Blunt Multiple Trauma (ISS 36), Femur Traction, and the Pulmonary Failure-Septic State

ROGER SEIBEL, M.D., JOHN LADUCA, M.D., JAMES M. HASSETT, M.D., GEORGE BABIKIAN, M.D., BARBARA MILLS, M.A., DONNA O. BORDER, M.A., JOHN R. BORDER, M.D.

Fifty-six blunt multiple trauma patients (HTI-ISS 22–57) were studied for the effects of immediate *versus* delayed internal fixation of a femur or acetabular fracture on the pulmonary failure septic state. The pulmonary failure septic state may be defined as an alveolar arterial oxygen tension difference greater than 100, plus fever and leukocytosis. These patients were divided into four groups. Group I (N = 20) had immediate internal fixation, postoperative ventilatory support, and was sitting up at 30 hours. Group II (N = 20) had 10 days of femur traction and postoperative ventilatory support. Group III (N = 9) was immediately extubated after surgery and had 30 days of femur traction. Group IV (N = 7) had special circumstances that should increase the duration of the pulmonary failure septic state. These four groups of patients were statistically identical by 20 different criteria on admission except that Group I had more recognized chest injuries than Group II (12 *vs.* 9). Group I required 3.4 ± 2.6 days of ventilator support and 7.5 ± 3.8 intensive care unit (ICU) days; they had 12 ± 8.8 elevated white counts, 3.8 ± 4 febrile days, 0.05 positive blood cultures per patient, four fracture complications out of 93 fractures, 59 injections of narcotics, and 23 ± 8.6 acute care days. Ten days of femur traction doubled the duration of the pulmonary failure septic state relative to Group I at a statistically significant level for nine out of 10 criteria, while increasing the number of positive blood cultures by a factor of 10, the number of fracture complications by a factor of 3.5, and the use of injectable narcotics by a factor of 2. Thirty days of femur traction increased the duration of the pulmonary failure septic state relative to Group I by a factor of 3 to 5 for all criteria at a statistically significant level, while increasing fracture complications by a factor of 17, positive blood cultures by a factor of 74, and the use of narcotics by a factor of 2. Group IV, which had four out of seven immediate internal fixations, behaved similarly to Group II. Femoral shaft traction should be avoided in the blunt multiple trauma patients because it greatly increases the cost of care and the risk of multiple systems organ failure. Operations conducted the night of admission, even if multiple, carry a reduced risk of complications relative to those conducted at 10 to 30 days, as long as they are done correctly and in the presence of good oxygen transport and blood clotting.

Presented at the 105th Annual Meeting of the American Surgical Association, New Orleans, Louisiana, April 25–27, 1985.

This work was supported by the County of Erie, State University of New York at Buffalo, Arbeitgemeinschaft fur Osteosynthesis Fragen.

Reprint requests: John R. Border, M.D., Department of Surgery, Erie County Medical Center, 462 Grider Street, Buffalo, NY 14215.

Submitted for publication: April 29, 1985.

From the Department of Surgery, Erie County Medical Center, State University of New York at Buffalo, Buffalo, New York

BLUNT MULTIPLE TRAUMA may be defined as two or more significant injuries in one body. It is typically produced by motor vehicle and motorcycle accidents and falls from a height. It is the most common form of major trauma in North America and Europe and probably many other areas. Most of the literature available focuses on only one aspect of the problem at a time (*e.g.*, fracture management, the ruptured spleen, liver, or pancreas, the flail chest, nutritional support, etc.). Unfortunately, patient management often reflects the literature so that the soft tissue trauma is managed in complete isolation from the fractures, both of which are managed in complete isolation from the intensive care unit (ICU). As a result, little effort has been expended on the ways in which all the injuries interact to produce the organ function changes that lead to life or death. This leads to attributing the organ failures that lead to death to the original injury. In fact, these organ failures must be a product of the original injury, the treatment of the original injury, and any preexisting chronic illnesses that may be present.

At our institution, we have had total control of the trauma patient from the emergency room to death or return to work because of historical precedents and personal interest. We have had a small group of three surgeons particularly interested in this problem since 1973. This group of three has been supplemented by one other surgeon from time to time over the years so that a total of six surgeons have been involved. This group of surgeons has performed all the surgery of the trauma patient, including the vascular surgery and fracture surgery, but excluding neurosurgery.

In the early 1970s, we began to do immediate internal fixation of femur fractures in blunt multiple trauma patients. We were very surprised at how much briefer and simpler their ICU care became, by the way in which the pulmonary emboli problem seemed to disappear, and by

TABLE 1. *Admission Comparison of Groups*

Group	N	HTI ISS	Age of Patient	Year of Admission	Resuscitation Fluid Volume	Admission Bicarbonate	Admission PO_2 Room Air	Admission Systolic Blood Pressure	Admission Diastolic Blood Pressure	Admission Pulse	Recognized Anatomic Injuries	Number of Fractures	Number of Diagnoses
I	20	36.3 ±9	24 ±8	79.7 ±2.5	4900 ±1800	18 ±1.8	81 ±17	99 ±22	58 ±19	120 ±17	9 ±5	5.4 ±3.4	10.1 ±3.6
II	20	37.3 ±10	31 ±13	77.9 ±3.5	3600 ±1700	18 ±3	76 ±28	100 ±26	62 ±22	109 ±20	7 ±2.4	4.2 ±2.1	9.4 ±3.6
p Values													
I to II		0.736	0.060	0.074	0.029	0.600	0.530	0.600	0.594	0.080	0.056	0.192	0.514
III	9	29.3 ±9	36 ±21	76.6 ±4.3	3500 ±2600	19 ±5.4	73 ±27	113 ±24	66 ±16	102 ±28	7.4 ±3.2	5.2 ± 3.6	10.3 ±4.2
p Values													
I to III		0.069	0.194	0.074	0.122	0.566	0.406	0.123	0.310	0.045	0.396	0.899	0.906
IV	7	42 ±6.6	29 ±13	80 ±2.5	6900 ±3600	16 ±1.7	52 ±14	96 ±19	54 ±29	130 ±28	8.4 ±3.1	4.1 ±1.6	12.4 ±5.2
p Values													
I to IV		0.135	0.275	0.70	0.198	0.015	0.002	0.773	0.691	0.290	0.778	0.360	0.217

a reduced number of fracture complications. Discussions with European surgeons, such as Allgower in Basel, showed that they had the same experience.[1]

Methods and Materials

In 1974, we set up a prospective study with fixed-ventilator weaning criteria to study this problem. Fracture therapy was left to the choice of the individual surgeon. All other aspects of care could be tightly controlled. We are now reporting this experience.

The inclusion criteria were a fractured femur or acetabulum that could be treated operatively or by traction, at least one other major injury, a hospital trauma index-injury severity score of (HTI-ISS) 22 or greater, and survival through the operating room phase of care. The exclusion criteria were age greater than 65 or less than 16, pre-existing significant cardiopulmonary or hepatic disease, and death prior to the completion of surgery. These criteria excluded one patient who died of an overwhelming head injury at 36 hours so that the series is sequential. The complications section of the HTI-ISS was not used.[2] The pulmonary failure septic state was defined as an alveolar arterial oxygen tension difference greater than 80 to 100 mmHg, in association with a leukocytosis and fever.

We have recorded the following in each patient: HTI-ISS, admission blood pressure, pulse, bicarbonate, oxygen tension on room air, resuscitation fluid volume, blood gases, vital signs, ICU time, time on the ventilator, conditions of ventilation, arterial blood gases, white blood cell counts, febrile days, blood cultures, total cultures, glucoses, albumins, bilirubins, doses of injectable narcotics, hospital days, rehabilitation and psychiatric days, fracture and other complications, all diagnoses, all procedures, and all subsequent hospitalizations. Our concern is for active care hospital days. We have accordingly subtracted rehabilitation and/or psychiatric days from the total hospital stay to achieve a number we call acute care days. This is the number of days the patient would stay in the hospital if he had good external family support and is, in general, the date of the last operation or active medical treatment plus 1 or 2 weeks. A fracture complication was defined as overt purulent drainage or the requirement for repeat hospitalization and surgery.

Data Management

Approximately 200,000 data entries have been made on our computer for these 56 patients. The data were analyzed on the university's Cyber 815® computer, using the SPSS standard program versions 8.3 and 9.0. This program was used for means, standard deviations, Student's t-test, Pearson cross correlations, and p values. The Student's t-test employed a two-tailed analysis of variance with the use of an F value to select pooled *versus* separate

TABLE 2. *Comparison of Groups on Admission*

Group	N	HTI ISS	Admission Total for Groups: Number Chest Wall Injuries	Number of Intrapleural Injuries	Operating Room Course Comparison: Packed Red Cells	Fresh Frozen Plasma	Plasma	Saline	Number of Procedures	Number of Fractures Operated on
I	20	36.3 ±9	12	12	1275 ±715	380 ±375	440 ±559	4200 ±1900	8.9 ±2.9	2.25 ±1.2
II	20	37.3 ±10	8	9	1000 ±910	316 ±467	187 ±339	2300 ±1240	9.8 ±3.3	2.55 ±1.4
p Values										
I to II		0.736			0.366	0.656	0.166	0.002	0.376	0.472
III	9	29.3 ± 9	2	4	1160 ± 1150	0	250 ± 250	1870 ± 1100	6.7 ± 2.7	2.0 ± 1.6
p Values										
I to III		0.063			0.822	—	0.567	0.016	0.067	0.650
IV	7	42 ±6.6	2	4	1720 ±1540	890 ±761	166 ±302	3300 ±2000	11.7 ±3.0	2.5 ±1.5
p Values										
I to IV		0.135			0.483	0.133	0.263	0.335	0.044	0.575

analysis of variance. The present analysis concerns only 29,000 of the data entries.

Patient Material

Fifty-six patients who had injury severity scores greater than 22 with a femur or acetabular fracture and at least one other major injury were studied. These 56 patients had a total of 446 recognized anatomical injuries, 576 diagnoses, and 516 procedures. They were severely injured by any criteria. The 56 multiple-trauma patients were divided on the basis of femur traction, ventilatory support, and the presence or absence of injuries (severe brain injury, devascularized limbs, severe rectal injuries, delayed diagnoses, or complications) which *a priori* would increase the ICU stay. Thus, four groups were considered. Group I had immediate and postoperative ventilatory support, and the femur or acetabulum was internally fixed the night of admission so they soon could be sitting upright. Group II had the same ventilatory support but were left in femur traction after surgery for femur or acetabular injuries and had delayed fracture surgery. On average, surgery was 10 days later. Group III was extubated immediately after surgery and had a femur placed in traction for an average 30 days. All Group III patients subsequently required ventilator support. Group IV had the same ventilatory support as Groups I and II but had special circumstances that *a priori* would increase ICU time and ventilator usage. Four out of seven of these patients had immediate internal fixation.

Results

Table 1 compares the four groups on admission in terms of means, standard deviations, and p values for 13 observations. Group I is the reference group for all comparisons. The four groups are statistically identical on admission except for the following: Group I received more resuscitation fluid volume than Group II ($p < 0.029$); Group III had a lower initial pulse rate than Group I ($p < 0.045$); and Group IV has a lower initial bicarbonate ($p < 0.015$) and admission PO_2 on room air ($p < 0.002$) than Group I.

Table 2 gives a similar operating room admission comparison of the four groups. Group I has more recognized chest injuries than Group II (12 *vs.* 9) and receives more operating room saline than Group II ($p < 0.002$) or Group III ($p < 0.016$). Group IV has a greater number of procedures than Group I ($p < 0.044$).

Table 3 explores mathematically whether or not the hospital trauma index-injury severity score (HTI-ISS) was used correctly for the study group of 56 patients using Pearson cross correlations. All cross correlations are significant at the $p < 0.05$ level, except for two which approach significance. By this evaluation HTI-ISS was correctly used for this cohort of patients.

Table 4 compares the results of management of the four groups. Group I required 23 ± 8.6 days of acute care, 3.4 ± 2.6 ventilator days, 7.5 ± 3.8 ICU days, 23 ± 12 arterial blood gases, and had 12 ± 8.8 elevated white counts, 3.8 ± 4 febrile days, 1.8 ± 3 blood cultures taken, 9 ± .8 total cultures taken, 1.7 ± 1.8 elevated bilirubins, and 1.6 ± .93 antibiotics. Group II appears initially identical to Group I except for 10 ± 7 days of femur traction. This change is associated with statistically significant increases in all measures of the duration and intensity of the pulmonary failure septic state except for the number of elevated bilirubins as compared to Group I. In general, all measures are increased by a factor of 2. This applies to acute care days, ventilator days, ICU days, number of arterial gases, number of elevated white counts, number of febrile days, number of blood cultures taken, total number of cultures taken, and number of antibiotics used.

TABLE 3. *HTI-ISS Pearson Cross Correlations*

	Resuscitation Fluid Volume	Admission Plasma Bicarbonate	Systolic Blood Pressure Admission	Diastolic Blood Pressure Admission	Recognized Anatomic Injuries	Number of Diagnoses	Operating Room				
							Number of Procedures	Packed Red Cells	Fresh Frozen Plasma	Number of Fractures	ORIF* of Fractures
Correlation	0.3426	−0.2945	−0.4884	−0.3955	0.2525	0.2616	0.4960	0.4527	0.3399	0.2480	0.3198
p Value	0.012	0.038	0.001	0.003	0.060	0.051	0.001	0.001	0.024	0.065	0.016
N	53	50	55	55	56	56	56	47	44	56	56

* Open reduction and internal fixation.

Group III has 30 ± 33 days of traction as compared to zero days for Group I and is, at least on average, less injured. This 30 days of femur traction was associated with statistically significant increases in all measures of the pulmonary failure septic state. In general, the mean values are increased by a factor of 3 or more for acute care days, number of elevated white counts, febrile days, and number of elevated bilirubins. The number of antibiotics used is increased by a factor of two. Ventilator days are increased by a factor of 5; ICU days, by 3.6; number of arterial gases, by 3.5; blood cultures taken, by a factor of 9; and total number of cultures taken, by a factor of 5.

Group IV is a heterogeneous group with problems that *a priori* increase the ICU stay. It is further heterogeneous by the fact that four out of the seven patients had immediate internal fixation of fractures. The statistically significant group changes relative to Group I occur for ICU days, number of arterial gases, number of elevated white counts, total number of cultures taken, elevated bilirubins, and number of antibiotics used. These changes increase the duration of the pulmonary failure septic state in Group IV relative to Group I. Arterial blood gases, elevated white counts, and antibiotics used are increased by a factor of 2.3. The ICU days and elevated bilirubins are increased by a factor of 3. The total number of cultures taken are increased by a factor of 2. There are no statistically significant increases in acute care days, ventilator days, febrile days, or blood cultures taken relative to Group I. The increase in the duration of the pulmonary failure septic state is less than in Group III and basically comparable to Group II.

Table 5 shows the Pearson cross correlations and their associated p value and Ns for all of the preceding measures of the duration of the pulmonary failure septic state relative to HTI-ISS and femur traction days. There are no significant cross correlations with HTI-ISS. In contrast, every cross correlation with femur traction days is both significant and positive for measures of the duration and intensity of the pulmonary failure septic state. The p values are mostly in the 0.000 to 0.001 range with only two values (bilirubin and number of antibiotics) exceeding these values (0.042 and 0.009). The cross correlation of HTI-ISS to femur traction days is negative and not significant. The more severely injured patients did not receive preferential traction treatment.

Table 6 shows the average number of positive blood cultures per patient and the number of patients per group with positive blood cultures. The names of these bacteria had no relationship to concurrent wound, tracheal aspirate, or urinary cultures. The average number of blood cultures per patient and the number of patients with positive blood cultures per group increase from Group I to II to III. The patients with multiple positive blood cul-

TABLE 4. *Results of Management*

Group	N	HTI ISS	Days of Femur Traction	Acute Care Days	Ventilator Days	ICU Days	Number of Arterial Gases	Number of Elevated White Counts	Febrile Days >101 F	Blood Cultures Taken	Total Number Cultures Taken	Bilirubins >1.5	Number of Antibiotics Utilized
I	20	36.3 ± 9.1	0	23 ± 8.6	3.4 ± 2.6	7.5 ± 3.8	23 ± 12	12 ± 8.8	3.8 ± 4	1.8 ± 3	9 ± 8	1.7 ± 1.8	1.6 ± .93
II	20	37.3 ± 10	10 ± 7	45 ± 16	9.7 ± 8.8	15 ± 12	43 ± 34	20 ± 9	8.8 ± 7	4.7 ± 5	19 ± 17	4.0 ± 5.4	2.6 ± 1.4
III	9	29.3 ± 9.0	30 ± 33	61 ± 29	21 ± 14	27 ± 16	82 ± 39	36 ± 29	13 ± 11	17 ± 18	44 ± 34	7.4 ± 6.6	3.5 ± 1.8
			—										
IV	7	42 ± 6.5	—	36 ± 25	11 ± 9	23 ± 12	52 ± 22	27 ± 11	6.3 ± 4.6	3.4 ± 1.5	18.2 ± 6.8	5.1 ± 2.8	3.8 ± 1.8
p Values													
I to II		0.736		0.000	0.006	0.012	0.024	0.007	0.009	0.043	0.031	0.109	0.025
I to III		0.069		0.004	0.005	0.007	0.002	0.032	0.034	0.037	0.024	0.032	0.027
I to IV		0.135		0.228	0.084	0.014	0.000	0.002	0.217	0.214	0.017	0.002	0.016

tures are all in Group III. This is the group that had the least severe initial injuries. Group IV, which had physical circumstances that should have increased the number of positive blood cultures and a more severe initial injury, has the same number of positive blood cultures as Group II.

Table 7 explores the Pearson cross correlations with significant p values and Ns related to the year of admission. In earlier years, we used more femur traction and had more acute care days, more total cultures, more ICU days, more arterial blood gases, and more febrile days. These correlations are to be expected. In contrast, in later years we did more procedures and used more operating room saline.

Table 8 explores the significant Pearson cross correlations with p values and Ns with the age of the patient. Older patients have a higher admission plasma bicarbonate and a lower pulse rate and require more acute care days. These probably relate to having less severe accidents for which they require more care.

Table 9 explores the significant Pearson cross correlations with p values and Ns for ventilator days. There are two negative correlations with year of admission and operating room saline. Given the present beliefs about fluid resuscitation and pulmonary failure, the negative correlation with operating room saline and the positive correlation with packed red cells would be expected. As ventilator days increase, there is more hypoalbuminemia, more hyperglycemia, more elevated white counts, more febrile days, more cultures taken, and more elevated bilirubins. These correlations are to be expected from increased duration of the pulmonary failure septic state (and probably pneumonia). Ventilator days increase with the number of diagnoses.

Table 10 explores the number of fracture complications as a function of group and, therefore, time of operation. Group I has the fewest fracture complications while having the most total and open fractures and the smallest number of patients lost to follow-up. Group II has 3.7 times as many fracture complications as Group I. Group III has a 17-fold increase in fracture complications per fracture relative to Group I. Group IV has the smallest number of fracture complications as a group, but is close to Group I. Delayed fracture surgery is associated with an increased number of fracture complications.

Table 11 shows the significant Pearson cross correlations of alveolar arterial oxygen tension difference for Group I as compared to Groups II and III. Group I has significant cross correlations for bilirubin (positive) and WBC (negative), but has no significant cross correlations

TABLE 5. *Pearson Cross Correlations and p Values Comparison of HTI-ISS and Days of Femur Traction*

	HTI ISS	Days of Femur Traction	Acute Care Days	Ventilator Days	ICU Days	Number of Arterial Gases	Number of Elevated White Counts	Febrile Days 101F	Blood Cultures Taken	Total Number of Cultures Taken	Bilirubins >1.5 mgm/dl	Number of Antibiotics Utilized
HTI-ISS	1.000	−0.1290	0.0235	−0.0099	0.1130	−0.0190	0.1359	−0.0654	−0.2050	−0.1381	0.1381	0.0461
p Values	0.000	0.348	0.863	0.943	0.407	0.894	0.337	0.638	0.137	0.324	0.357	0.743
N	—	55	56	56	56	52	52	54	54	53	51	53
Days of Femur Traction	−0.1290	1.000	0.7310	0.6257	0.5996	0.5688	0.6684	0.6469	0.7592	0.7040	0.2883	0.3604
p Values	0.348	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.042	0.009
N	55	—	55	55	55	51	51	53	53	52	50	52

TABLE 6. *Comparison of Positive Blood Cultures per Patient*

Group	Number of Positive Blood Cultures/Patient	Number of Patients with Positive Blood Cultures
I	0.05	1/20
II	0.50	8/20
III	3.7	6/9
IV	0.4	3/7

TABLE 8. *Significant Pearson Cross Correlations with Age of Patient*

	Admission Plasma Bicarbonate	Admission Pulse Rate	Acute Care Days
Correlations	0.3394	−0.4213	0.3822
p Values	0.016	0.002	0.004
N	50	54	56

with glucose and positive end expiratory pressure in spite of 132 and 82 observations. In contrast, Groups II and III have no significant cross correlations with WBC and bilirubin (371 and 339 observations), but have significant cross correlations with glucose and positive end expiratory pressure (PEEP), 309 and 331 observations, respectively. The same kind of difference is also found with multiple regression analysis comparing all patient days in traction to patient days not in traction. This is the subject of another paper to be developed.

Figure 1 compares the mean daily observations of PAa O_2 and PEEP in Groups I and II. The total number of observations, NT, is much greater in Group II than Group I. By day 7, Group I had so few observations per day that further plotting of these lines did not seem reasonable. In the 7 days of combined plotting, the PEEP in both groups was not significantly different, but the PAa O_2 of Group II was continually much greater. The desired weaning criteria of a PAa O_2, 80 to 100 mmHg on 5 cm H_2O PEEP, was achieved for Group I on day 3 when they were actually weaned. Group II was weaned from the ventilator on day 9.7. At this time, the mean Group II PAa O_2 was 130 mmHg on a mean PEEP of somewhat more than 5 cm H_2O. Weaning in Group II occurred on the background of worse lung function than in Group I. A mean PAa O_2 of 100 mmHg was not achieved for Group II until 16 days. Even then, 6 cm H_2O PEEP was required.

Figure 2 compares the mean daily observations of PAa O_2 and PEEP for Groups I and III. As in Figure 1, there are statistically significant higher values of PAa O_2 for Group III in the 7 days in which comparisons are possible to Group I. Group III is weaned from the ventilator, on average, at day 21. A mean PAa O_2 of 100 mmHg is achieved for Group III on day 18 on 6 cm H_2O PEEP. Weaning for Group III occurs on day 21 with a mean PAa O_2 of 90 mmHg (on 6 cm H_2O PEEP). The preset criteria for weaning are, therefore, largely met for Group III.

Figure 3 compares the mean daily plasma glucose and bilirubin values for Groups I and II. The mean daily plasma glucose values for Groups I, II, and III (not shown) are largely the same for the first 10 days. After 10 days, Groups II and III (not shown) continue hyperglycemic and with a large number of daily observations, while Group I has a plasma glucose value in the normal range and very few daily observations. The same kind of observations are made on the plasma bilirubin values, but that divergence occurs around day 7. Until day 7, the plasma bilirubin values of Groups I, II, and III (not shown) are largely the same. After day 7, the mean daily plasma bilirubin in Groups II and III (not shown) are consistently above the upper limit of normal and have, relative to Group I, large numbers of daily observations. In Groups II and III the hyperbilirubinemia persists at least to 24 days of observation.

Figure 4 compares the mean daily WBC for Groups I and III. The mean white blood count (WBC) in Groups II (not shown) and III is consistently higher than in Group I. In Groups I, II, and III, the course of the WBC is largely the same for the first 10 days and diverges in subsequent days as the WBC in Group I returns to normal, while the mean daily WBC in Groups II (not shown) and III remains persistently above normal in the 12 to 20,000 range.

The persistence of the respiratory problem is emphasized if one examines the number of days of nonventilatory, respiratory support that follows weaning. This includes use of face mask oxygen, intermittent positive pressure breathing (IPPB), PEEP without the ventilator, and a variety of other ways of providing respiratory support independent of the ventilator. These are soft numbers,

TABLE 7. *Significant Pearson Cross Correlations with Year of Admissions*

	Femur Traction Days	Acute Care Days	Total Number of Cultures	Number of Procedures	Operating Room Normal Saline	Ventilator Days	ICU Days	Number of Arterial Gases	Febrile Days
Correlations	−0.3385	−0.3169	−0.4583	0.2832	0.3462	−0.4466	−0.3567	−0.4788	−0.4041
p Values	0.011	0.017	0.001	0.034	0.021	0.001	0.007	0.001	0.002
N	55	56	53	56	44	56	56	52	54

TABLE 9. *Pearson Cross Correlations with Ventilator Days Significant*

	Year of Admission	Albumins Less than 3.3 g/dl	Blood Glucoses >135 mg/dl	Number of Diagnosis	Operating Room Packed Red Cells	Operating Room Normal Saline	Number of Elevated White Counts	Febrile Days	Total Cultures Taken	Elevated Bilirubins
Correlations	−0.4551	0.6084	0.3111	0.2666	0.3275	−0.2984	0.7422	0.7084	0.7955	0.5601
p Values	0.001	0.001	0.023	0.047	0.025	0.049	0.001	0.001	0.001	0.001
N	56	51	53	56	47	44	52	54	53	51

but they are interesting. Thus, Group I required an average 4.25 days of such support; Group II, 7.7 days; Group III, 12.2 days; and Group IV, 8.7 days. The use of injectable narcotics is also of interest. Group I received an average of 59 doses per patient; Group II, 105 doses; Group III, 112 doses; and Group IV, 74 doses.

Discussion

Groups I through IV are originally statistically identical on the basis of 21 comparisons. If there is any bias, it is toward Group IV being most severely injured, Group I being next most severely injured, Group II being less injured than Group I, and Group III being least injured. Group IV is heterogeneous in that four out of seven patients had immediate operative fixation of their fractures. Group IV has the problems that *a priori* increase the duration of the pulmonary failure septic state. These include two severe brain injuries, two attempted but failed limb salvages, one with a very severe anopelvic injury, two delayed diagnoses—one of a ruptured spleen and one of the diaphragm—and one subphrenic abscess. Group I has more recognized chest injuries than Group II. All four groups are weaned from the ventilator at the preset criteria of a PAa O_2 < 80 to 100 mgHg on 5 cm H_2O of PEEP. Group II is the exception; they are weaned a bit too early.

In spite of this initial statistical identity and the biases discussed that do not show up in statistics, these groups of patients had radically different courses in terms of the magnitude and the duration of the pulmonary failure septic state as measured by 13 criteria and in terms of Pearson cross correlations. These differences in the pulmonary failure septic state were tightly associated with days of femur traction. Ten days of femur traction doubles the duration of the pulmonary failure state and the cost of care, while quadrupling the incidence of fracture complications. These further increase the cost of hospital care and the time out of work. Thirty days of femur traction triples to quadruples the duration of the pulmonary failure septic state, while increasing the fracture complications by a factor of 17. Thirty days of femur traction was associated with multiple positive blood cultures and with two cases of advanced multiple systems organ failure in Group III. Group I with zero days of femoral traction had only one positive blood culture out of the 36 taken in 20 patients. Group II had 10 positive blood cultures out of the 94 taken in 20 patients. Group III had 33 positive blood cultures out of 153 taken in nine patients. Increased days of traction are tightly associated with increased risk of bacteremia and with advanced multiple systems organ failure. This risk was recognized by the clinicians caring for the patients as reflected by the increase in the number of blood and all cultures taken and antibiotics used as one goes from Group I to II to III.

Riska[3] pointed out in 1976 that the incidence of the "fat emboli syndrome" was 22% in 384 patients with conservative fracture management, and four per cent in 245 patients with early internal fixation of fractures. In a 1982 report on immediate internal fixation of fractures in 211 multiple trauma patients, he gives a fat emboli incidence of 1.5% (24). We suspect strongly that his diagnosis of fat emboli syndrome is equivalent to our pulmonary failure septic state. However, use of the term "fat emboli syndrome" implies diagnosis of mechanism, while pulmonary failure septic state relates only to the observations made and has no necessary implication as to mechanism.[10]

TABLE 10. *Effect of Immediate or Delayed ORIF on Fracture Complications*

Group	N	Fractures	Fractures Open	Fracture Complications	Patients Not Followed Up
I	20	93	26	4	2
II	20	76	22	12	3
III	9	16	4	12	3
IV	7	28	6	0	1
Totals	56	213	58	28	9

TABLE 11. *Significant Pearson Cross Correlations of PAa O_2 Difference*

Group		WBC	Bilirubin	Glucose	PEEP
I		−0.2061	0.3366	—	—
	p	0.014	0.001	—	—
	N	141	133	132	82
Groups II and III		—	—	0.2028	0.2221
	p	—	—	0.001	0.001
	N	371	339	309	331

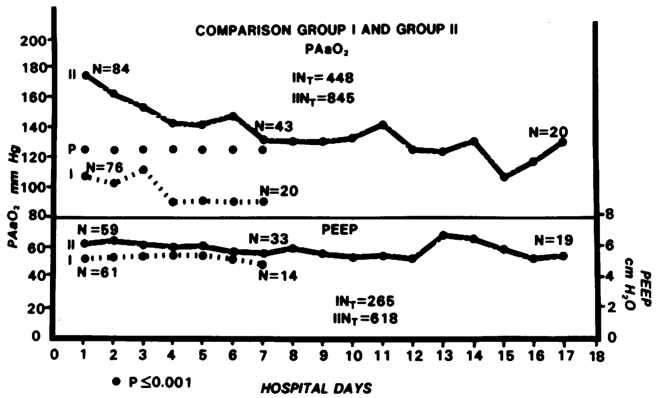

FIG. 1. A comparison of the group mean daily values for Groups I and II for PAa O_2 and PEEP. Group I has the preset criteria for weaning of a PAa O_2 of 80 to 100 mmHg, and 5 cm H_2O of PEEP by day 3 and is appropriately weaned. Group II is weaned at day 10 when the PAa O_2 is 130 mmHg, and the PEEP is about 5 cm. The difference in the pulmonary problems between Group I and Group II is also reflected in their NTs for PAa O_2 of 448 and 845, and for PEEP of 265 and 618.

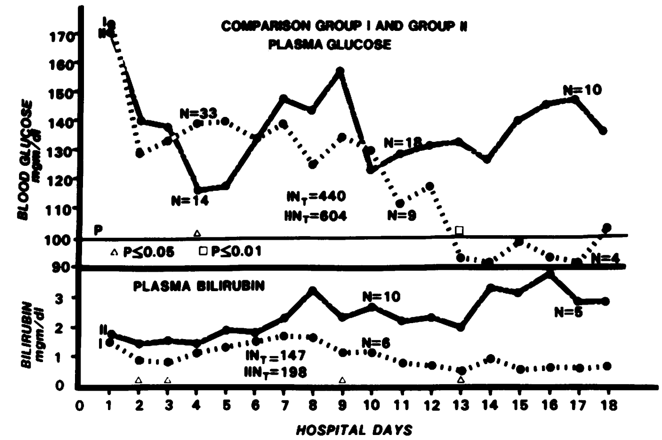

FIG. 3. A comparison of Groups I and II for plasma glucose and bilirubin. Group I rapidly develops so few observations per day that statistics are not appropriately used while Group II continues to maintain a large daily number of observations. After 10 days, Groups II and III (not shown) remain persistently hyperglycemic. Long after the plasma glucose and bilirubin have returned to normal in Group I, Groups II and III have persistent hyperglycemia and hyperbilirubinemia.

In 1978 Wolff et al., from Basel, reported on 117 multiple trauma patients that had immediate total care with internal fixation of fractures and prophylactic ventilation after surgery. There was one death in a patient with bilateral severe lung lacerations and gastric aspiration.[1]

In 1981, Meek et al. reported on a consecutive series of multiple trauma patients with mean injury severity scores about equal to our study. There were 70 patients of which 49 had conservative fracture management and 21 had immediate operative management. The ICU management was given by a third group who had no interest in the outcome. The randomization was by the name of the surgeon on call. There were no deaths in the immediate internal fixation group and 14 deaths in the conservatively managed fracture group.[4]

In 1982, Goris et al. reported on their experience with 58 consecutive multiple trauma patients. The mean injury severity scores were in the same range as our group (39.4). Immediate internal fixation of fractures was associated in 38 patients with one acute death and an average of 2 days on the ventilator. In contrast, conservative fracture management in 12 more severely injured patients (mean HTI-ISS, 55) was associated with an average of 10 days on the ventilator and a 42% late septic multiple systems organ failure death rate. When these data are cleaned by considering only patients with injury severity scores above 50 (mean Group HTI-ISS 56 and 58), there are no late deaths from sepsis in the immediate internal fixation group out of 13 patients. In contrast, in the conservatively managed fracture group there are five late septic deaths

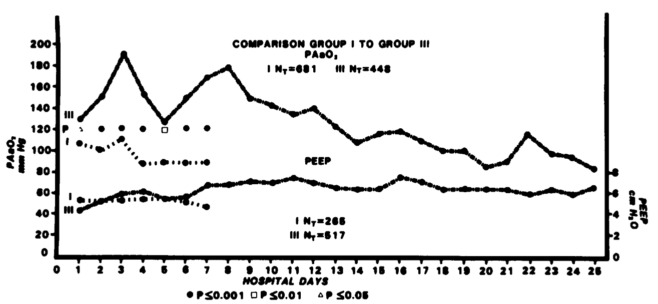

FIG. 2. A comparison of the group mean daily observations for PAa O_2 and PEEP for Groups I and III. Group III attains a PAa O_2 of 80 to 100 mmHg on days 19 to 20 and is actually weaned on day 21. The PEEP at this time is 6 cm H_2O. There are significant differences in PAa O_2 for the 7 days in which comparisons are possible to Group I but no significant difference in PEEP.

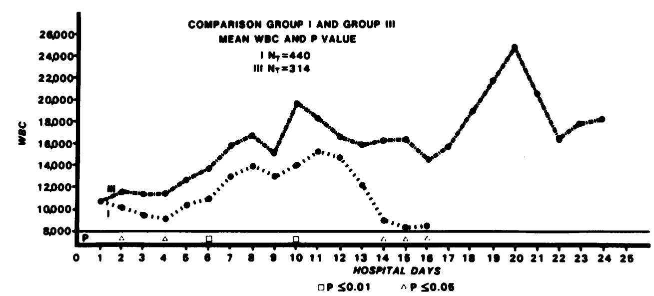

FIG. 4. A comparison of the mean group daily observation for WBC of Groups I and III. At about 10 days, the Group I WBC begins to return to normal, as does the Group I plasma glucose and bilirubin. Group II's (not shown) and Group III's WBC counts remain persistently high (range 12 to 20,000), as do the glucose and bilirubin.

out of 10 patients. In addition, the immediate internal fixation groups required, on average, 4 days of ventilator support while the conservatively managed group required, on average, 16 days of ventilatory support. Goris et al. had consistent survivors at HTI-ISS of 50, seven out of 12 survivors at HTI-ISS of 57, and three out of four survivors at ISS of 66.[5]

Johnson et al. have also reported that immediate internal fixation of fractures drastically reduces the incidence of the acute respiratory distress syndrome, but only in patients with an injury severity score greater than 40. In our experience, the lower limit of this effect is much lower, probably closer to 22.[6]

The data of Baker et al. and Semmlow et al. were obtained primarily on conservatively managed fracture patients. It shows, at a mean ISS of 35, a mortality rate of about 30%.[7,8] The data obtained by Champion et al. in the major trauma outcome study show, for the ISS range 34 to 38, a mortality rate of 24%.[9] The major trauma outcome study would predict 13.4 deaths in our series of 56 patients where we had no deaths. It is, therefore, of considerable interest that conservatively-managed-fracture, multiple trauma patients in the studies of Wolff et al., Meek et al., and Goris et al. show mortality rate of about 30%. In contrast, the immediate internal fixation multiple trauma groups in all series show a mortality rate of zero to five per cent. These mortality rates are all for mean ISS about 35.

The following statements appear reasonable summaries at this stage:

1. In blunt multiple trauma, femur traction is the first in a series of steps that has a significant probability of leading to the grave *via* bacteremia and multiple systems organ failure.
2. Femur traction always significantly increases the cost of hospital care, with common increases of two- to three-fold.
3. Femur traction with delayed fracture surgery is associated with an increased probability of fracture complications in blunt multiple trauma relative to fracture surgery done the night of admission.
4. Blunt multiple trauma produces a pulmonary failure state that lasts, on average, about 3 days. The rest of the pulmonary failure septic state is due to the therapy selected.
5. Femur traction in blunt multiple trauma is to be severely discouraged.
6. The blunt multiple trauma patient should be managed with simultaneous operating teams so that all surgery required is completed the night of admission. This is not associated with an increased risk of operative complications as long as the operations are done correctly, maximal oxygen transport is maintained, and good blood clotting is present.
7. Orthopedic traumatologists should be members of the front-line trauma team.

The mechanism by which conservative fracture management leads to the prolonged pulmonary failure septic state is of considerable interest. The following factors must be considered: (1) fat emboli;[10] (2) the enforced supine position;[11] (3) increased pain with fracture motion; and (4) a large fracture hematoma as retained necrotic tissue.[12–19]

The acute fat emboli problem that occurs between the initial trauma and definitive fracture management would be the same in all groups. If there is a difference in fat emboli, it may occur because fat emboli continue after traction is instituted but not after operative fracture management.[10]

The enforced supine position which occurs in the blunt multiple trauma patient with femur traction must be detrimental to the lungs. It causes the weight of the abdominal viscera to press continuously up against the diaphragm in patients who have abdominal wounds, rib fractures, and gastrointestinal distention. They are lethargic and are normally unable to breath deeply or cough. This could lead to progressive atelectasis and retained secretions to limit ventilation and decrease the ventilation perfusion ratio.[11] It would also lead to a persistent increase in the posterior capillary hydrostatic pressure with dependent pulmonary edema. This same arrangement would target the posterior dependent lung to receive particulate bloodborne emboli and factors from the periphery. It seems quite clear that the enhanced phagocytosis that occurs with retained necrotic tissue by virtue of release of activated aggregate leukocyte emboli, platelet emboli, complement split products, fibrin split products, prostaglandins and leukotrienes, and probably many other mechanisms can induce the low pressure pulmonary edema called the acute respiratory distress syndrome.[15,16,19,20,21] Concurrent with these events, the enhanced phagocytosis by macrophages also releases interleukin 1 so that the pulmonary failure and the septic state are tightly associated independent of bacterial infection.[13,14,18,22] This is a routine observation. Given these conditions, positive end expiratory pressure would be expected to push the diaphragm down and thus increase gas exchange to some degree, but would have no effect on the posterior dependent lung with its multitude of reasons for interstitial pulmonary edema. Thus, positive end expiratory pressure would improve gas exchange but not allow weaning from the ventilator. These same changes would allow increased bacterial exposure in the lung because of the need for prolonged intubation while interfering with the antibacterial activity of both the mucosal IGA system and the pulmonary alveolar macrophage. They would thus increase the probability of pneumonia to further prolong ventilatory support.[11,12,15-17,19,21,23]

Given the preceding considerations, traction treatment of femoral shaft fractures should be associated with a prolonged pulmonary failure septic state both because of the enforced supine position and because of the effects of the fracture hematoma as retained necrotic tissue on release of phagocytic products to the lung. Immediate operative treatment of femoral fractures allows the immediate upright position of the chest so the weight of the viscera pulls the diaphragm down to expand the lung while concurrently drastically reducing the release of phagocytic products which also produce pulmonary failure.

The bacteria isolated from the blood have different names than those concurrently isolated from tracheal aspirate, urine, and wounds. Antibiotics directed against tracheal aspirate, urine, and wound bacteria seem to have little effect on the systemic septic state. These patients have many causes of enhanced protein catabolism. These include the original trauma, the persistent septic state, pain on fracture motion, the cold exposed leg of femoral traction, prolonged oral intubation and anxiety, prolonged lack of oral intake, and multiple operations. Thus, there is every reason to believe that the patient treated in traction should have a much greater degree of protein malnutrition than the patient who receives immediate operative fixation of his femur fracture and is therefore quickly extubated and able to eat. There are also many reasons to believe that such protein malnutrition would first affect the gut mucosa liver complex.[12,13,18]

We have spent many years studying multiple systems organ failure. It is our conclusion that this is predominantly protein malnutrition which affects the gut mucosa liver complex first and, by this mechanism, allows entry of gut contained endotoxin and bacteria into the systemic body.[12,13,18] For this reason we have had, since 1979, as specific policies in the ICU: maximal cardiopulmonary support to maximize oxygen transport together with the goal of delivering 2 to 4 grams of protein and 30 to 40 calories of energy per kilogram/day. Both patients who developed advanced multiple systems organ failure with multiple positive blood cultures did not receive this level of protein support and were initially extubated immediately after the surgery and left in femur traction. Their multiple systems organ failure and their positive blood cultures cleared with the initiation of high protein enteral support. This is consistent with the rest of our experience.

It appears as a reasonable statement that we prevented the late septic deaths which might otherwise have occurred (*e.g.*, Goris et al.) in the traction group by aggressive protein support as much enterally as possible. This has no influence on the prolonged pulmonary failure septic state *per se*, but does compensate for its associated enhanced protein catabolism.

Based on this experience, we would suggest that the pulmonary failure that occurs immediately after trauma and persists on average for 3 to 4 days is not the acute respiratory distress syndrome but reflects the direct effect of the initial thoracic trauma and resuscitation. Postoperative use of the ventilator and positive end expiratory pressure is most important in treating this entity.[20,21,23]

After this period of 3 to 4 days, the acute respiratory distress syndrome begins and is tightly associated with the release of a wide variety of products from retained necrotic tissue with enhanced phagocytosis. This is the true pulmonary failure septic state. It is clearly made worse by the enforced supine position. If bacteria gains access to the retained necrotic tissue so that infection occurs, the rate of phagocytosis will be magnified and this portion of the pulmonary failure septic state will be accentuated. This portion of the pulmonary failure septic state can be prevented by excision of all necrotic tissue the night of admission; these should include fracture hematoma, burn wounds, and other forms of necrotic tissue. It can also be reduced significantly by the upright chest position.

If the preceding is not accomplished, then a prolonged pulmonary failure septic state occurs. This leads rapidly to atrophy of the muscles of ambulation, a lack of effect of the interleukein 1 complex in mobilizing amino acids, and gut mucosa hepatic protein malnutrition. This allows entry of gut-contained endotoxins and bacteria, widespread infection in the systemic body, and leads to death.[12,13,18] This portion of the problem can be prevented by exogenous high protein support at 2 to 4 grams of protein and 30 to 40 calories per kilogram/day given as much enterally as possible.

The blunt multiple trauma patient who is operated on the night of admission with vigorous cardiopulmonary support to maximize oxygen transport and has maximal attention devoted to excision of all necrotic tissue does not have an increased rate of wound infection, no matter how badly the wound may be contaminated.[3,12,24,25] The problem with increased wound infection rates develops with delayed surgery and reflects protein malnutrition, unresolved wound problems, and acquisition of hospital-based bacteria.

Fracture complications increase with delay in surgery. This reflects the scar tissue which develops between poorly placed fragments. Delayed fracture surgery then leads to more devascularized pieces of bone, worse reduction, and a poor internal fixation. In contrast, the night of admission the fragments may be easily moved without further loss of blood supply, exactly reduced, and a much better internal fixation obtained.[24]

The following must be noted as incidental side benefits:

1. Doing all the surgery the night of admission with multiple operating teams drastically reduces operating time and essentially removes the problem of subsequent semiemergent operations that destroy operating room schedules for all surgeons.
2. Doing all the surgery the night of admission not only reduces the time in the hospital but also the time out of work.
3. Immediate fracture surgery not only reduces fracture complications and their increased time out of work but also improves extremity function considerably.[3]

References

1. Wolff G, Dittman M, Ruedi T, et al. Koordination von chirurgie und intensivmedizin zur vermeidung der posttraumatischen respiratorischen insuffizienz. Unfallheilkunde 1978; 81:425–442.
2. American College of Surgeons: Hospital Trauma Index. Bull Am Coll Surg 1980; 65:32–33.
3. Riska E, Von Bonsdorff H, Hakkinen S. Primary operative fixation of long bone fractures in patients with multiple injuries. J Trauma 1977; 17:111–121.
4. Meek R, Vivoda E, Crichton A. A comparison of mortality in patients with multiple injuries according to method of fracture treatment. J Bone Joint Surgery (British) 1981; 63(B):456.
5. Goris R, Gimbrere J, Van Niekerk J, et al. Early osteosynthesis and prophylactic mechanical ventilation in the multiple trauma patient. J Trauma 1982; 22:895–903.
6. Johnson K, Cadambi A. Incidence of ARDS in patients with multiple musculoskeletal injuries: effect of early operative stabilization of fractures. Program of the American Association for the Surgery of Trauma, 1985; New Orleans: 32–33.
7. Baker S, O'Neill B, Haddlon W. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974; 14:187–196.
8. Semmlow J, Cone R. Utility of the injury severity score: a confirmation. Health Services Research 1976; 11:45–52.
9. Champion H. Major trauma outcome study.
10. Peltier LF. An appraisal of the problem of fat embolism. Surg Gynec Obstet 1957; 104:313–324.
11. Border J, LaDuca J, Seibel R. Priorities in the Management of the Patient with Polytrauma. *In* Allgower M, Bergentz S, Calne R, Gruber US, eds. Progress in Surgery. Basel, Switzerland: Karger, 1975; 87–122.
12. Border J. Trauma and sepsis. *In* Worth M, ed. Principles and Practice of Trauma Care. Baltimore: Williams and Wilkins, 1982; 330–388.
13. Clowes G, Hirsch E, Ville C, et al. Significance in survival from trauma and sepsis of response in protein metabolism induced by proteolysis inducing factor. Program of the American Surgical Association, 1975; New Orleans: 67–69.
14. Clowes G, George B, Villee C, Saravis C. Muscle proteolysis induced by a circulating peptide in patients with sepsis or trauma. New Eng J Med 1983; 308:545–553.
15. Craddock PR. Complement mediated intravascular leukostasis and endothelial cell injury. *In* Nosell H, Vogel J, eds. Pathobiology of the endothelial cell. New York: Academic Press, 1982; 369–386.
16. Gelfand J. How do complement components and fragments affect cellular immunological function. J Trauma 1984; 24:S118–125.
17. Heideman M, Hugli J. Anaphylatoxin generation in multiple systems organ failure. J Trauma 1984; 24:1038–1044.
18. Pearl R, Clowes G, Hirsch E, et al. Prognosis and survival as determined by visceral amino acid clearance in severe trauma. Program of the American Association for the Surgery of Trauma, 1984; New Orleans: 12–13.
19. Till O, Beauchamp C, Menopace D, et al. Oxygen radical dependent lung damage following thermal injury of rat skin. J Trauma 1983; 23:269–278.
20. Hechtman H, Lonergram E, Shepro D. Platelet and leukocyte lung interactions in patients with respiratory failure. Surgery 1978; 83: 155–164.
21. Lewis F, Blaisdell W, Schlobohm R. Incidence and outcome of posttraumatic respiratory failure. Arch Surg 1977; 112:436–441.
22. Powanda M, Beisel WR. Hypothesis: leukocyte endogenous mediator/endogenous pyrogen/lymphocyte activating factor modulates the development of nonspecific and specific immunity and affects nutritional status. Am J Clin Nutrit 1982; 35:762–768.
23. Border J, Hopkinson B, Schenk W. Mechanisms of pulmonary trauma. J Trauma 1968; 8:47–62.
24. Bone L, LaDuca J, Seibel R, Border J. Primary open reduction and internal fixation of open fractures. J Trauma 1980; 20:580–586.
25. Malagoni M, Dillon L, Klamer T, Coudon R. Factors influencing the risk of early and late serious infections in adults after splenectomy for trauma. Surgery 1984; 96:775–784.

Discussion

Dr. Donald Trunkey (San Francisco, California): President Bricker, I rise to congratulate Dr. Border on a very nice study. I think this was a difficult study because of the heterogeneity of the patients and the multiple variables that he studied. Nevertheless, I believe he did a very careful analysis, and I think his conclusions are quite valid.

We have also advocated immediate internal fixation of long bone fractures as soon as possible after the injury. Priority is always given first to head injury, then torso injury, then peripheral vascular injuries, and then the long bone fractures.

We would delay the long bone fracture fixation only if the patient is hemodynamically unstable after treatment of his head injury or his torso injury. This delay should optimally not extend past 48 hours, and this time is used primarily to correct coagulation disorders and treat hypothermia.

As Dr. Border points in his paper, the mortality for an injury severity score of 35, which was his mean, is approximately 30% in the American College of Surgeons trauma outcome study, and he has reduced this very significantly by his approach.

I think this is extremely important. The reason is that 80% of late trauma deaths are due to sepsis and multiple organ failure. Our studies have shown that an injury severity score of 30 is associated with an immune failure. This is probably caused by the release of products of inflammation that increase with the severity of the injury. These products of inflammation include prostinoids, leukotrienes, kinins, monokines, and lymphokines, which brings me to my first question.

Dr. Border, did you measure any of these products of inflammation in your study and relate this to the groups that you studied?

My second question is: Did the antibiotic management of these patients vary among groups? Did that in any way alter your findings?

Thirdly, what was your nutrition management in these patients? Did that alter the outcome, and, finally, I can not help but think that part of your good outcome may be due to the reduced stay in the intensive care unit. It is my feeling that the intensive care unit is a hostile environment where we select out the opportunistic organisms. By reducing that stay, you reduce the chance of these patients becoming infected.