Patterns of Infection and Mortality in Thoracic Trauma

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Tissue infection and systemic sepsis are common causes of morbidity and late mortality after major thoracic trauma. To seek causative mechanisms, prognostic indicators, and areas of possible improvement in therapy, we reviewed 310 consecutive adults admitted with major thoracic trauma. Of these, 56 (18%) died of massive injuries in the first 5 days; the remaining 254 were considered at risk for infectious complications. There were 21 late deaths in this group, and 15 (71%) were caused by systemic sepsis. Eighty-four patients (33%) developed thoracic infections, and 15 (6%) had significant nonthoracic infections. Markers of increased risk of infection included blunt injury, shock and unconsciousness on arrival, and splenectomy. Pulmonary infection was increased significantly following prolonged endotracheal intubation, but was virtually absent following tracheostomy. The risk of infection was increased significantly if prophylactic antibiotics were not used, but no definite correlation could be made to advanced age, pre-existent disease, nor post-traumatic malnutrition. Attention to some of these factors may decrease the risk of infection in thoracic trauma.

WHILE MUCH of the morbidity and mortality in patients sustaining serious thoracic injuries is a direct result of the trauma itself, several post-traumatic complications contribute significantly to prolonged hospitalization and late death.[1,2,3] Foremost among these is infection, although brain death, adult respiratory distress syndrome, coagulopathy, various organ system failures, thrombosis and embolism, and gastrointestinal bleeding are not uncommon.

This review of thoracic trauma was undertaken with the idea of identifying both markers of future infection and possible areas of therapeutic modification. The results demonstrate the following: thoracic trauma patients can be stratified into groups with varying degrees of risk; even within an institution with a high volume of trauma work, there can be significant variance in therapeutic approaches; and several areas in the treatment of these patients merit further study towards a reduction in post-traumatic morbidity and mortality.

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Material and Methods

Over a 2-year period, 1980 to 1982, 310 consecutive patients were admitted with major thoracic trauma to the Hermann Hospital. These patients form the basis of this report. All those with significant thoracic injuries were admitted to the study, regardless of whether or not they had other injuries. "Major" thoracic trauma included all those with penetrating injuries of the chest, and those with blunt injuries who had one or more of the following: pneumothorax, hemothorax, significant lung contusion, or proof of damage to another intrathoracic structure. Those few patients with minor rib fractures and no evidence of intrathoracic injury were excluded.

Since this study was designed to examine those instances of morbidity and mortality due to infectious complications, 56 patients (18%) dying of massive injuries during the first 5 hospital days (usually the first 24 hours) were excluded from the group. This left a study cohort of 254 patients considered at risk for infection. While clinical infection was apparent in a few of the 56 patients who died, it did not appear to contribute significantly to their deaths, which were generally related to uncontrolled bleeding, irreversible shock, or multisystem organ failure. Infectious complications appearing in the first 5 hospital days in the 254 long-term survivors were considered in the study.

The study group comprised 200 men and 54 women, with an age range of 13 to 76 years. Ten patients were 65 years of age or older. One hundred and one patients (40%) sustained penetrating injuries, whereas 153 (60%) had blunt trauma; the ratio of men to women was 6:1 for those with penetrating injuries, and 3:1 for those with blunt injuries. One hundred and ninety-one patients (75%) were transported by Life Flight helicopter; the remainder (25%) arrived by a variety of ground transportation methods.

Infections were generally of three types: pneumonia, empyema, and intra-abdominal (usually subphrenic) abscess following major abdominal injury. Minor wound infections and the occasional episode of phlebitis were not considered here. No patient had significant morbidity or mortality from bacteremia originating from a site other than the lung, pleural space, or abdomen. The diagnosis of pneumonia entailed typical physical signs: a new pulmonary infiltrate by radiograph, and a new positive culture from the sputum. Pneumonia was occasionally lobar, but most often bronchoalveolar in distribution; atelectasis without the above factors was not considered primarily infectious. The diagnosis of empyema required a significant amount of pus retained in the pleural cavity, positive bacteriology, and appropriate clinical signs. Abdominal abscesses were all proven at operation or autopsy.

Of the whole group of 254 patients, 97 (38%) showed signs of hypovolemic shock or frank circulatory arrest on admission, and 48 (19%) were unconscious on admission.

Major abdominal trauma requiring laparotomy was present in 65 patients (25%); 36 patients had splenectomy; five had repair of splenic injury; 20 others had major liver injuries; and four had major abdominal trauma not involving the liver or spleen.

Prophylactic antibiotics were used from the time of admission in 181 patients (71%). Sixteen different antibiotics or combinations of antibiotics were used, the most common of which was Mandol® alone, for periods varying from 1 day to 33 days. Thirty-three of the prophylactic antibiotic group (18%) received the same prophylactic antibiotic continuously for periods of ten or more days.

With respect to duration of endotracheal intubation and assisted ventilation, 68 patients were never intubated, 121 patients had endotracheal intubation for less than 1 week, 32 for between 1 and 2 weeks, 17 for between 2 and 3 weeks, and 16 for more than 3 weeks. Twenty-six patients underwent tracheostomy.

Statistical significance of results was calculated by the chi square test, corrected for continuity.

Results

Of the whole group of 254 patients, 86 (34%) suffered one or more major infections; those with blunt injuries had a statistically significantly ($p < 0.01$) higher incidence of infection than those with penetrating injuries, 39% *versus* 27%, as shown in Table 1. The specific combinations of the three forms of infection (pneumonia, empyema, and abdominal abscess) are shown in Table 2. Fifty-four patients had one of the three types of infection, 28 had two types, and four had all three types.

TABLE 1. *Infection in Thoracic Trauma Results*

	Infected Patients/Total	Per cent
Significant infection	86/254	33
Infection (blunt)*	59/153	39
Infection (penetrating)	27/101	27

* $p < 0.01$ for blunt *versus* penetrating.

Endotracheal Intubation and Tracheostomy

There was a direct correlation between the duration of endotracheal intubation and the incidence of pulmonary infection, as seen in Table 3. Of 68 patients never intubated, only one developed pneumonia. Infection with intubation ranged from six out of 67 (9%) intubated for less than 3 days, through six out of 17 (35%) intubated for five or six days, to 15 out of 16 (94%) intubated for more than 3 weeks. Table 3 also shows a convenient division of the patients into those intubated for less than 1 week, with 21 of 121 (17%) developing pneumonia, and those intubated for 1 week or more, with 50 out of 65 (77%) developing pneumonia. This difference was highly significant ($p < 0.001$).

By contrast, 26 patients underwent tracheostomy with only two (8%) subsequent instances of new pulmonary infection.

Prophylactic Antibiotics

There were 38 patients with infection (21%) in the group of 181 receiving prophylactic antibiotics from the time of their admittance to the hospital. Forty-eight patients with infection (66%) in the group of 73 were not receiving prophylactic antibiotics ($p < 0.005$).

Since prophylactic antibiotics were selected for the various patients, and not randomized, it could be postulated that those receiving antibiotics were more seriously injured and, therefore, more prone to infection, causing this difference. That this did not seem to be the case was shown by the statistically higher incidence of shock (43% *versus* 27% in 97 patients; $p < 0.01$) in those who received antibiotics compared to those who did

TABLE 2. *Infection in Thoracic Trauma Sites*

Pneumonia alone	44
Pneumonia/Empyema	19
Empyema alone	8
Abdominal abscess/Pneumonia	7
Abdominal abscess/Empyema	2
Abdominal abscess/Pneumonia/Empyema	4
Abdominal abscess alone	2
Total	86

TABLE 3. *Infection in Thoracic Trauma versus Prolonged Endotracheal Intubation*

Days	Patients	Pneumonia	Per cent
0	68	1	1
1–2	67	6	9
3–4	37	9	24
5–6	17	6	35
7–10	18	11	61
11–14	14	10	71
15–21	17	14	82
22+	16	15	94
Total	254	72	28
1–6	121	21	17*
7+	65	50	77*

* $p < 0.001$.

not. There was no significant difference in the incidence of unconsciousness-on-arrival (15% *versus* 22% in 48 patients) between the two groups. Prophylactic antibiotics were used in similar numbers of patients with blunt and penetrating injuries, and in similar numbers of patients with and without significant abdominal trauma.

Abdominal Trauma and Splenectomy

Significant abdominal trauma requiring emergency laparotomy was present in 65 patients, 25% of the entire group. Of these, 36 underwent splenectomy as part of their procedures. Twenty-eight of the 36 (78%) had significant infections, compared to 9 of 29 (31%) who did not require splenectomy ($p < 0.001$). Twenty-four of the 29 nonsplenectomy laparotomies involved repair of significant liver trauma, and for this reason it seems unlikely that the difference in infection rate was related to varying degrees of severity of trauma.

Of the splenectomy group, 33% developed subphrenic abscesses, and the remaining 44% (78% infected minus 33% subphrenic abscesses) had thoracic infection without abdominal infection. Five patients in the nonsplenectomy abdominal trauma group underwent splenorrhaphy, and there was no significant infection in any of these.

Shock and Unconsciousness

Both shock and unconsciousness on admission to the hospital were predictors of future infection, 47% versus 25%, and 58% versus 28% respectively.

TABLE 4. *Infection in Thoracic Trauma versus Prophylactic Antibodies*

	Patients	Infection	Per cent	Shock* (%)	Unconscious† (%)
Antibiotics	181	38	21	43	15
No Antibiotics	73	48	66	27	22

* $p = 0.008$.
† Not statistically significant.

Other Factors

Other potential predictors of future infection that we tested were age, pre-existing disease, and post-traumatic malnutrition, but we were unable to come to any significant conclusion.

Eight patients were 65 years of age or older; seven of these survived, and only three had infectious complications. They had prolonged hospital stays (average = 40 days in the seven survivors), but appeared to make adequate recoveries.

Several of the patients had pre-existing diseases, including ischemic heart disease, chronic obstructive pulmonary disease, diabetes, osteogenesis imperfecta, and muscular dystrophy, but we were unable to find evidence of increased risk of infection in the group.

We focused on post-traumatic malnutrition, and indeed many of the patients with prolonged courses received either enteral or parenteral alimentation or both, but we could not show either beneficial effects of this, or deleterious effects in its absence.

Mortality

There were 21 deaths in the group of 254 patients, six of which (2%) were from irreversible cerebral injury, and 15 of which (6%) were due to tissue infection and systemic sepsis. The infectious death rate was six per cent for both blunt and penetrating injuries, and not statistically different between those who received prophylactic antibiotics (nine out of 181, five per cent) and those who did not (five out of 73, seven per cent). Of note, four of the five deaths in the no-prophylactic-antibiotic group were caused by *Staphylococcus aureus* septicemia, while this organism was not the cause of death in any of those receiving prophylactic antibiotics. Shock on admission was related significantly to late death from infection, but unconsciousness was not.

Thus, while many factors were significant predictors of morbidity from infection, only shock on admission was also a predictor of late mortality.

Discussion

Many factors can contribute to infection in the patient with multiple injuries, including aspiration, contamination of body cavities both from the outside and from viscera including the lungs and major airways, multiple complex operative procedures, prolonged mechanical ventilation, and chronic multisystem organ failure (which can include immunological compromise). It was at the same time surprising to us that the infection rate was so high, 34%, while the late mortality rate from infection was relatively low, six per cent, considering the gravity of the injuries and the frequency of serious complications.

We believe that we have shown beyond doubt the value of tracheostomy in thoracic trauma, at least in our hospital. Pneumonia was linearly related to the duration of endotracheal intubation, and was associated frequently with empyema. Tracheostomy allows improved airway toilet, hygiene within the mouth and pharynx, and a concomitant theoretic decrease in acute sinusitis. We have observed frequently following tracheostomy an immediate recovery from what may be described as toxemia (fever, tachycardia, poor gastrointestinal function promoting malnutrition, and moderate obtundation), which we believe is due to an ongoing subclinical infection of both the upper and lower airways.

While the general consensus[2] leans towards early tracheostomy for respiratory failure in those with thoracic trauma, several studies[4–6] have suggested that prolonged endotracheal intubation may be as satisfactory for long-term management of assisted ventilation with respect to infection as tracheostomy. But, in general, these studies have not addressed the question of the injured lung, as opposed to those who just required ventilation from respiratory failure. Our conclusion is supported by another report[7] of a large number of thoracic trauma patients from a major trauma center, and we continue to believe in the utility of early tracheostomy in the prophylaxis of infection. While assisted ventilation is clearly life-saving in most of these patients, there is ample evidence from series other than ours supporting the concept of infection produced by intubation, and Shackford et al.[8] have advocated an aggressive policy of avoiding intubation for flail chest wherever possible. Many reports[9,10] document severe complications of tracheostomy such as tracheal stenosis and tracheo-innominate fistula. We are aware of no particular complication in the 25 long-term survivors of tracheostomy in our group.

There is clear evidence of an increased risk of major infection following splenectomy, not only in children but also in adults.[11–13] Our data show a correlation between splenectomy and major postoperative infection, not only in the abdomen but also in the chest, compared to a similar group of patients with major abdominal trauma, most of whom had liver trauma. Whether this is a local or a systemic effect, or both, is unknown. There is experimental evidence supporting the idea of immunocompromise in animals with abdominal sepsis,[14] and it seems likely that patients such as ours who have subclinical multiorgan system failure do, indeed, have acute compromise of the immune systems. Whether or not splenectomy contributes to this in the short-term is not known, but it is accepted that splenic preservation is useful in long-term infection prophylaxis.[15,16] We believe it may be useful in the adult population also. None of our five patients undergoing splenorrhaphy suffered major infectious complication.

The use of prophylactic antibiotics has been accepted as routine in virtually all major surgery, including cardiac, vascular, thoracic, and intestinal procedures. Our data lend strong support to their utility in the majority of patients with thoracic trauma, excepting those with minor injuries requiring neither intubation nor operation.

Virtually all of these patients were managed by general surgeons, some of whom were interested in trauma as an intellectual discipline but most of whom were not. There was almost no input from thoracic surgeons. The large number of surgeons involved explains in part the observed therapeutic variability with respect to factors like prophylactic antibiotics and the timing of tracheostomy.

What could the thoracic surgeon offer these patients who have survived their injuries for 5 days? The most common violation of thoracic surgical principles that we observed was the failure to maintain an empty pleural space with apposition of the lung to the chest wall. There were many instances where clotted hemothoraces and pleural effusions, with or without concomitant pneumothorax, contaminated from the outside, from the lung, or from abdominal trauma, were not drained effectively. These not only promoted their own infection, but they also compressed the lung and contributed to its infection. Effective use of chest tubes, appropriate mechanical ventilation, and early thoracotomy can contribute to prophylaxis of severe infections and their potentially lethal complications in these already compromised patients. A second problem observed was a tendency to maintain endotracheal intubation and assisted ventilation longer than was necessary. We have documented the progressive incidence of thoracic infection with prolonged endotracheal intubation, and believe that the thoracic surgeon experienced in assessing and managing the extubation process can contribute significantly in this area.

Despite advances in our knowledge of the pathogenesis and therapy of systemic infections, they continue to be a significant cause of morbidity and mortality in patients surviving thoracic injuries. We believe that attention to some of the factors outlined here, and more consistent approaches to the subject, are worthy of further study, and may contribute to obviation of some of these complications of trauma.

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Discussion

DR. ARTHUR C. BEALL, JR. (Houston, Texas): I certainly enjoyed this paper from the other medical school in Houston. We also tend to get some of the thoracic trauma at Ben Taub General Hospital.

(Slide) We too have been interested in the problem of infection and ways to prevent this in patients with thoracic trauma, and during the period from 1965 to 1983 we had over 14,000 patients with penetrating thoracic trauma. Of this group, roughly 85% were handled initially by intercostal tube thoracostomy. Fifteen per cent required immediate operation.

The group in which we were interested contained 155 patients who had residual hemothorax after tube thoracostomy and/or thoracentesis and perhaps a second tube. We tried to recognize these patients early and, when necessary, to decorticate them before infection developed, thereby preventing the development of empyema, which is a very serious complication in these patients.

(Slide) In the group in which we did early evacuation of the clotted hemothorax, which requires a relatively small incision and just evacuating the blood, there was no mortality and very few complications. Among those in whom decortication was delayed more than 5 days from admission, the mortality rate was slight, but was there. In fact, the one death in this group was associated with a complication of hyperalimentation required for other injuries.

However, if the patient went on to develop empyema, the mortality rate was up to 9.4%, and of these deaths all but one were associated with sepsis. This is the same thing that Dr. Walker has told us.

(Slide) Perhaps significant in this time of DRGs, those patients undergoing early decortication were out of the hospital in an average of 10 days. If the decortication was delayed beyond 5 days, they were in the hospital for an average of 25 days. If they went on to develop empyema, however, the average period of hospitalization was 37.9 days.

Therefore, it is our opinion that in the patient with residual hemothorax after intercostal tube thoracostomy, it should be recognized early, and decortication carried out before 5 days, therefore preventing mortality from infection and decreasing significantly the average period of hospitalization.

DR. LEWIS M. FLINT, JR. (Buffalo, New York): I too have enjoyed listening to this paper. I think the areas of agreement that we have (based on a clinical experience my former associate, Dave Richardson, and I have worked on, which now is in excess of 600 patients) is that we recognize infection as an important component of severe chest trauma. We also recognize that prolonged endotracheal intubation is a frequent factor associated with infection following chest trauma.

Aside from that, though, I think we have minor to major disagreements with almost every point that Dr. Walker made.

First of all, we would disagree that tracheostomy has a beneficial effect on infection. Since he believes to the contrary, I would like to ask a question about that: Were the patients who were trached already infected? If they were, the incidence of new infection following the tracheostomy is perhaps not as important as one might think.

Second, what was the incidence of tracheostomy complications? In our group, nearly 60 patients have undergone tracheostomy, with a complication rate of about six per cent. The mortality of that complication rate is significant at about 30%.

I wonder if Dr. Walker has attempted to avoid endotracheal intubation, using physiologic measures to select patients for intubation or a nonintubation program. We found that the vast majority of our patients, regardless of their chest wall abnormality or x-ray appearance, can be handled without endotracheal intubation.

Finally, as to the question of prophylactic antibiotics, since prophylactic antibiotics have never been shown to have any effect on intra-abdominal infection following trauma, I think that it may be an error to lump the intra-abdominal infections with the chest infections; and for that reason I would ask Dr. Walker to tell us about the patient who had only pneumonia or empyema, and whether prophylactic antibiotics had any effect on the frequency of infection in that group.

I think the messages that we have been able to establish from our clinical experience in Louisville are that intubation may be avoided, prophylactic antibiotics have a minor role, as they do in most surgical infections, and that patients with chest trauma can be managed in a selective fashion to achieve the kinds of results that Dr. Walker wishes to achieve in his patients.

DR. WATTS R. WEBB (New Orleans, Louisiana): I also was interested in the problem of tracheostomy, but our experience has not coincided with that of Dr. Walker. We have usually continued with the endotracheal tube for 10 to 14 days, and then switched to tracheostomy at that point. This is done quickly as a nursing procedure, so that we could mobilize the patients a lot easier and get them out of bed, if intubation really does need to be continued.