RISK FACTORS FOR INFECTION IN THE TRAUMA PATIENT

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The most common cause of late death following trauma is sepsis. The traumatized patient has a significant increased risk of infection. Transfusion, hypotension, and prolonged ventilatory support are predictive of septic complications. In addition, the trauma patient has a higher predisposition to pneumonia than nontrauma patients (18% versus 3% incidence of pneumonia, $P<.001$). Additional risk factors include the degree of nutrition status and the type of medications used during surgery. Immunologic depression may be an additional risk factor. There is mounting evidence that trauma can result in host defense abnormalities. To prevent the significant mortality caused by sepsis, close surveillance must be maintained, nutritional status must be optimal, and liberal use of antibiotics should be discouraged. Their use should be guided by appropriate cultures and sensitivities. (*J Natl Med Assoc.* 1992;84:1019-1023.)

Key words • trauma patients • sepsis • infection • infectious complications

In recent years, the trauma patient has benefited from the better use of blood products, improved monitoring techniques, new drugs, and sophisticated respirators. These advancements have prolonged life and improved survival. However, for the trauma patient who survives longer than 3 days, infection is second only to severe head injury as the leading cause of death. The burn patient has the highest risk of infection, and the victim of blunt trauma has a significantly greater risk than the penetrating trauma patient. The following factors place the multiply injured patient at great risk for infection:

- open wounds allowing entry of bacteria,
- additional surgery,
- extensive invasion of these patients by various tubes and drains,
- depressed immune system,
- transfusions,
- medications, and
- suboptimal nutritional status.

Prevention of sepsis begins at the time of the initial resuscitation.[1] The trauma patient must be thoroughly evaluated in order to avoid missed injuries. Sterile technique should be employed for all invasive diagnostic and therapeutic maneuvers. Lines placed in the emergency department should be changed or removed if not needed. Open wounds, particularly those that involve fractures, should be graded (ie, clean, clean-contaminated, or contaminated), cultured, and debrided, and prophylactic antibodies should be started. Prophylactic antibodies should be given, but their use should be limited in terms of duration. Emphasis should be placed on the avoidance of superinfections or the development of fungemia.

A dreaded complication of open wounds is contamination with gas-producing organisms. Surgical debridement and antibiotic therapy should be instituted immediately. When gas gangrene secondary to clostridial infection is suspected, debridement, antibiotics, and hyperbaric oxygen therapy should be implemented.[2]

INTRA-ABDOMINAL INFECTION

Victims of intra-abdominal trauma are at significant risk of incurring an infection due to peritoneal contamination by gastrointestinal contents.[3] Associated risk factors are advanced age, injury to the left colon

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necessitating colostomy or primary repair, a larger number of injured organs, the amount of blood transfused, and time of injury. There is also some question as to whether shock plays a role in the development of infection.[4-6] The incidence of intra-abdominal sepsis following penetrating abdominal trauma varies from 2.4% to 45.7%.[7-11]

The most common locations for abscess formation are the subdiaphragmatic, pelvic, and subhepatic spaces.[12] Poor prognosis is seen in older patients, in those with multiple system failure, in the persistently bacteremic patient, and in patients with recurrent or persistent abscesses, multiple abscesses, and lesser sac or subhepatic abscesses. Close surveillance and early diagnosis is the goal in addressing intra-abdominal infections before potentially preventable events such as bacteremia, organ failure, and multiple loculation of the abscess develop.

In an effort to lower risks of infection and bacteremia, victims of abdominal trauma resulting in rupture of the gastrointestinal tract should receive antibiotics as early as possible.[13] The antibiotic used must have adequate activity against anaerobic organisms, especially *Bacteroides fragilis* and *Enterobacter* species for optimal benefit.[14] At our institution, we tend to use a single agent such as cefotetan. However, many clinicians are advocates of multiantibiotic regimens for preventing intra-abdominal infection, although there is no clear evidence that this is more beneficial than single-drug therapy.[15]

Patients who undergo splenectomy are at risk of incurring sepsis postoperatively. Singer estimated that 1.4% of patients splenectomized for trauma develop this type of sepsis, usually pneumococcal in origin.[16] It is felt that patients who undergo traumatic splenectomy or splenorrhaphy with excision of significant amounts of spleen should receive Pneumovax (pneumococcal vaccine polyvalent, Merck Sharp & Dohme, West Point, Pennsylvania).[17] There is evidence that the immune response of these patients is not comparable to normal controls.[18]

RESPIRATORY INFECTIONS

A substantial number of patients who have extended hospital courses with prolonged periods of coma or immobilization and who are ventilator dependent are at enormous risk for pulmonary infections. Helling et al, in analyzing infectious complications in the severely head injured, found that pulmonary infections occur most commonly, affecting 41% of the patients selected.[19] The predominantly offending organism was a gram-negative organism.

A study was conducted in our trauma unit looking at pneumonia in the trauma versus the nontrauma population. In the intensive care unit, the incidence of pneumonia in trauma patients was 18%, while in the nontrauma population, the incidence was 3%, a substantially significant difference ($P<.001$).[20] The statistics for bacterial types of pneumonia were similar for both groups: *Haemophilus influenza, Staphylococcus aureus,* and *Pseudomonas* species. However, early in the trauma patients' hospital course, a propensity toward *H influenza* often occurred. In our patient population, an additional risk factor for developing pneumonia was injury above the diaphragm. Trauma to the lung parenchyma can cause a pneumothorax, hemothorax, and intra-alveolar hemorrhage, contributing to localized edema.[21]

The clinical diagnosis of pneumonia includes fever, leukocytosis, purulent secretions, and new or progressive infiltrates in a chest radiograph that do not clear with chest physiotherapy. In our intensive care unit, we institute an aggressive attempt at preventing pneumonia by diligent involvement of both the chest physiotherapist and nursing, complemented by the early involvement of rehabilitative medicine. We have found that performing surveillance of sputum gram stains and cultures allows infections to be detected early. We also institute the use of sucralfate (with the appropriate pH). Alkalinization of the stomach contributes to colonization of the upper gastrointestinal tract, which may be of major importance when considering aspiration pneumonia. It has been shown that sucralfate recipients have a lower concentration of gram-negative bacilli in gastric aspirate, pharyngeal swabs, and speculum aspirates.[22,23]

The prophylactic use of antibiotics does not appear to alter the development of infection. However, there is some disagreement, particularly in the clinical setting, of chest trauma requiring a thoracotomy tube. LoCurto et al described a significant reduction in infectious thoracic complications, including pneumonia.[24] In many instances, antibiotic therapy is empirical, depending on the condition of the patient. If a pathogen is subsequently cultured, a greater selectivity of antibiotics should be used based on sensitivities.

OCCULT INFECTIONS

Patients who present with persistent fever must undergo close evaluation to ascertain the source of infection, ie, open wounds, intra-abdominal infections, or respiratory infections. These tend to be the more common sources of infection leading to sepsis. In addition, the urinary tract is an equally common source

of infection and must always be considered in the differential diagnosis.[25,26]

At our institution, the most common pathogen is a gram-negative bacillus: *Enterobacter coli, Klebsiella* species, and *Pseudomonas* species. We encourage aseptic technique for inserting urinary catheters, irrespective of the situation, and catheters are removed as soon as bladder control returns or when intermittent catheterization is appropriate.

In many centers, line infection is the leading cause of bacteremia,[27,28] the incidence ranging between 20% to 30%. Arterial lines, particularly cutdowns and central venous lines, are the more common sites of line-associated infection. In our intensive care unit, arterial and Swan-Ganz lines are changed on the fifth day. The insertion of these lines (Swan-Ganz catheters and central venous lines for hyperalimentation) is done with mask, gowns, and gloves. The predominant organism is *S aureus.*[29] For diagnosis, we require:

- a positive line tip culture,
- a positive blood culture or purulence at the site of insertion, and
- no other potential source of bacteremia.

Cryptic fevers are common in the trauma patient; sites of infection that tend to be more difficult to identify are central nervous system infections. Virtually all these infections are associated with dural disruption.[30,31] Meningitis is usually seen with cerebrospinal fluid rhinorrhea or otorrhea. Brain abscesses occur predominantly after severe penetrating head injuries, most developing within the first months after the injury.[32] Intracranial pressure monitors, particularly ventriculostomy catheters, place the trauma victim at increased risk, with a 5% incidence of infection.[33]

The more common organisms seen with meningitis are *Streptococcus pneumoniae* and *S aureus.*[30,34] *Haemophilus* species are commonly seen as a cause of meningitis, and lumbar puncture, being the standard for diagnosis (provided the patient is not plagued with cerebral edema) places the patient at risk of herniation.

Some trauma patients who have been on nasotracheal intubation for a prolonged period of time and who have indwelling nasogastric tubes are predisposed to acute paranasal sinusitis. However, this is an unusual complication. Sinusitis involving the maxillary sinus was first recognized in the 1970s.[35,36] Other risk factors include medications (ie, steroids) and facial fractures. Diagnosis begins with sinus radiographs, computerized tomographic scans, and needle aspiration. The organisms can be varied, eg, *S pneumoniae, H influenza, Enterobacter* species, *S aureus, Pseudomonas* species, *Klebsiella* species, *E coli,* enterococci, and anaerobes.

BLOOD TRANSFUSION

The immunosuppressive effects of blood transfusion were first noted in renal transplantation.[37] Blood transfusions have been implicated in an increased incidence of bacterial infections following elective colonic operations and penetrating abdominal trauma.[4] At our institution, we demonstrated a significant correlation between transfusion history and septic complications in penetrating trauma. It was predictable that patients who required more than 10 units of blood would have septic complications.[38,39]

In a study done by Wilson et al, all of the patients who died more than 2 days after receiving 20 or more units of blood had developed severe infections, with gram-negative pneumonias predominating.[40] In addition, it was pointed out that the duration of shock also is a factor, particularly as it relates to mortality. Polk et al, in their study of host defense, did not see an increased incidence of major infection as a consequence of massive blood transfusion. However, major transfusion is associated with an increase in the absolute number of circulating T-suppressor cells and an increase in HLA-DOC expression, implying a graft versus host reaction to allogenic lymphocytes in the transfused blood.[41,42]

IMMUNOLOGIC DISTURBANCES FOLLOWING TRAUMA AND NUTRITION

Thermal injuries have augmented our understanding of immunologic function and host resistance. We are gradually beginning to understand the deficits in the immune system following blunt trauma.[43-45] The alteration in immunity appears to be multifactorial with depression of both the humoral and cell-mediated systems.

As mentioned earlier, it has been observed that patients who receive transfusions of 20 units or more have lower T-cell or lymphocyte counts.[41] The total T-cell count can decrease as early as 24 hours after injury, a deficit that can last up to 10 days.[46]

Significant suppression of function of lymphocytes is seen in major trauma. The decrease response can be seen with such stimuli as phytohemagglutinin, pokeweed mitogen, and mumps antigen, lasting for as long as 3 weeks.[47] As for B cells, which are lymphocytes that are responsible for immunoglobulin production, little change has been demonstrated following blunt trauma.[48]

It is common to find leukocytosis following trauma; however, in the patient receiving multiple transfusions, total leukocyte count can be lowered.[41] In addition, neutrophil chemotaxis is depressed within hours following major injury.[49] Palder et al noted that a transient decrease in neutrophil chemotaxis predated clinical sepsis by 2 to 5 days, correlating with the incidence of bacteremia.[50] Chemiluminescence is an indirect measure of bactericidal function and oxidative metabolism of neutrophils. After injury, there is a decrease in chemiluminescence.[51]

Monocytes originate in the bone marrow, becoming important in the immune system when they process and present antigen to lymphocytes. Following major trauma, monocyte antigen-presenting capacity is reduced to half, increasing to normal by 25 days.

Phagocytosis is a series of well-defined steps occurring in sequence. There is chemotaxis, which is a drawing of white cells to the area of infection, opsonization, the process by which bacteria are made susceptible to ingestion by neutrophils, and finally the killing of bacteria. Posttrauma, there is a depression in phagocytic function.

Activation of complement components leads to increased bacterial phagocytosis by increasing leukocyte adherence and stimulating chemotaxis of monocytes, macrophages, and neutrophils. There appears to be a preferential activation of the alternate pathway of complement activation versus the classic pathway. Alternate pathway titers have been shown to decrease markedly.[52]

The nutritional state of the trauma patient potentially compounds the problem of immunologic disturbance. The most common cause of secondary immunodeficiency is protein-caloric malnutrition.[53] Alexander et al, using the burn model, demonstrated that an ω3 fatty acid-enriched enteral formula induced better cell-mediated immunity and higher opsonic index.[54] It is important that the catabolic trauma victim receive nutritional supplement early in his or her hospital course in order to improve healing and host defense.

SUMMARY

The multiply injured patient represents a significant challenge to the trauma surgeon. Improvements in management have allowed patients to survive longer. As a consequence, the trauma patient incurs several risks of infection and sepsis. The injury as well as the diagnostic and therapeutic procedures that are instituted place the patient at great risk of infection. The predisposition for infectious complications can alter the many components of the host immune system. It can be challenging for the trauma surgeon to prevent infection, to recognize who is at risk through close surveillance, to appreciate the complexities of the alterations to the host immune systems, and finally, to treat complications in an efficient and expeditious manner.

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