1971

# The Significance

*"Antibiotic therapy has not decreased the overall incidence of infections in post-trauma patients . . . while we have been successful in preventing or controlling some types of bacterial infections, others have taken their place."*

# of Infection in Trauma

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**THE SUCCESSFUL TREATMENT** of patients suffering from trauma is one of the greatest challenges facing surgery today. Not only is trauma currently the fourth leading cause of death in the United States, but infection, one of its unsolved complications, continues to add to its seriousness as a health hazard (20). When infections develop in patients with trauma, they continue to produce important consequential effects on morbidity, mortality, and the final result of the surgical treatment (5, 6, 11). Death, deformity, disability, and delayed healing may be the results. Moreover, the quality of life, both physical and psychological, may be affected or permanently altered.

The numbers of violently injured people have been increasing as a result of the hazards of rapid transportation, mechanized industry, the pursuit of vigorous sports, and the social unrest which are so prevalent in our society today (6, 7, 16, 20, 24). An interesting development in regard to the latter has been a 400 percent increase in the number of patients admitted during the past three years to the surgical services of the Cincinnati General Hospital with gunshot wounds of the abdomen (16). These and other developments bring with them the threat of further increases in numbers of infection in trauma patients.

Bacteriology has contributed greatly to the advancement and safety of surgery through the development of the germ theory of surgical infections, antiseptic and aseptic technic, and passive and active immunization. Each of these has had revolutionary effects on the practice of surgery. After the general use of modern antibiotic therapy for more than a quarter of a century, it has become apparent that the overall incidence of infection in the trauma patient has not been decreased, and that many related problems are still with us.

Questions must be asked, "Why has the acceptance of the germ theory in surgical practice not decreased the overall incidence of infection in trauma patients during the past 40 years? . . . Why has the daily practice of aseptic and antiseptic technic not given a greater decrease in infectious complications? . . . Why has the general use of antibiotic therapy not eliminated hospital-acquired wound infections as a threat to the trauma patient?"

These and other questions have emphasized the obvious need for a more comprehensive understanding of the significance or meaning of infection and a better definition of the various factors contributing to its development.

## In brief . . .

*This is the Scudder Oration on Trauma, presented on October 19, 1971, at the fifty-seventh Clinical Congress in Atlantic City. Dr. Altemeier is Christian R. Holmes professor of surgery and chairman of the department at the University of Cincinnati, as well as a member of the University's Center for the Comprehensive Study of Trauma.*

*The Scudder Oration is named in honor of the first chairman of the College's Committee on Fractures, predecessor of the Committee on Trauma. Dr. Scudder was appointed chairman in 1922.*

### Definition of trauma

Before exploring the significance of infection in trauma, it is advisable that we consider the definition of trauma.

Trauma represents a broad spectrum of bodily damage produced by numerous and

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varied physical forces and chemical agents. Usually it is considered to include penetrating and nonpenetrating wounds of any part of the body resulting from violence, accidental injury, or surgical operation. It must be remembered, however, that it also encompasses tissue damage from excessive heat and cold, bites of animals and man, and stings of venomous snakes and insects. Also, in its broadest sense, it includes psychic trauma.

The damage resulting from trauma may be local or systemic. The local damage depends upon the characteristics of the wounding agent itself, the tissues traversed, and the pathophysiological effects produced in the organs or tissues involved. The systemic effects, which are relatively little understood, may be infectious, cardiovascular, pulmonary, metabolic, hematologic, gastrointestinal, or psychologic.

#### Historical significance

Infection in trauma was a terrifying chapter in the annals of human history. Before the revolutionary studies of Pasteur and their application by Lister (35) to wounds a little more than 100 years ago, most, if not all, wounds became infected, and the resultant mortality of deep or extensive wounds approached levels of 70–90 percent (9, 32, 33, 34, 41). Since the great majority of major wounds in the pre-Listerian era were caused by trauma, much of the stimulation for solutions to the problems of infection came during times of war.

To obtain a better perspective of the historical significance of infection in trauma, let me invite you to journey with me into the intellectual mists and uncertainties of the past in which patients suffered unbelievably much and surgeons labored in ignorance before the discovery and application of antisepsis and asepsis. It is a long hard journey over dark roads obstructed by the miasmas of putrefaction and morasses of phlegmon, over avenues through the putrid stench of hospital gangrene, the dangers of septicemia, the fires of erysipelas, the chills of pyemia, and into impasses of ignorance, empiricism, and blind dogmas (9, 26).

**IN SUCH TIMES** the chief causes of death in patients with trauma were associated with putrefaction and infection, being described as erysipelas or "St. Anthony's Fire", hospital gangrene or "hospitalism", sepsis and tetanus or "lockjaw". Such conditions forced surgeons to avoid elective amputations, and most elective surgical operations were limited in peace times to more minor and superficial operations.

The introduction and use of gun-powder in Europe in the thirteenth century worsened this situation (44). For over 600 years thereafter Europe was involved in a series of almost unending wars during which the great majority of wounds seen by surgeons were frightful in extent, badly lacerated, and grossly contaminated. Thus most surgeons acquired a therapeutic doctrine of despair based upon their belief that gunshot wounds were poisoned and that wound healing would not occur unless treated by some method to overcome the poison.

A look at the Crimean War affords us the opportunity to observe the frightful significance of infection in 1854–1856. According to a report by Chenu on the health condition of the French army in Crimea and in Turkey at that time, wound infections played a significant role in this historical event (9). Of the army of about 300,000, approximately 10,000 were killed, but 8 times as many or 85,375 died as the result of sickness and wounds. In other words, a fourth of the army, composed of strong and healthy men, fell victim to various types of infections. The number of men who died as a result of wounds approximated the number killed—10,000. They were reportedly victims of erysipelas, scab, gangrene, general septicemia, and hospital gangrene. The amputation cases, especially, succumbed to the latter. According to Chenu, the mortality of the wounded on whom resection of the femur was performed was tremendous. Of 1681 individuals submitted to that operation only 136 recovered from it. The mortality, thus, reached 92 percent. Amputations of the tibia had a better record; nevertheless, close to 1,000 patients or 71 percent died of it. Septicemia was widespread in all of the field hospitals.

**THE LOSSES** in the Russian army from 1853 to 1856 were even more considerable. According to Chenu, the number killed in the war was estimated to be 30,000, while those who died as a result of wounds or diseases numbered twenty times as many, or about 600,000. According to other data, the mortality of the Russian armies during the Crimean campaign, though less than the above figures, was still extremely high. Doctor Pirogoff, the great Russian surgeon who played a very active role at that period, was horrified at the great number of wounded who succumbed to postoperative infections, stating: "In looking on the cemeteries where repose those who fell victim to hospital infections, I do not know what to marvel at more: the stoicism of the surgeons

seeking for new operative methods, or at the confidence which the governments and society continue to enjoy".

According to Pirogoff's description of the Second Continental Hospital at St. Petersburg: "the large, badly ventilated wards are filled with patients suffering from erysipelas, acute and purulent edemas and septicemia (9). The nurses, without any scruples, were in the habit of transferring the linen serving as compresses for the wounds from one patient to another. The mal-administration of hospitals went as far as to preserve, for the purpose of resale, soiled and ill-smelling lint taken from the wounds, as well as the dressings, compresses and linen, which were put up in special stockrooms, situated close to the sick-wards".

Into this milieu of wounds, sepsis, and death, came Louis Pasteur and Joseph Lister.

Louis Pasteur not only showed that putrefaction was a fermentation caused by the growth of microbes, but he proved that these could not arise *de novo*. Thus the germ concept of infection developed and the dreaded changes in wounds after injuries received new significance (9).

**LISTER** went through the same experiments which Pasteur had made on fermentation in order to convince himself that the wound putrefaction and other changes were caused by microbes (35). We have his account of the history of his beneficent discovery of the principle of antiseptic surgery: "Nothing was formerly more striking in surgical experience than the difference in the behavior of injuries according to whether the skin was implicated or not. Thus, if the bones of the leg were broken and the skin remained intact, the surgeon applied the necessary apparatus without any other anxiety than that of maintaining a good position of the fragments, although the internal injury to bones and soft parts might be severe.

"If, on the other hand, a wound of the skin was present communicating with the broken bones, although the damage might be in other respects comparatively slight, the compound fracture, as it was termed, was one of the most dangerous accidents that could happen.

"What was the cause of this astonishing difference? It was clearly in some way due to the exposure of the injured parts to the external world. One obvious effect of such an exposure was indicated by the odor of the discharge, which showed that the blood in the wound had undergone putrefactive change by which the blood nutrient liquid had been converted into highly irritating and poisonous substances.

"These and many other considerations had long impressed me with the greatness of the evil of putrefaction in surgery."

**IT REMAINED** for Lister to search for an antimicrobial chemical which would inhibit or kill bacteria finding their way into the wound. It soon appeared that diluted carbolic acid would answer this purpose and the principle of antisepsis was established (9).

Von Bergmann then developed his principle and practice of aseptic surgery, and a new day dawned in the practice of surgery which offered the hope of surgery with freedom from infection. This hope was not realized in patients with trauma, however, and in World War I the mortality rate of compound fractures of the femur approached 80 percent, and Frey noted that of the Germans dying in World War I following fracture of the femur, two thirds died from infection (9).

Thus the establishment of the germ concept of wound infection and the development of the principle and practice of antiseptic and aseptic surgery did not materially decrease the incidence of infection and death from this type of severe trauma. A similar story could be told about burn injuries and other serious types of open wounds.

Hitler realized the significance of the failure of these two discoveries to prevent or control infection in severe wounds. In anticipation of a possible World War II, he appointed a commission headed by Gerhard Domagk to find a chemotherapeutic agent which would be effective against hemolytic Streptococcal and other infections. He was successful in this search when prontosil and sulfonamide were rediscovered (9).

A similar search for an agent effective against the Staphylococcus was conducted in Great Britain by a research team headed by Doctor Howard Walter Florey. Working with the mold *Penicillium notatum* and following the lead of Alexander Fleming's observations made in 1928 (27), Florey and his group developed penicillin (28). Mass production methods were worked out in the United States and the new era of clinical antibiotic therapy began in 1942 and 1943. A large number and variety of antibiotic agents effective against a large number of bacterial types followed.

Antibiotic therapy has been used now for over a quarter of a century. Clinical and laboratory studies have indicated that it has failed to reduce the overall incidence of infection associated with surgical operations or other

trauma, either accidental or otherwise (20, 22, 23, 31). Accurate data are not available. The following table indicates the estimated incidence of hospital admissions, operations, and infections occurring in operative wounds in the United States during the year 1967 (11, 20).

**Table 1: Hospital Infections U.S.A.—1967**

| Estimated Incidence | |
|---|---|
| Hospital admissions | 31,600,000 |
| Surgical operations performed in the operating room | 18,800,000 |
| Estimated number of postoperative wound infections for all types of operations (7.4 percent of operations) | 1,391,200 |
| Estimated number of hospital-acquired infections | 2,101,037 |

This observation leads us to the realization that antibiotic prophylaxis has not been enough, and that we should look further for the deeper meaning of surgical infections.

### The significance of infection in relation to microbial infection

Most people think of infection in relation to the bacteria causing them, and, of course, bacteria are the fundamental cause of wound sepsis in trauma. Bacterial contamination occurs to varying degrees in all wounds produced by accidental injury or resulting from violence. These microorganisms vary in virulence, and fortunately only a small percentage becomes successful in colonizing wounds and producing infections (4, 6, 12, 39).

It is interesting to note the large number and varieties of microorganisms which have been demonstrated to be infecting agents in surgical wounds. This observation suggests that infection is a complex phenomenon with the growth of the infecting microorganisms being dependent to a large degree upon other factors. The mere presence of virulent bacteria in a wound *per se* does not make infection a certainty, however. Rather, the evidence indicates that the physiologic state of the tissues within the wound before and after treatment is more important than the presence of bacteria.

Surgical infections are frequently mixed infections with multiple bacterial strains participating in symbiotic or synergistic activities, and these may also be an important determining factor of the nature and severity of the infection.

### The significance of infection relative to other causes

Too often, the physician and bacteriologist have "tunnel vision" with emphasis and fixation on the bacterial etiology of wound infections, and other etiologic factors of considerable importance may be overlooked. An overview of these can be found below.

**Table 2: Wound Infections**

**Etiologic factors other than bacterial**

1. The presence and amount of devitalized tissue within the wound.
2. The presence of impaired local circulation.
3. The presence and types of foreign bodies.
4. The location, nature, and duration of the wound.
5. The local and general immunity response of the individual.
6. The type, time, and thoroughness of treatment.
7. The general condition of the patient.

Compound fractures, burns, gunshot and high explosive wounds, fracture dislocations, extensive laceration, crushing injuries or similar types of wounds which contain torn devitalized muscle and dirt, have been particularly prone to develop infections (11, 15, 16, 17, 30, 41, 42). It is important to keep in mind that the presence of unhealthy, irritated, or dead tissue in wounds invites and supports the growth of virulent and to lesser degrees nonvirulent bacteria. Healthy tissues on the other hand possess a remarkable resistance to bacterial colonization and invasion of wounds (18).

Impaired circulation also decreases local resistance and may produce local derangements in the physiologic state of the wound with the development of a wound pablum favorable to bacterial growth and invasion. Maintenance of an adequate blood supply therefore becomes a prime consideration.

The location of wounds is another consideration since various tissues of the body are known to have different powers of local resistance. The abdomen, thigh, calf, and buttock are especially susceptible, while the face, scalp, and thorax are less so (11, 17).

**FOREIGN BODIES** frequently harbor large numbers of bacteria in wounds and enhance the probability of infection through their local irritative action on tissues. The presence of foreign bodies, such as dirt, gravel, cinders, bits of clothing or fragments of wood, metal, or glass, has seemed to increase the virulence of contaminating clostridia. This has been clearly demonstrated experimentally in a study of gas gangrene in animals by Altemeier and

Furste who found that the minimum lethal dose of a standardized strain of *Clostridium welchii* was decreased 1,000 times in the presence of crushed muscle and dirt (18). Thus it took one million times less bacteria to produce a fatal infection in the presence of devitalized muscle and dirt as it did when the bacteria were injected into healthy muscle. Buried suture and prosthetic material may also act as foreign bodies in the presence of contamination.

The time, type, and thoroughness of treatment alone may alter the outcome. The earlier treatment is instituted the better the likelihood of success. Of primary importance is the excision and removal of all devitalized tissue and foreign bodies within the wound whenever possible and within four to six hours after injury in an effort to remove any potential pablum before invasive bacterial growth can occur. Delayed definitive treatment may permit the inception of infection. Inadequate debridement, primary closure of incompletely debrided wounds, tight packing of wounds, closure under tension, and application of improperly fitting casts or splints may favor the development of devitalized tissue and bacterial colonization of wounds (4, 11, 17).

**THE MULTIPLICITY** of severe wounds in one person may compromise his treatment and make adequate debridement of one or more of his wounds impossible. Because of severe shock, hemorrhage, or the association of wounds, the local treatment of wounds may necessarily assume a relatively secondary role in relation to the early overall treatment of the patient. If the period of time required for the successful general treatment exceeds six to ten hours, infection may have occurred before local definitive treatment is possible (4, 11, 39).

The relative importance of the immune response of the individual has become increasingly apparent in the past ten years as the limitations of prophylactic antibiotic therapy became more obvious. Resistance may be local, regional, or general. Local immunity depends partly on the type of tissue, but particularly its vascularity. Other important factors include the action of the regional lymph nodes, phagocytosis, and intracellular killing of the microbial organisms. The latter process may be adversely influenced by severe injuries such as burns or debilitating chronic diseases including diabetes mellitus, uremia, and leukemia.

Improvements in the clinical management of patients with severe trauma have led to an overall increase in survival which has resulted in considerably larger numbers of patients who are susceptible to infectious complications. Recent research involving trauma patients has shown that they develop a variety of immunological deficits which render them "high risk" patients. Perhaps the most important of these deficits is the relative abnormality of neutrophilic function which has been reported by Alexander (2, 3). It occurs at periodic intervals in normal patients, but it is accentuated by trauma. Its biological importance can be appreciated by the observation that in patients with serious burns all of the serious infection occurred at times when a marked abnormality of neutrophil function was present. An intensive search has been made for the regulatory mechanism of this neutrophilic abnormality, but thus far, the cause for the cyclic variation has not been elucidated. However, it has been found that steroid therapy can depress the overall antibacterial function of neutrophils at all points during the cycle.

**ATTENTION** needs to be focused now upon correction of such immunological abnormalities of the host in addition to other methods of management related to control of the bacteria or treatment of the wound. Since prevention of many of the abnormalities of basic host defense must of necessity await the elucidation of biochemical control mechanisms, it would seem that research in host defense mechanisms will give clinical benefits for some years to come. This is not necessarily true, however. Recent research has provided compensation for certain physiological or induced immunological deficiencies. For example, until recently Pseudomonas infections continued to cause septic deaths in a large segment of patients surviving the initial period of resuscitation after large burn injuries despite vigorous systemic and topical antimicrobial therapy with effective agents. The development and use of a specific vaccination with a heptavalent Pseudomonas vaccine has been effective in producing an 80 percent reduction in deaths from Pseudomonas sepsis in this group of patients (1). As an outgrowth of these clinical experiments, a hyperimmune anti-Pseudomonas human globulin has been prepared which seems to be effective as an adjunctive therapeutic measure.

### The significance of wound infections in relation to contributing factors

Other factors may predispose or contribute to the development of wound infection, and

these have been considered to be of increasing importance (Table 3).

**TABLE 3: Significance of Infection in Trauma**

**Other Contributing Factors**

1. Age
2. Extreme obesity
3. Remote active infection
4. Duration of operation
5. Associated diseases: diabetes, uremia, and cirrhosis
6. Debilitating injuries
7. Iatrogenic factors

**Iatrogenic infections**

In exploring the possible reasons for the apparent failure of antibiotic therapy to prevent postoperative wound and hospital acquired infections, our attention has become focused on the fact that many surgical infections may be caused by the surgeon and his treatment, and are, therefore, to be considered to be iatrogenic (6, 11, 23, 43).

For example. recent experience has indicated that prolonged intravenous therapy with indwelling needles or catheters has been an unusually active source of postoperative infections (13, 22). This was particularly evident in high risk debilitated and aged patients, and patients under steroid therapy. A recent survey at the University of Cincinnati showed that over 70 percent of patients with indwelling intravenous catheters for 72 or more hours developed significant areas of thrombophlebitis or active cellulitis, along with their resultant discomfort, fever, and increased morbidity. Serious and fatal infections initiated by intravenous therapy have been observed. A new syndrome called the "Third Day Fever" has been described as a gram negative septicemia occurring three days postoperatively in trauma and other high risk patients (22). It would appear that this type of hospital acquired infection is significant of contamination of the intravenous solution or catheter and that there is need to provide better methods of continuous intravenous therapy. (Fig. 1)

Emergency tracheostomy, while a useful and life-saving procedure in severely injured or seriously ill patients, may become the route of life-threatening pulmonary infections caused by the *Staph. aureus*, *Pseudomonas*, or other

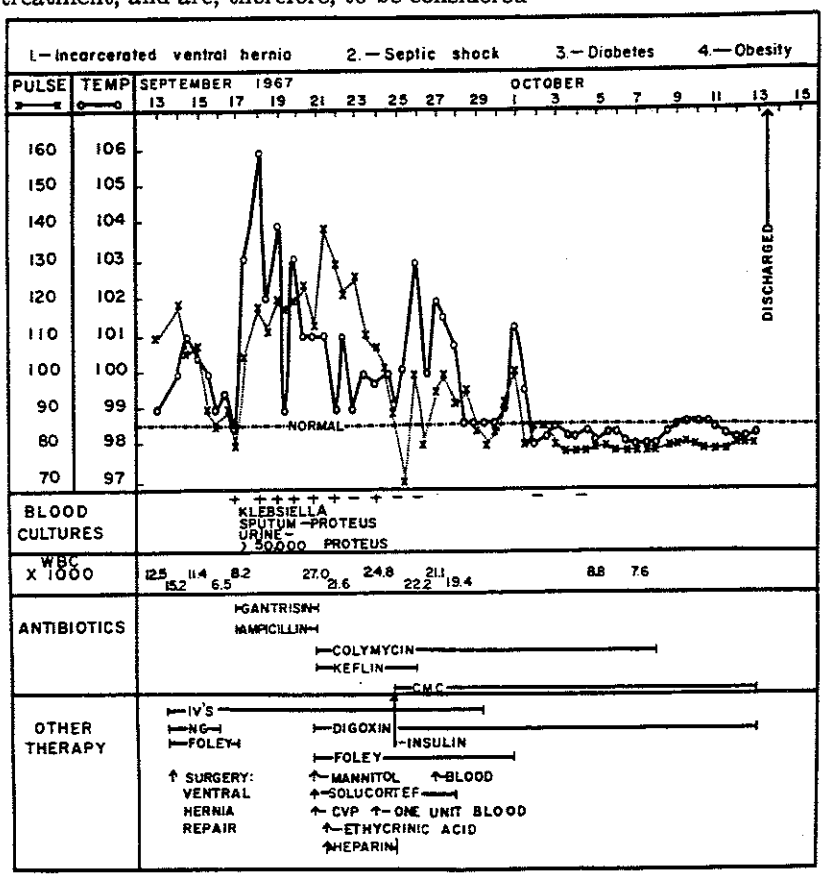


FIGURE 1.
Chart showing course of 45-year old obese diabetic female patient with third day fever with chills, high fever, septic shock, and oliguria developing three days after operation for an incarcerated ventral hernia and as a result of *Klebsiella* sepsis.

virulent bacteria of the hospital reservoir (23). Numerous examples of this type of iatrogenic infection have been observed and reported.

Other iatrogenic infections may be the result of certain procedures or practices in anaesthesia. It should be remembered that virulent and potential respiratory pathogens are present even in asymptomatic patients. While the mucous membrane in most patients has acquired the ability to confine the growth of these bacteria to its surface, experience has shown that they are often opportunists capable of initiating infections of the respiratory tract when the local resistance of the tissue is depressed or when the mucous membrane barrier is broken by instrumentation.

The extension of surgical operations to aged or debilitated patients has required complicated and prolonged anaesthesia which has increased the opportunities for infection in a more susceptible group by bacteria present in the respiratory tract. Moreover, spinal and epidural anaesthesia introduces the possibility of infection of the central nervous system through contamination from hands, instruments, materials of skin of the patient. Instances of iatrogenic meningitis complicating spinal anaesthesia have also been reported (29).

#### Changing patterns in surgical infections

Another factor of significance in trauma has been the recent changing of pattern of infection in trauma patients. Throughout the years the bacteria of greatest importance in wound infection have been the *Staphylococcus*, *Streptococcus*, and *Pneumococcus* (4, 6, 9, 11). In recent years, however, there have been significant changes in the types of infection seen in surgical patients (11, 13, 21, 23. 36, 40).

These changes have included the following:

1. An increasing incidence of gram-negative infections;
2. Superimposed or secondary infections developing during antibiotic therapy;
3. The increasing incidence of gram-negative infections by bacteria of low virulence;
4. Mixed bacterial infections of wounds in which synergism of bacterial action occurs;
5. Infections by *Candida albicans;*
6. Association of an increasing number of infections with "L" forms and other atypical bacterial forms. Wound abscesses, abdominal abscesses, brain abscesses, and thromboembolic diseases are examples, and
7. Growing awareness of the importance of gram-negative anaerobic infections produced principally by the *Bacteroides.*

Gram-negative bacillary infections have become of greater frequency and importance during the past 15 years (13, 22, 23, 38, 40). Since the discovery and widespread use of penicillin and other antibiotic agents, gram-negative sepsis has become a serious threat in modern surgical practice. Between 1942 and 1956, two-thirds of the invasive wound infections seen in surgical practice were caused by gram-positive bacteria. Between 1956 and 1970, however, a fourteen-fold increase in the number of gram-negative infections occurred, and now two-thirds of the infections are of this type. In a study of 480 patients with this type of infection, the causes of this increase were not clear, but they seemed to be related to the widespread and intensive use of antibiotics, the rapid extension of new and complex surgical operations and diagnostic procedures to elderly and other high-risk patients, and a series of iatrogenic factors (13, 14, 22, 23). (Fig. 2)

**THE BACTERIA** most concerned with this increased incidence of gram-negative sepsis were *E. coli*, *Aerobacter aerogenes*, *Proteus*, *Pseudomonas aeruginosa*, and *Serratia*, and their sources were the urinary tract in over half of the cases. The respiratory tract, the alimentary tract, continuous intravenous therapy, and various iatrogenic procedures followed in importance (22, 23).

Of particular interest has been the observation that approximately 80 percent of these serious infections occurred while patients were on antibiotic prophylaxis.

In this regard there has been the suggestion that intensive or prolonged antibiotic therapy might be contributing to the development and increasing incidence of this type of sepsis, including some cases by bacteria previously considered to have little or no virulence (13, 36). During the past five years, for example, there has been a sharp increase in the number of cases of *Serratia marcescens* septicemia on the surgical services of the University of Cincinnati Medical Center. A retrospective and prospective study of 42 patients with this infection has been made, and it is interesting to note that 80 percent were also associated with antecedent or concurrent antibiotic therapy, often in large dosage. This may suggest that *Serratia* sepsis is an emergent secondary infection by an organism of otherwise low virulence or that antibiotic therapy depresses the patient's resistance and permits invasive infections by

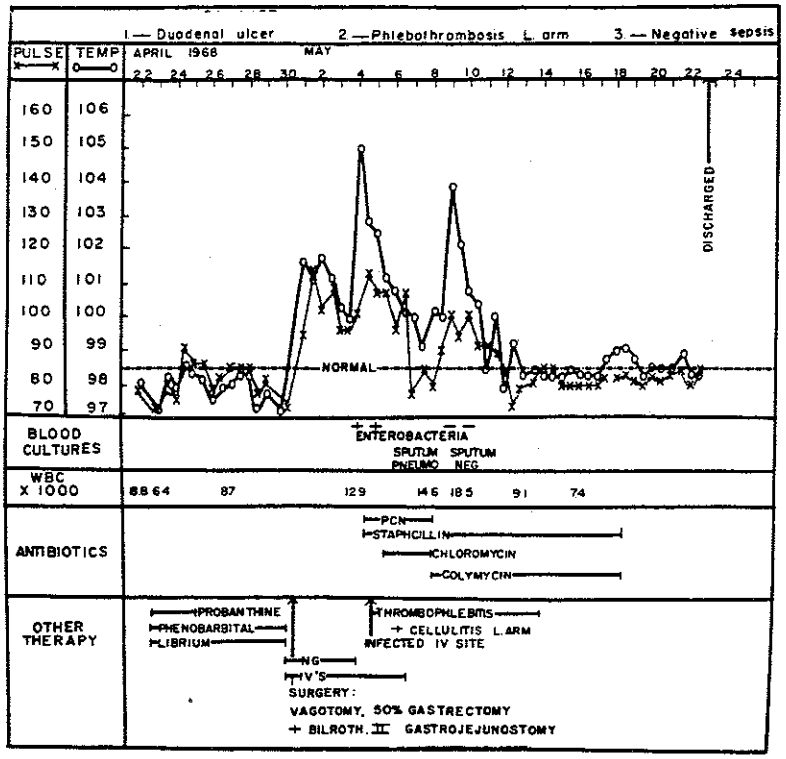


FIGURE 2.
Course of 34-year old male patient with *Enterobacter* septicemia secondary to thrombophlebitis complicating continuous intravenous therapy during postoperative state for gastrectomy and vagotomy for duodenal ulcer.

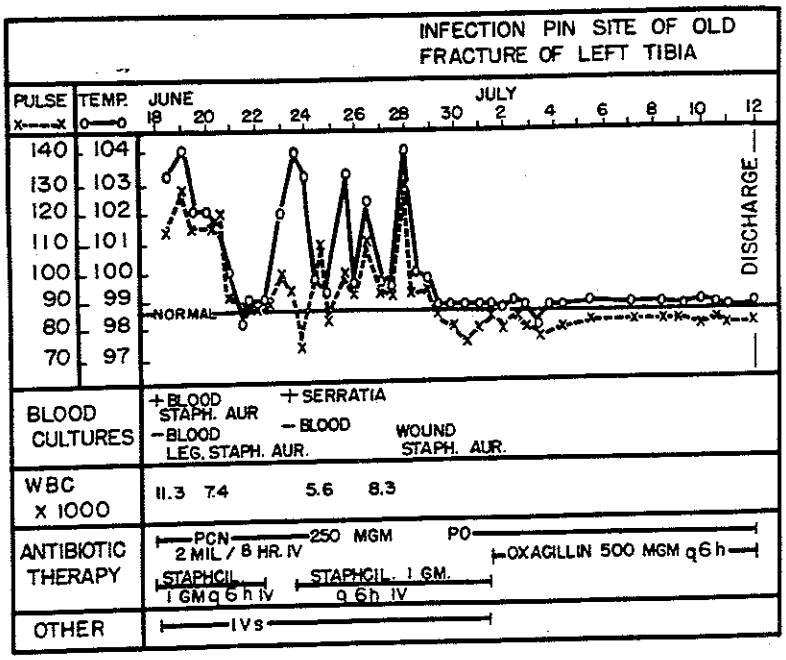


FIGURE 3.
Chart illustrating the course of a 31-year old male patient with *Serratia marcescens* sepsis which emerged during antibiotic therapy with penicillin and staphcillin for a *Staphylococcus aureus* septicemia.

such a microorganism (13). The seriousness of this emerging infection is emphasized by its mortality of 40 percent. The infection is of particular significance when it occurs in the debilitated surgical patient with predisposing or pre-existing diseases. (Fig. 3)

Of special interest was the observation in the first thirteen cases that eleven had developed spontaneously during intensive antibiotic therapy, during use of Keflin in three cases, and with penicillin in doses above 20,000,000 units per day in nine cases.

The association of upper gastrointestinal hemorrhage with sepsis by *Serratia* and other gram-negative bacteria has been noted in approximately one-third of the patients we have studied (13). The significance of this association is under further study.

Other examples of increasing numbers of infections now occurring in surgical practice are those caused by *Candida albicans* and *Herpes.* The latter infections have been noted in patients with severe trauma, such as burns, and in patients under immunosuppressive therapy (36).

**Clinical conditions associated with "L" form and other atypical bacterial forms**

Another interesting study has been that of Altemeier and Hill on the presence of "L" forms and other atypical bacterial forms in various surgical infections such as thrombophlebitis, wound abscesses, brain abscesses, empyema, tubo-ovarian abscesses, and similar lesions (11, 19). The etiologic significance of the "L" forms has remained obscure and debatable.

Interest in those atypical micro-organisms has centered about three observations which have been under study in the Research Surgical Bacteriology Laboratory of the University of Cincinnati during the past ten years:

1. Their spontaneous appearance in the blood stream and cerebral spinal fluid in patients during antibiotic therapy and in association with signs of sepsis;
2. Their presence in pure culture and abscesses of patients during or following antibiotic therapy, and
3. Their presence in the blood stream, cerebral spinal fluid, or thrombi of patients with recurrent thrombophlebitis and thromboembolic disease. (Fig. 4)

"L" and other atypical forms were found in the blood or thrombi in all cases in a study of 54 patients with thromboembolic disease. Cul-

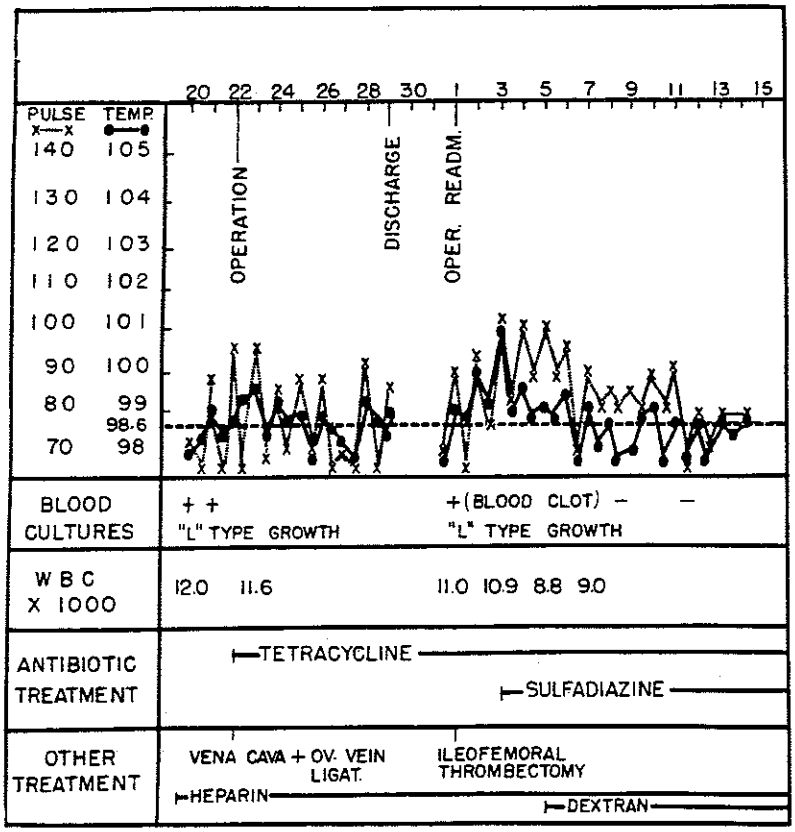


FIGURE 4.
Chart showing studies of a 34-year old female patient with acute recurrent thromboembolic disease associated with "L" from bacteremia.

tures of the blood in a similar number of patients randomly selected were negative. The etiologic association of these micro-organisms with the thromboembolic disease has been under clinical and laboratory investigation (4).

#### The significance of wound infection to the patient

When wound infection occurs, particularly in large wounds, it becomes a serious complication especially in critically ill patients. It may have a serious effect on morbidity, mortality, and the final result of the patient's operation. Its occurrence may determine the issue of life or death, particularly in aged and debilitated patients. Other effects may occur such as lengthened hospital stay, increased medical costs, loss of income, loss of extremities with prolonged or permanent disability, and undesirable cosmetic results (11, 24, 25, 31, 37).

Even in its simplest forms, wound infection may create more pain than the uncomplicated postoperative state. This contributes to heightened anxiety which is aggravated further by the repeated manipulations and dressings of the infected wound. Such anxiety may be converted into dissatisfaction with treatment and even dissatisfaction with the surgeon and physician. In this cycle of anxiety, dissatisfaction, economic loss, temporary isolation, and unhappiness, a situation is created which has become a fertile field for malpractice litigation.

**ANOTHER** important consideration of the significance of infection in the trauma patient is his bodily response to the sepsis (5, 11). The surgeon must realize that the control of the bacteria producing the infection by antimicrobial therapy is not the only treatment the patient requires, but he must be knowledgeable of the pathologic change and impairment of physiology produced in the patient by the infectious agents.

These body responses may take various forms, varying with the type of infecting bacteria, the resistance of the host, the severity of the infection, the time at which the diagnosis is made, and the effectiveness of treatment. In addition to the effect on temperature, pulse, and respiration, the following possibilities should be kept in mind and treated appropriately:

*1*. Fall in blood pressure; *2*. Changes in circulating blood volume; *3*. Alterations in cardiac function; *4*. Changes in the peripheral circulation; *5*. Impairment in renal function; *6*. Changes in blood and coagulation; *7*. Altered pulmonary function with impairment of respiration and oxygen transfer; *8*. Derangements in lymphatic function; *9*. Depressed resistance and immunity; *10*. Altered central nervous system function; *11*. Effects on endocrine function, and *12*. Impairment of wound healing.

#### Significance of wound infection to the surgeon

The development of a postoperative wound infection becomes a matter of immediate concern to the surgeon, and there is a direct effect of this complication on his practice. Its occurrence brings concern to the physician for the safety of his patient, increased demands on his time for treatment, the threat to his professional status, and the increased possibility of liability. He recognizes infection as a great deterrent to wound healing and knows that destruction of tissues, biochemical alterations, increased morbidity, increased mortality, decreased cosmetic results, loss of function, and loss of limb may develop.

In a recent study at the Cincinnati General Hospital of over 500 patients with penetrating wounds of the abdomen, a marked difference in the length of hospital stay was found in those patients whose course was uncomplicated by infection as compared with those in whom infection developed. In patients with comparable initial injuries without development of subsequent infection, hospitalization averaged 12 days. In those in whom subsequent infection occurred, the hospital stay was 32 days, an increased hospital stay of 166 percent.

The shortage of physicians in this country is a matter of growing apprehension, yet if one considers that approximately 7.4 percent of all types of operative wounds will develop infectious complications and that the occurrence of infection will prolong the hospitalization by approximately 166 percent, one may derive an estimate of an additional 12 percent increase in hospital stay contributed by those patients who develop wound infections. This 12 percent increase in stay is magnified in its effect due to the increased care required consisting of frequent dressing changes, periodic re-examinations, multiple laboratory testing, and management of additional medications with their attendant risks.

The almost universal shortage of nursing help is similarly aggravated by the development of infection postoperatively. These patients require a great deal more nursing care than those with an uncomplicated postoperative course. Since there is often no reservoir

from which to draw this additional help, application of more nursing time to these problems necessarily deprives other patients of needed care. Thus surgeons are faced with one more frustrating circumstance in inadequately staffed hospitals (8, 20).

An additional burden is produced in many hospitals by the generally unsatisfactory laboratory assistance available for bacteriologic studies. Not only are there significant delays in obtaining important culture and sensitivity reports, but anaerobic bacterial culture reports are frequently not available. The lack of information on the importance of anaerobic bacteria in wound sepsis has been largely due to the difficulty encountered in culturing and identifying those organisms.

**Summary**

In reviewing the subject of infection in trauma, one must conclude that surgical sepsis is a complex phenomenon in human life whose dimension is real, significant, continuing, demanding, and changing. The application of the germ concept of infection, antiseptic and aseptic technics, immunization procedures, and general use of antibiotics during the past century have had revolutionary effects, but infections nevertheless continue to be serious problems of world-wide scope.

Antibiotic therapy has not decreased the overall incidence of infections in post-trauma patients, and the estimated cost of the wound infections occurring in the United States of America in 1967 was approximately $9.8 billion. This estimate does not include all hospital-acquired infections, however, some of which appear to have been iatrogenic. While we have been successful in preventing or controlling some types of bacterial infections, others have taken their place.

In this regard, there is evidence that hospital acquired and iatrogenic infections have become a serious threat, and that there has been a 14-fold increase in the number of gram-negative infections during the past 15 years.

The pattern of surgical infections has been changing for this and other reasons, making it of increasing importance to find efficient means of preventing gram-negative bacterial and a variety of nonbacterial infections.

A better understanding of the pathophysiological effects of the body to infection is also necessary for more intelligent treatment of the trauma patient with infection.

Factors which depress the resistance of patients and their wounds to bacterial growth need better definition and further study. Those which are iatrogenic should be corrected. For those which are related to the injury and its effects we must look to research for enlightenment and correction.

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