case that recovered with a temperature over 105 was after incision.
6. Bone decompression in first 7 days with temperature over 102 had a mortality of 64%.
7. There were 6 incisions in the first 7 days in patients with a temperature over 102 and no deaths.
8. Over 102 and after 7 days, mortality 30% for decompression.
9. In same temperature range and period, 4 incisions—no deaths.

The gist of this analysis shows decompression to be a decimating process in early phases of acute hematogenous osteomyelitis and that incision is a safer method at any time, preferably not immediate. (7)

Along the lines of conservative treatment another man becomes prominent. Hawk (17) has worked out, what he considers an expert way of treating wounds. He says that inflammation is a condition into which the tissues enter as a reaction to irritation. This reaction in bone infection means efforts at destroying the bacteria,
neutralizing the bacterial toxins, removing the necrosed debris, and repairing the tissue defect. The purpose of treatment must be to aid nature in fulfilling these functions. Any form of treatment that stimulates the exudate and neutralizes the agencies which are harmful to repair is desired. This implies more than simple protection to the wound. It means a stimulant to the exudative process and a provision for free drainage and hygienic measures that will augment the blood supply to the part. Some form of chemical hyperemia is desired in bone infections. Therefore, the principle of osmosis is used to hasten the healing of wounds and to care for the infection present. Some solution with high osmotic action, whose solute has a high valence with active ionization for the precipitation of colloids and destruction of bacteria, is desired. It should be non-toxic to viable tissues and not too irritating to sensory nerves. (17)

The formation of exudates is accomplished largely by the action of osmosis, and the equilibrium is governed by the relative concentration of the fluids inside and outside the capillaries. These vessels will ordinarily allow only the serum globulins, crystalloids, and smaller structures to pass through the walls. Injury will allow the albumins to pass, and sometimes in
such quantities as to render the concentration outside equal to the plasma albumin. The capillary walls are made more pervious by inflammation in direct ratio to the intensity of the infection. This seems to be nature's way of increasing the exudate, in the absence of artificial means. But by adding to this the powerful effects of a high osmotic fluid, the exudate is much increased and the granulations spring up more abundantly. The forceful exosmotic action eliminates the toxins and markedly reduces the number of bacteria present. It is obvious, therefore, that to hasten the healing of a wound and to diminish absorption, it should be filled with a solution, capable of exerting a high osmotic pressure, which will accelerate the formation of an exudate and also exert antiseptic action on the infection, without injury to viable tissues. Exosmosis, and the precipitating action of ionized salts, on the bacteria, will accomplish this end.

In the practice of treating a wound by plugging with vaselin gauze—a substance non-miscible with water—and the part enclosed in a plaster cast for an indefinite period, is more than the writers' imagination can encompass. (17)

He, therefore, advocate frequent dressings, in order to keep the wound clean and replenish the exosmotic fluids. In case bacteriophage may be considered
to play a part in those forms of treatment which involve plugging the bone with a non-absorbable substance, it is well to bear in mind the fact that phage respires, during its destruction of bacteria, absorbing oxygen and emitting carbon dioxide. Truly, the plugged wound offers little chance for respiration to take place. Phage is often found in a wound, but is usually not lytic to wound bacteria,—living there in symbiosis. Purulent material, exudate, blood, and diluted serum are all inhibitory to lytic action of phage, even in dilutions of 1:1000. These findings necessitate continuous cleansing of the wound, if phage is to play a part in the sterilization and healing.

The procedure which the author follows is first to evacuate all the dead and pus-infiltrated bone, regardless of its extent, the only limiting bounds being the epiphyseal discs in the young, and the sparing of sufficient bone in the shafts to maintain strength. The time of operation is as soon as diagnosis is made. After the mechanical work is done and the wound treated as above described, it is packed with gauze, well impregnated with a paste made of one part glycerol and two parts magnesium sulphate. The gauze serves as a wick, when the paste is thinned by absorption of blood
and exudate. The wound does not have to be completely dried, but spurters should be closed with bone wax. The paste should be prepared beforehand with incorporated layers of gauze and the whole autoclaved. In case the wound is small, it should be filled with paste and gauze laid on top. An ample amount of paste is placed over the gauze covering the wound, and the whole encased in an oiled-silk dressing, which should be snugly bandaged to the limb. There will be some oozing which will wash the wound and bring blood to the part, while the paste prevents any reabsorption.

In case one is unable to remove all diseased tissue from an acute case, the dressing should be changed in from 4-7 days, depending on the temperature. If the temperature rises, it means absorption with dilution of the paste to a hypotonic solution. The pus is removed by pouring peroxide of hydrogen into the cavity. The foam and remaining liquid is removed by a cotton pledget, not gauze. The cavity is again packed with the paste and gauze as before and the same dressings applied. In comparatively clean cases the dressings should be changed twice weekly. In badly infected cavities it should be done every second day.

In regard to immobilization—he emphasizes that bone is rigid tissue and any infection therein is
splinted by nature to the nth. degree, the only alteration that an enclosing plaster cast can accomplish is to render circulation more sluggish, and thus interfere with healing. We advise getting the patient on his feet as soon as he has recovered from the mechanical work in the operating room, providing enough bone has been left to support the limb. Bone is viable tissue, and living tissue increases its vitality with use. In all cases, healing is aided by dry heat treatments. The efficiency of thermal therapy is unquestioned.

When one views a patient lying in bed week after week, with the involved part enclosed in a cast, and absorbing putrefactive products from the wound, with a sluggish circulation from no exercise, one is not surprised to see him sallow and toxic in appearance, and what little appetite he may have, diminished by a foul stench. (17)

In contradiction to the above method of treating an osteomyelitis Starr (40) presents a more radical picture than the above. The diagnosis being made early, treatment should consist of incision over the area of greatest tenderness, through the skin, subcutaneous tissue and periosteum of the bone. Being careful to keep the incision on the diaphyseal side of the
epiphysis to preserve the periosteal attachment to the epiphyseal line. This safeguards to a large extent extension to the joint. If frank pus is encountered, this incision is sufficient, if a drain is kept in for some time. If no gross pus is found, the periosteum is stripped for a short distance on either side, to be sure that the incision is not in the wrong place.

If still no pus is seen, a series of possibly three drill holes is made from the cortex, obliquely downward toward the epiphyseal line.

Cultures from the debris removed always show infective organisms, even though free pus is not obtained. These drill holes establish drainage of free pus in 24 hours.

In no case has the medullary canal been opened, and in all cases the infected bone seems limited to the area present at the time of establishment of drainage.

If the periosteum is opened and holes drilled into the shaft at the metaphysis one can hope to relieve the symptoms and prevent necrosis sufficient to produce sequestration. Even if free pus has stripped the periosteum, if it is confined to a small area, regeneration of the necrotic area may take place without seq-
In a series of six cases under this treatment; the wounds healed in 3 or 4 weeks without sequestration. There was also 3 patients with positive blood cultures on repeated examinations, who recovered with greater or less sequestration of necrotic bone.

In the later stages the plan of treatment adopted is this: After efficient drainage has been established, operation is delayed until the sequestrum is separated. Then a channel sufficiently large enough to remove the sequestrum is chiseled through the involucrum; the cavity is gently curetted until it is free of dirty granulations; the cavity is sponged with iodine, and packed tightly for 48 hours with iodoform gauze after which all packing and drains are removed. If the cavity left is too large to fill easily by granulation, the edges are made saucer-shaped, or flattened, to permit the soft tissues and periosteum to fall in and obliterate it.

The practice of attempting to chisel away necrotic bone before it has delimitated itself is to be condemned, as it is impossible to determine where the necrotic bone ends and where living bone begins. Living bone is thus taken away or necrotic bone left.

In the operation of making a depressed or saucer-shaped cavity the periosteum should not be separated
widely from the living bone, because of possible extensive injury to the circulation of the bone tissue immediately beneath. This would, of course, make a new necrotic area and subsequent sequestrum.

Sequestrotomy should be done in a bloodless field, using a tourniquet wherever it can be safely used.

Ill considered and incomplete operations in the latter stage are largely responsible for the fact that so many of these bone cases have discharging sinuses for years. (40)

Hart (16) believes the treatment of acute hematogenous osteomyelitis includes a conservative surgical plan following the principles laid down by Starr. Adequate attention to the general state and dehydration of the patient are also primary considerations. Children with acute hematogenous osteomyelitis should be divided into two groups. The division depends on whether or not the abscess has perforated the cortex of the infected metaphysis. In the first group the infection is confined within the metaphysis. This phase is present during the first 24, 36, or 48 hours of the clinical manifestations of the disease. It is this phase in which diagnosis is rarely made and surgical drainage more rarely provided. If adequate surgery is employed extensive involvement of the main shaft with necrosis
and sequestration may be prevented. Prognosis as to mortality and morbidity can be and is greatly influenced.

Through a small incision the surgeon exposes the affected metaphysis and not the main shaft. The incision is made directly over the point of maximum tenderness. The periosteum should not be elevated except in the region of the metaphysis which is to be decompressed. Several drill holes are made directly into the cancellous end of the metaphysis, or a window about a half-inch by one inch is removed from the metaphyseal cortex in the juxta-epiphyseal region. If pus is encountered, a specimen should be sent to the laboratory for bacterial cultures. If pus is not found, a culture should be taken of a small portion of cancellous bone. The wound is packed lightly with petrolatum gauze and then covered with sterile dressings and sheet wadding. A plaster-of-Paris cast is applied properly for the dual purpose of physiologic rest and the prevention of deformity of the affected extremity.

As the metaphyseal abscess develops it will drain through the surgical openings or window into the overlying dressings instead of taking a subperiosteal course with spread of the infection to the main shaft and medullary cavity.
The clinical course will usually continue as a severe general infection until the defensive mechanisms of the body begin to gain control. However, the extremity should be vigilantly observed for swelling, redness, edema, pain, and tenderness, which are clinical manifestations of spread of infection. During this critical period the patient needs rest and fluids in order to combat the problem of dehydration. Other bone lesions may develop subsequent to the primary one. They are, as a rule, less acute but should be dealt with in the same manner as the primary.

Although the clinical course of the acute infection is not appreciably shortened by this program of therapy, the skeletal involvement and morbidity are greatly reduced.

In the second stage of the acute phase of osteomyelitis the infection has perforated the cortex of the metaphysis and spread subperiosteally along the shaft of the affected bone or directly within the neighboring joint. There is a definite change in the clinical manifestations of the disease. Pain and tenderness are no longer localized to the primary focus in the metaphysis but extend over a greater area corresponding to the spread of infection. Swelling, redness, and edema are now present. The contour of the extremity is no longer normal as it was before perforation. It is during this critical period that the disease is
generally recognized and treated. The treatment is not only delayed but too radical. This group of patients are extremely dehydrated. Sincere measures to restore general resistance of the patient and restore body fluids should be made. Generous quantities of normal saline, glucose, multiple transfusions and immune serum may be indicated.

A subcutaneous or subperiosteal abscess is present. The abscess may extend the entire length of the diaphysis. The bone is stripped of its periosteum and may appear dead but x-ray fails to give evidence of infection.

It is certain that the abscess should be completely incised and drained. It is also just as certain that the shaft and medullary cavity need not be attacked with a chisel and mallet. Too frequently a radical saucerization or gutter operation is performed on the main shaft of the bone. The medullary cavity is not infected as a rule during this stage.

The chisel or drill may be used to enlarge the opening in the cortex of the metaphysis through which the infection had spread beneath the periosteum. Infrequently, the medullary cavity may be filled with pus. Therefore, a relatively large drill hole, about
three-eights of an inch in diameter, should be made through the cortex into the medullary cavity a short distance on the diaphyseal side of the infected metaphysis. Hart (18) believes that pus is encountered in the medullary cavity often enough to make the above procedure part of the routine. It does no harm and gives valuable information.

The wound is lightly packed with petrolatum gauze and covered with sterile dressings. Continuation of the clinical manifestations should be expected as in the first stage and need not indicate further surgical interference.

In all cases the wound should fill in with granulation tissue from the bottom and the walls should not be permitted to come in contact. To accomplish this and to control odor the petrolatum dressings should be changed about every ten or more days.

Conclusions drawn from these facts are:

1. The first manifestation of acute hematogenous osteomyelitis is localized within a single metaphysis.
2. The primary bone involvement is not in the cortex of the main shaft and medullary cavity.
3. Acute hematogenous metaphysitis is a definite clinical entity.

It represents the earliest clinical phase of acute hematogenous osteomyelitis when the infection is confined within the interior of the affected metaphysis. It is during this phase that proper surgical treatment may prevent extensive osseous and joint involvement,
necrosis and sequestration of bone.

4. **Radical gutter operations on the cortex of the main shaft and medullary cavity during the acute stage of the disease are surgically and anatomically unsound.**

5. **Dehydration should be prevented and controlled if present.**

6. **The surgical treatment includes conservative but adequate metaphyseal drainage.**

7. **The pathogenesis of the disease is determined by anatomic features of the bone and joint system.**

8. **The moment the infection perforates the cortex of the metaphysis and spreads beneath the periosteum the prognosis as to morbidity is critically altered.**

9. **Acute hematogenous osteomyelitis is divided into two stages. The first stage is before and the second stage is subsequent to perforation of the thin cortical wall of the affected metaphysis. The clinical and pathologic changes, treatment and prognosis of the two stages differ distinctively. (16)**

   Key (23) has developed what he classes a rational ideal in the treatment of acute hematogenous osteomyelitis. He thinks treatment of patients with acute hematogenous osteomyelitis may be divided into four overlapping groups:

1. **Patients with a mild infection not acutely ill.**
2. Severely ill patients with a spreading infection but in good general condition.

3. Severely ill patients with a spreading infection but in poor general condition.

4. Patients in whom the infection has localized and is subsiding.

Treatment of the first group need not be an emergency affair, but there is no reason why these patients shouldn't be operated on and the bone drained as soon as convenient after diagnosis is made. If these patients are not treated a localized chronic osteomyelitis may develop which will demand radical treatment. Consequently it is advisable to operate on such patients and drain the focus, in the bone early in order to prevent the probable later chronic disease.

The severely ill patients with a spreading infection of the bone with high fever and marked toxemia but who are not dehydrated and whose general condition is good. In such cases it is advisable to do immediate operation with opening of the bone as gently as possible and with as little disturbance to the patient as possible. After operation the wound should be packed loosely with petrolatum gauze and the extremity should be immobilized. Sedation for pain relief, small trans-
fusions, force fluids, etc., will aid in combating the infection.

In the third group of patients it is unwise to operate immediately—because of the patients' resistance which is very low and has been taxed by the infection. Hence, it is better to give such a patient bed rest, sedation, massive wet hot packs, splint and traction. Fluids should be forced by mouth and intravenously.

The question as to how long to continue the conservative treatment arises. This cannot definitely be stated, but it is logical to continue it for a matter of twelve hours or so until the patient either improves or gets worse. As soon as the patient has had some rest and sleep from morphine and immobilization and as soon as body fluids have been restored he should be operated. To defer the operation is not a matter of allowing localization of the infection, but one of restoring the patient to better condition. Consequently the delay should be a matter of hours and not days.

In the last group of patients, in whom the infection has broken through the bone and formed an extraneous abscess and whose acute illness is subsiding; the time of operation is not so important. However, the sooner the abscess is drained the less likely are secondary foci to develop.
Conclusions:

1. Early diagnosis is important, and each case should be treated individually, and according to the surgical principle that a deep abscess should be drained as early as possible provided the patient is in condition to stand the operation.

2. Not every case of acute osteomyelitis requires immediate operation, but every patient should be seen by a surgeon as early as possible after diagnosis. He should decide when to drain the focus.

3. Early and adequate drainage is the most effective means of preventing chronic osteomyelitis.

Lucas (28) after years of practice feels that the condition of the patient should occupy a large part of the surgeon's logic before any surgical procedure is done. He states, "there is no such a requirement for immediate surgery, if the patient's condition is such that an anesthetic plus surgical shock might carry it over the threshold, and destroy its chance of successfully combating the disease". He does, however, advocate drainage of the focus with as little damage to the neighboring tissues as possible. In post-operative care he leans toward the Orr method. He summarizes the treatment of osteomyelitis by basing it upon the following:
1. Correct diagnosis followed by early drainage offers the best hope of cure and lessens the chance of further metastasis and extension into the adjacent joint.

2. The expectant or conservative treatment is to be carried out in those cases where operative interference would further endanger the life of the patient.

3. Osteomyelitis should be considered a local manifestation of a generalized infection. Therefore, a great deal of attention should be directed toward the care of the sick patient.

From another angle the more or less conservatism in treatment seems to be of value. Robertson (36) has noted that the cases recovering developed a high level of antitoxin against the organism. Which is due to the fact that the resistance of the individual depends upon two agents, one is the natural antitoxin that neutralizes or renders inert the toxin produced by the organism, and the other has to do with the destruction of the organism by phagocytosis. The former is very important, as the intoxication increases the level of production of antitoxin is spontaneously increased. Thus, in his mind it seems evident that introduction of antitoxin intramuscularly would be excellent treatment.
The use of maggots in the treatment of osteomyelitis has been widely popularized by the work of the late Dr. Baer and by the wave of publicity following his investigation. If the use of maggots for this purpose is as beneficial as the reports indicate, a further investigation may be valuable.

Sterile maggots can be purchased at a quoted rate of five dollars per thousand. This number is sufficient for one ordinary application. The number of applications necessary varies from one to thirty-six, with an average of eleven. At a cost of $5.00 per application, the cost of maggots alone would average $55.00. This cost plus the cost of a long hospitalization makes it almost prohibitive to the average patient. Therefore a simple, inexpensive method, by which maggot treatment may be made available to everyone, has been worked out and will be described.

When Baer began his work, he used unsterile maggots successfully until two of his cases developed tetanus. Unsterile maggots are just as efficient as sterile maggots in their action on the lesion and, had Baer given priphylactic antitoxin his cases would have been successful. The only pathogenic organism present other than tetanus is the gas bacillus. Baer proved that maggots protect against gas bacillus infection. No cases of gas gangrene have been reported,
whether sterile or unsterile maggots were used. There is, then, no valid reason why sterile maggots are more effective or safer than unsterile maggots. Livingston has used unsterile maggots extensively at the Hines memorial Hospital with no unfavorable reports in a large series of cases reported by him. Weil and Nettour, Goldstein, Rohn, Wilson, Thorek all confirm such results.

The culture of flies and raising of maggots is amazingly simple. The varied conditions under which they may be grown make their controlled culture inexpensive.

A supply of maggots can be purchased and raised on raw beef without any attempt at sterility.

A box approximately 18x24x36 inches can be set on legs. Glass windows fitted in front. Two old thermometers can be used to control the temperature, one as a safety unit. A 200 watt light near the back of the box will supply the heat. A pan of water placed under it to provide moisture. No attempt to circulate the air is needed. A small shelf will hold the jars of maggots so they can be kept in the dark. The temperature should be regulated from 70-90 degrees F.; the higher temperature promotes rapid growth of maggots.
but the flies live longer at the lower temperatures.

The original stock of maggots put on a piece of raw beef in a jar will in a few days reach adult size. Sand is poured on them and they crawl into it and pupate. These pupae are placed in a petri dish in a cage constructed as follows: A flat box of a size that will fit into the incubator is used. The top and bottom are replaced with screen wire with a door placed in one end. The cage thus stands on one side. The door is at the bottom to facilitate cleaning and prevent escape of flies. After about 7 days, the pupae hatch into flies.

Flies feed on a mixture of one ounce of honey, one dram of yeast and eight ounces of water. This is all the flies require and should be constantly present and not allowed to ferment. The food is placed on a slice of bread in a petri dish. One such supply lasts 48 hours. About 7 days after hatching flies are ready to lay and the eggs are collected on a small piece of agar or bread.

The media for culturing the maggots to proper size for use in treatment is prepared as follows: A circular hole is cut in the lid of an ordinary petrol-agar jar. A piece of raw liver, about one inch in diameter, is put in and the jar filled to level of the
top of the liver with peptone agar to which yeast has been added in the proportion of about one cake to 1000 cc. A single layer of old sheeting is placed over the top and the lid screwed on tight. The jars are autoclaved twice, with a 24 hour interval of incubation, and stored in the ice box until needed.

Eggs are transplanted to this media. The jars are then incubated until the maggots are the proper size for use. At this time the maggots will be about one-fourth inch long or slightly more. The air must not be shut off or the maggots will die.

The maggots may be washed and made ready for use, then stored. Two tablespoonfuls of sugar to each jar after it has been nearly filled with water will separate the maggots from the media. They are then rinsed in tap water and placed for 30 minutes in a 1:1000 solution of bichloride of mercury and 25% alcohol. They are then placed in jars and put into the incubator for future use. Each generation of flies will live and produce eggs for about 4-6 weeks. For replacing flies, one laying of eggs may be grown to maturity, in about 7 days. Large jars of media may be prepared for this purpose. When the adult maggot size is reached they are transferred to sand and pupate in 48 hours. Pupae may be kept on ice for 2-3 weeks before hatching.
Technique of Implanting Maggots.

In implanting the maggots and keeping them in the wound, several procedures are useful. If maggots are strictly confined to the wound, the patient has no discomfort unless there are nerves exposed. If this is the case sedatives such as bromides and codeine are valuable in controlling the pain.

The most important single consideration in keeping maggots in the wound is the maintenance of adequate drainage, so that the maggots can't escape by the same route. A satisfactory method for keeping maggots in the wound consists of placing a close fitting screened cage over the wound and taping it down tightly.

The skin is cleaned with either and a layer of flamed adhesive is applied to the wound edge. The maggots are then put into the wound and covered with the screen and taped down. The maggots are left for five days at each application. If drainage stops the maggots are probably dead, and should be removed. Using a support for bed covers, a light is made to shine on the screen. The light drives the maggots deep into the wound and adds to the patients comfort. Between applications of maggots, a days rest is given, the wound being tightly packed with dry gauze.
In all cases there is a tendency for the wound to heal at the outer surfaces. In these cases a small glass tube taped down may be used to keep open drainage. As the wound heals shorter tubes can be used.

If the maggots die, it is the result of inadequate drainage, too much moisture, or if air is excluded. McKeever has many cases which have had many applications, in which maggots live for 5 days if good aeriation and drainage is maintained.

The number of maggots used is dependent upon judgement. Use the number that will fill the wound when they have reached adult size. This is about $1/4 - 1/3$ of the wound volume when the maggots are at the three day stage. The maggots rapidly seek out and devour all devitalized tissue for a full five days.

After the bone is covered with granulations, the question of secondary closure of the wound arises. If the bony involvement is extensive and a wide incision, the healing may progressively slow and may be completely arrested. If the wound does heal, the resulting scar is wide and thick, circulation becomes poor, and it may break down. If secondary closure is done after the bone is healed, a much better result is obtained.

Summary:

1. A method is presented by which maggots may be raised
for us in a hospital or private practice.

2. Very little time is required in culture and growth of maggots by this method.

3. The expense of equipment is negligible.

4. If maggots are properly applied, any discomfort can be controlled.

5. With proper drainage, maggots do not die in the wound.

6. Secondary closure of extensive wounds, after bone is covered with granulation tissue, is advisable. (30)

According to Jewett (20) the only substances used to cover the edges and hold the wire or gauze covering are adhesive tape, rubber plaster, or collodion. Most patients complained more or less of irritation of the skin by the maggots. Both adhesive and rubber plaster not only lead to skin irritation when removed, but they also tend to separate from the skin in many cases, thus allowing maggots to creep up on the skin. The irritation that occurs in a case requiring many applications becomes important.

This led to the use of Unna's paste to fasten the covering to the skin. The formula used:

Zinc oxide-----------------------2 1/2 parts.
Gelatin--------------------------6 1/4 parts.
Glycerin and water, each---------19 parts.
It seals the skin effectively and also keeps the wire or gauze glued down. It should be applied warm.

Maggots are implanted into the wound by use of sterile cotton applicators.

Ordinary gauze is used as a framework on which to put the wire gauze. After the wire is fitted over the lesion, more layers of Unna's paste and gauze are placed overlapping the wire edges. Then as a final covering adhesive tape is placed over the gauze. The advantages of this covering are as follows:

1. It produces no skin irritation.
2. The paste can be placed close to the open lesion, sealing off all cracks and crevices, confining maggots to the lesions.
3. Secretions from osteomyelitic lesions irritate the skin. This paste protects the skin from these secretions.
4. It can be washed off easily with warm water and leaves the skin in excellent condition.

Maddock (29) used maggot therapy in the treatment of 23 cases (31 lesions) of acute hematogenous osteomyelitis of the tibia. Most of the patients had been operated on by other surgeons, and treatment with maggots was begun after a period of antecedent treatment. The great advantage in the use of maggots seems
to lie in the high percentage of closed lesions and in the relative scarcity of recurrences. This is doubtless due to the ability of the larvae to uncover hidden sequestrums and to seek out small abscesses which might otherwise become included in the new bone. Maggot therapy is not indicated in all cases of osteomyelitis. Only when the patient fails to make reasonable progress clinically is it necessary to consider the use of maggots. For chronic osteomyelitis their usefulness is probably greatest and no lesions should be given up as hopeless until maggot therapy has been tried. Of the 31 lesions, 26 up to date (Dec. 1938) were closed; one still required treatment, two had necessitated amputations and two patients were lost track of.

When maggots are implanted in an infected wound they feed upon the necrotic and purulent materials present and, at the same time take up large numbers of bacteria. The digestion of such bacteria is one means by which maggots could reduce wound infection. To determine the fate of infested bacteria, observations were made of their progress down through the alimentary canal. A progressive destruction of the infested bacteria was found to take place in the alimentary canal. The sterility of the intestine is evidence that the bacteria are destroyed in the stomach.
It is recognized that necrotic tissue remaining in the wound favors increased infection as well as absorption of toxic substances. Myers and Cazaja (31) have shown the difficulty or impossibility of completely eliminating all such tissues surgically. Furthermore additional necrosis frequently occurs.

Maggots feed voraciously upon the devitalized and purulent materials which accumulate within the wound, and are usually found in such areas. The amount of necrotic material which each implantation of maggots is capable of removing is surprisingly large. The average implantation will consume as much as ten to fifteen grams. This is augmented by further implantations every four or five days. Maggots, therefore, aid in cleaning up the wound by penetrating necrotic areas, suitably opened up, and feeding therein, thus making the condition less favorable for bacterial growth.

During maggot treatment the wound is stimulated to secrete a thin, serous discharge in comparatively large quantities. This is heavily contaminated and carries off numbers of the pathogenic organisms of the wound.

The effects obtained in this investigation have
all been the result of the direct activities of living maggots. Mixtures of macerated maggot tissue gave negative results in culture. The removal of necrotic tissue, which is important in treatment, also requires living maggots. The presence of living maggots, therefore seems to be of prime importance.

This differs from the viewpoint expressed by Livingston and Prince (27) who reported that a maggot extract was "in itself a curative agent". The use of such an extract in wounds, whereby maggots could be eliminated would be desirable. However, insufficient data for proof is as yet reported.

The abundant growth of granulation within the wound is one of the outstanding characteristics of the maggot treatment. This growth is sometimes regarded as the result of a stimulation by maggots. In conditions where more necrotic tissue is found and where absorption of toxins is greater the result may be an inhibition of natural growth of granulation tissue. Under the maggot treatment, with its more rapid cleaning up of the wound, the tissue may be forced to grow spontaneously at its normal rate; and, in contrast with the usual rate, may appear to be a stimulation.

Summary:
1. When used in infected wounds, the surgical maggots
are able to hasten disinfection.

2. Maggots ingest bacteria in large numbers in feeding upon necrotic tissues of the wound and these bacteria are destroyed in passing through the alimentary canal.

3. Maggots feed upon the necrotic and purulent materials within the wound. They thus, aid in cleaning up the wound and making its condition less suitable for bacterial growth.

4. Drainage from the wound is stimulated under maggot treatment. The excessive discharge, which is heavily contaminated with bacteria, assists in wound disinfection.

5. The increased growth of granulation tissue within the wound and its relation to maggot activity seems evident. (37)
In 1932, Livingston and Prince (27) obtained a saline extract of whole maggots, which when chemically analyzed was found to contain, natural allantoin. Later allantoin was found to be an oxidation product of uric acid. It is the end product of purine metabolism. It is found in human urine in small amounts (5-15 mgms. per day).

The use of this material in the treatment of osteomyelitic lesions has been used and used quite successfully. It promotes discharge from the open wound, and promotes healing of the wound.

When allantoin is used in a 0.4% solution, the drainage is copious, thin, yellow and without odor. The drainage resembles that which occurs when maggots are used. The edges of the healing wound are similar to that occurring with maggot therapy. A quicker, natural debridement seems to occur when allantoin is applied by an ointment into the cavity.

Some physicians say the same results can be obtained by using the less expensive urea crystals. Others state that the objectionable uriniferous odor is repulsive, and allantoin to be the better substance.

This product in summary seems to act similar to maggot therapy but with better results. It can be obtained chemically pure, free of objectionable sub-
stances and the ever-present possibility of tetanus organisms. It can be used in hematogenous, acute, or chronic osteomyelitis as a wet dressing, instillation or ointment pack; it is the active principle which maggots excrete, and can be placed in the wound for longer intervals. (6)

Among the more recent methods of treatment of acute hematogenous osteomyelitis we find that osteomyelitis with Friedlander's bacillus, which is a rare disorder and always grave, is a good example. It deserves study here because of the difficulty in treating the disease. It is of an extremely tenacious character in that it reappears after apparent cure. It can be differentiated into four anatomicopathologic forms of ostitis.

1. A periosteal form with abscess.
2. A form in which under the periosteal abscess an osteomyelitis was discovered.
3. A massive osteomyelitis.
4. A form of dry diaphyseal caries. (42)

It is impossible to give general directions about the local treatment because practically all measures have been known to produce cure in one case and have been followed by death in others. Some derivatives of sulfanilamide have proved successful against some
capsulated organisms. The authors (42) observed a
rapid effect in the treatment with mandelic acid. They think that in the future chemotherapy will be
important in the treatment.

Crossan (8) says treatment should be divided into
four main topics:

1. Time of operation.
2. Type of operation.

Time of operation—There is distinctly two groups:
Those who would defer operation. Those who would oper­
ate immediately. The latter seems to have the fewer
adherents. The arguments for the former sound con­
vincing.

1. Disabilities and death as a result of unnec­
essary delay in treatment.
2. Delayed treatment is dangerous because of
possible joint complications.
3. A delayed operation may mean chronic osteomyel­
itis.

Arguments for delayed operation are also convincing.
1. Early operation may spread the disease.
2. Allow for localization of the infection to take place.
3. Allows time for accurate diagnosis.
4. Allows fulminating course to subside.
From these statements it is difficult to judge which is the better method.

**Type of operation**——For many years guttering was considered the only operation for acute osteomyelitis. Since Starr (40) in 1922, drilling or opening a window has become the accepted method.

Key (23) however, still advocates the guttering operation, but he does not that the operation should be as simple as possible.

As previously most authors advise drilling by methods prescribed by Starr (40) and most all of them advocate early operation. Many advise drilling even though pus is only sub-periosteal, a few, however, who favor drilling, limit the operative procedure to incision alone in cases with only subperiosteal pus.

The adherents of early operation, believe in bone drainage, are of the opinion that the disease arises in the bone and the systemic symptoms are due to absorbed toxins from the confined pus. The other groups, who counsel deferred treatment, argue that bone infection is subsequent to blood stream infection. The first groups considers urgent operation spreads infection. There is nothing in the literature to settle the dispute.
Post-operative treatment—Orrs method of treatment of the wound has been widely accepted throughout the world. (33) The Loehr method, consisting of packing the wound with cod-liver-oil paste; the vitamins are said to do some good in healing the wound. Albee recommends the treatment by bacteriophage. (1)

Therefore, surgeons have proposed as post-operative treatment, the Orr method, cod-liver-oil, maggot, bacteriophage and many others. It seems that any method that tampers not too much works well.

Auxiliary methods—Neosalversan has been reported to cure the disease. Antitoxin is mentioned. (41) Mercuric perchloride has had good results. Blood transfusions are reported as good measures. Sulfanilamide may prove to be of value. (8)

To attempt to point out the better method of treatment of acute hematogenous osteomyelitis is mere folly. One must for the most part make a complete study of the disease, learn to know its possibilities and characteristics before he can develop a method of treatment. After years of experience with various methods he may come to some conclusion as to how to treat the disease. Probably basing it upon the success he has had with the treatment.
In the majority of cases, the generalized severe fibrile symptoms regress, and the process localizes to the diseased bone. If the suppuration followed by necrosis is very chronic, the individual may die many years later from amyloid degeneration of the internal organs, perhaps with ascites, and anasarca. But if a number of bones are involved from the very beginning, the pyemia is quickly fatal. Metastasis from osteomyelitic foci may be manifested in other bones, as well as in the internal organs, particularly the lungs, kidneys, heart, and also the skin in the form of metastatic abscesses. Death usually follows in a few days or weeks from the generalized infection. Transfer is by means of septic thrombi in the veins of the bones (ostophlebitis), which may spread, from the femur to the deep femoral veins or the iliac vein. Necrosis, and the formation of sequestrae are very frequent consequences of osteomyelitis and periostitis.

A seemingly healing, or periodic exacerbations, perhaps even a continuous process with severe neuralgic pains, are characteristic of the chronic forms of sclerosing osteomyelitis, in which operation reveals a so-called central abscess in the diffusely thickened sclerosed metaphysis. (22)
Hobart and Miller (18) reported several severe complications from osteomyelitis. Three cases of malignancy of soft tissues (2.6%), two pathologic fractures (1.9%), two cases of toxic neuritis of the eighth nerve (1.3%), and one case of toxic encephalitis (0.3% in a series of 108 cases).

Crossan (8) quoting Brisgard had a series of 51 cases of pyo-arthritis complicating acute hematogenous osteomyelitis. It occurred from direct extension in 42 cases and by metastasis in 9 cases. There was ankylosis in 62.2%, limitation of motion in 32.6%, and restoration to normal in 13.2% of the 51 cases.

The treatment as advised by Pyrah and Pain (34) is early incision and perhaps early amputation. In Robertson's series of 13 immediate incisions the mortality was 23%, and in 7 cases which were observed pre-operatively the mortality was 14%. (36)

It was formerly thought that the occurrence of deformity in osteomyelitis due to involvement of the epiphyseal cartilage was relatively infrequent. In view of this Siegling (39) reviewed the cases of osteomyelitis seen at the University of Chicago Clinic.

To understand properly the production of osteomyelitis growth deformity, it is perhaps wise to review briefly the physiology of bone growth. Hass has
demonstrated experimentally that the most important elements for longitudinal growth were located in the columns of cartilage cells in the epiphyseal plate, and that destruction of these cells resulted in growth arrest with asymmetry and shortening.

The findings are recorded in the accompanying table:

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cases of osteomyelitis</td>
<td>423</td>
</tr>
<tr>
<td>Total cases in children</td>
<td>277</td>
</tr>
<tr>
<td>Total cases in children with long bone involved</td>
<td>241</td>
</tr>
<tr>
<td>Total patients with overgrowth, 4.9%</td>
<td>12</td>
</tr>
<tr>
<td>Total patients with growth arrest, 31.5%</td>
<td>76</td>
</tr>
<tr>
<td>Total long bone lesions in the 241 children</td>
<td>419</td>
</tr>
<tr>
<td>Total bones having growth arrest, 24.5%</td>
<td>103</td>
</tr>
<tr>
<td>Total bones having overgrowth</td>
<td>13</td>
</tr>
</tbody>
</table>

The growth deformities of greatest significance were either shortening of an extremity due to complete arrest of growth, or deformity resulting from arrest of one part of an epiphysis with continuation of growth of the remainder. Another interesting irregularity was overgrowth due to stimulation of growth by the infection. As will be noted in the table, twelve patients had longitudinal overgrowth of a bone. In no instance was this sufficient to require a raised shoe and in no case showed unequal overgrowth of only part
of a bone. Thus, overgrowth is interesting but not of very great importance as a truly deforming factor.

In any case of osteomyelitis which threatens the growth disc it is of extreme importance to point out to the parents the possibility of deformity and to have adequate follow-up x-ray and clinical examination. Where one is suspicious of growth arrest, it is always best to compare the suspected epiphysis with its mate and to look for evidence of closure of the epiphyseal cartilage line on the roentgenogram. Irregularity of the epiphyseal line and deviation from the perpendicular when compared with the normal corresponding epiphysis are presumptive evidence of arrest.

In many cases in this series the epiphyseal cartilage plate seemed to act as a limiting body, and as infection cleared, the lesion grew away from the epiphysis. In several instances, although infection penetrated the cartilage into the epiphysis, arrestment of longitudinal growth did not occur. This is a surprising fact and one that serves to complicate the prognosis. (39)

Early recognition of growth arrest is important. Where progressive inequality of leg length is occurring, surgical arrest of growth of the corresponding
epiphysis on the other extremity will prevent further discrepancy. Where shortening is considerable, surgical fusion of several of the epiphyses of the normal extremity will allow equalization of leg length by the end of the growth period.

It is particularly desirable to stress that the integrity of the epiphysis is vital to normal longitudinal growth. In the surgical approach to an osteomyelitic focus at or near the epiphyseal plate one should use every caution not to strip periosteum from the cartilage. The osteotomy should be started at a safe distance from the epiphysis and directed toward the lesion. Curettage in the depths of the focus should be avoided. Simply wiping out the granulations has been suggested and has proven satisfactory.

Conclusions from this study:

1. Lesions involving the growth cartilage can and do cause varying degrees of arrest of longitudinal growth.

2. Whether or not a lesion will cause arrest and deformity is not always predictable.

3. Possibility of growth arrest in such lesions should be kept in mind and explained to the parents.

4. Surgical approach to the epiphysis should be made with extreme caution.
5. Repeated clinical and x-ray examinations should be made, so that methods of treatment can be instituted at the proper time to prevent progressive deformity. (39)

Capener and Pierce (3) state that pathological fractures in cases of osteomyelitis of the shafts of long bones has occurred in one and two-thirds percent of a total of 1088 cases. Osteomyelities is responsible for about 33-35% of all pathological fractures in long bones.

In all cases of acute osteomyelitis a bacteremia is present and a blood culture will be positive if taken at the right time. If the blood infection becomes so extensive and virulent that the resistant powers of the blood stream are unable to combat it a septicemia results. Repeated cultures will show the offending organisms and very few of these patients go on to recovery.

A Brodie's abscess may develop very insidiously after the acute condition. It is usually diagnosed by the aching character of the pain which are especially pronounced at night, and by x-ray. (26)

Crossan (8) found that slightly more than one-fifth of the patients died; nearly two-thirds of the survivors were crippled; some of those not crippled
were invalids or faced periods of invalidism because of the disease. Fortunately, the disease is uncommon, and it is even said to be disappearing.

Stookey (41) observed that in the years 1930, 1931, and 1932 there were reported in the United States 3,160 deaths from the disease. He also notes that 90% of all deaths occurred in the first two weeks of the disease, which fact he interpretes as being due to "a lack of defense mechanism in the host" and, quoting further, "once host has had time to develop immune substance the death rate drops".

Findlay (11) observed in 50 cases with 12 deaths that in the cases in which death occurred the average time between the onset of symptoms and hospitalization was 5.8 days.

Various authors speculated on the death rate as being between 10 and 50%. Humphries (13) reports 20 cases without a single death. Green and Shannon had only one death in their last 20 cases. (13)

The highest mortality reported was 41%. During the period from 1932-1937 Crossan (8) found that 1,504 cases were reported; there were 318 deaths, a mortality rate of plus 21%. From this study it was found that of 140 deaths, 82 or 58% occurred after operations were per-
formed the first week of the disease. From the combined reported statistics during this same period crippling occurred in 39% of the patients.

McKeever and Wilson (44) found that 53% of the 85 bone foci of the disease caused growth disturbance. Johnston had "complete or incomplete" bone growth in 50 bones, or 55%. Green and Shannon (13) had the best results; 5 deformities in 41 patients; Kulowski (24) reports "locomotor disturbance" in 30% of his cases.

Prognostic signs are seemingly quite variable. Wilensky (43) believes that ultimate recovery or death depends on the factor of general infection and the mortality statistics of early acute hematogenous osteomyelitis reflect accurately the mortality of the general infection. Lebeuf's report states that if the temperature goes above 40 or 41 degrees C. the patient will die in a few days. Kulowski notes that visceral metastasis is almost invariably fatal. (24)

Fraser (13) gives the following prognostic criteria:

1. A history of previous recurrent skin infections is serious because it indicates deficient resistance to the organism.
2. Pronounced general disturbance has an ominous significance.
3. Acute local symptoms are less disturbing, they
may indicate appreciable resistance to the infection.

4. There is a less severe course and lower mortality in the first three years of life.

5. The nearer the focus to the trunk and body centers, the more gloomy is the prognosis.

6. Larger metaphyseal areas become serious possibilities because of the area involved.

7. Every fatal case is due to Staphylococcus.

8. A leukocyte count of 20,000 with a polymorphonuclear count of 75% is a favorable sign.

9. Prognosis is improved if operation is delayed until the focus is reasonably established.

10. In infections of the metaphyses enclosed in synovial membranes, pyo-arthritis is more likely.

In conclusion to this study on acute hematogenous osteomyelitis it is extremely difficult to analyze fairly and accurately the relative values of each method of treatment. There is seemingly an unlimited amount of literature on all the various methods and each seems to have facts and statistics to prove that their results are the better. Upon closer inspection we discover that each writer claims about the same percentage of failures. They all claim from 60-70%
cures and more or less reluctantly admit 20-40% failures.

Becoming a little more specific and looking again at the various methods we find that the temperature and general illness of the patients is important. In most cases with severe illness, high temperature etc., the mortality became increasingly high. Also noticed is the change in the type of treatment as the temperature becomes higher, which immediately disrupts our statistical study. However, it is definitely noticed that in the higher temperature ranges the mortality was higher, regardless of the method of treatment. In general it may be said that treatment was usually delayed for a varying length of time in all cases of severe toxicity.

Perhaps, the largest number of surgeons, the country over, believe in and practice the Orr method of treatment for acute hematogenous osteomyelitis and for chronic cases. This method has no doubt become the greatest advance in surgery of the skeletal infections for many years. However, one must not become prejudiced. He must of necessity consider all the methods of treatment, and accept the better methods if he wishes to obtain results befitting the profession.
In the past years the method proposed by Starr has gained reputation. It seems to fit more closely a slightly less radical picture, and therefore, appeals to many surgeons.

The bacteriophage is seemingly gaining in favor. The logic with which it is presented is excellent and statistics seem to prove it shortens the convalescent time. It will, to me, continue to gain in favor and become an important aid in treatment of surgical infections.

Maggot therapy for bone infections is almost outmoded largely because of the patients dislike for such treatment. Personally I do not blame them for disliking the crawling, wiggling, irritating larvae. It seems to me the thought of such treatment would be enough to mentally distract even the hardiest of patients.

The value of allantoin, uric acid, cod-liver-oil, etc., is only problematical and time may iron out the good and bad points.

After closely studying this subject I have come to the conclusion that a combination of the various methods would result in a relatively ideal method of treatment. It seems to me that by using the Starr method of operation (drilling following incision in cases of absence of pus under the periosteum), plus
the Orr method of post-operative care (immobilization in plaster-of-Paris cast), plus the use of the bacteriophage in certain cases would make for a more equalized stable manner of treatment. Why do I believe this would make a good technique?

Because:

1. The Starr method of operation is not a too radical procedure.

2. It must be easier to drill for metaphyseal pus than to open widely and take a chance on injuring the epiphysis.

3. Why open widely and possibly gutter a lesion for sub-periosteal pus.

1. The Orr method of post-operative treatment is a method coinciding with the rest procedure in all treatment of ill patients.

2. Prevents to a large extent reinfection by repeated dressings.

3. Prevents injury to tissues by movement.


5. The results obtained are excellent.
1. The bacteriophage seems logical and gives good results.

2. It can do no harm if chemically pure.

3. It may in the future develop into an important field in treating infected wounds.

Of course, it must be remembered that the patient himself must be considered. The severity of the illness, toxicity, duration of the disease, amount of dehydration etc., must all be considered and treated accordingly. The best procedure would probably be to defer treatment until the dehydration, shock, and morbidity of the patient is combated sufficiently to offer a better operative risk.
"BIBLIOGRAPHY"


