Survival after Trauma in Geriatric Patients

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In contrast to other studies, a recent report from the authors' institution has shown a good prognosis for functional recovery in geriatric patients that survive trauma. Because most survivors regained their pre-injury function, the authors examined factors related to nonsurvival in this population of 82 consecutive blunt trauma victims older than the age of 65. Seventeen patients died (21%). Compared with survivors, nonsurvivors were older, had more severe overall injury, and had more severe head and neck trauma but did not differ in severity of trauma that did not involve the head and neck, number of body regions injured, mechanism of injury, or incidence of surgery after injury. Nonsurvivors experienced more frequent complications (82% *vs.* 33%, $p < 0.05$), including a higher incidence of cardiac complications (53% *vs.* 15%, $p < 0.05$) and ventilator dependence for 5 or more days (41% *vs.* 14%, $p < 0.05$). Mortality rates were increased in patients who were 80 years of age or older compared with those ages 65–79 (46% *vs.* 10%, $p < 0.01$), despite injury of similar severity. More frequent complications may contribute to an increased mortality rate in the older group, including an increased incidence of prolonged mechanical ventilation (36% *vs.* 12%, $p < 0.025$), cardiac complications (54% *vs.* 10%, $p < 0.01$), and pneumonia (36% *vs.* 16%, $p < 0.06$). Severely injured patients (Injury Severity Score [ISS] ≥ 25) older than 80 years old had a mortality rate of 80%, and the survivors required permanent nursing home care. Discriminant analysis yielded a reliable method of differentiating survivors from nonsurvivors based on age, ISS, and the presence of cardiac and septic complications. To assess the accuracy of the discriminant function, 61 consecutive patients admitted during 1985 were reviewed prospectively. Discriminant scoring predicted outcome correctly in 92% of these patients. A Geriatric Trauma Survival Score (GTSS) based on the discriminant function was calculated for each of the 143 patients studied and was highly correlated with mortality rate ($r = 0.99$, $p < 0.001$). Thus, the GTSS may serve as a valuable tool for evaluating death in geriatric trauma victims. Furthermore, because complications are potentially avoidable and contribute to increased mortality rates, routine aggressive care for geriatric patients with moderate overall injury is indicated.

Although the elderly population is growing, few studies have examined the outcome of seriously injured elderly patients. Oreskovich et al.[1] suggested that aggressive care of these patients is futile because of a high mortality rate and the finding that survivors rarely regained their pre-injury function. In contrast, we have recently reported a favorable prognosis for functional recovery in 63 consecutive geriatric patients with trauma.[2] Clearly, further studies to define factors related to mortality rate and outcome are required before aggressive care of any geriatric patient with trauma is withheld. Because most of our survivors were able to return home, we have now studied factors related to nonsurvival in this population. Our goals were as follows: (1) to determine any factors that predicted that resuscitation would be futile; and (2) to assess the impact of potentially avoidable complications on mortality rate.

Methods

We reviewed the records of 82 consecutive patients older than age 65 admitted to the Rhode Island Hospital Trauma Service from September 1982 to December 1984. All patients with thermal, penetrating, or isolated orthopedic injury were excluded. An Injury Severity Score (ISS)[3,4] based on the 1985 revision of the Abbreviated Injury Scale (AIS)[5] was calculated for each patient and confirmed by the analysis of a second, blinded observer. The AIS values for head and neck, thorax, abdo-

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men, and extremity trauma were also recorded. The age, sex, mechanism of injury, number of body regions injured, presence of pre-injury cardiopulmonary disease, and length of hospital stay were noted for each patient. Those patients who required surgery after injury were grouped into emergent (less than 24 hours after admission) and delayed surgery groups. The type of surgery required was also recorded.

Cardiac, pulmonary, and septic complications and the number of complications during each patient's hospitalization were noted. Cardiac complications included myocardial infarction, arrhythmia with hypotension, and unstable or recent-onset angina. Pulmonary complications included pneumonia and ventilator dependence for 5 days or longer. The diagnosis of sepsis required blood cultures with positive results in the presence of a characteristic hemodynamic profile.

Data are presented as mean plus or minus standard error. Characteristics of survivors and nonsurvivors were compared by the chi square test and analysis of variance with comparison of individual means by use of Newman-Keuls testing.[6] A multivariate discriminant analysis using SPSS-X[7] (Brown University Computer, IBM VM/CMS 3081D) was used to identify variables that differentiated survivors from nonsurvivors. A stepwise model was used wherein variables were sequentially selected to enter the analysis. The order of selection was such that the residual variance in the population was minimized with the addition of each variable.[8]

In order to assess the predictive value of the discriminant analysis, we tested the ability of the function to predict outcome in a second population of geriatric trauma victims (test population). We prospectively reviewed 61 additional patients admitted from January through December 1985. The discriminant score calculated for each individual test case was used to assign it to the group (survivor or nonsurvivor) for which its probability of membership was greatest. The percentage of patients classified correctly (*i.e.*, predicted and actual outcome identical) was taken as an estimate of the predictive value of the discriminant function.

TABLE 1. *Characteristics of 82 Geriatric Trauma Victims*

Age (years)	75.8 ± 0.8
Sex	54 M/28 F
Mechanism of injury	39 falls, 40 MVAs, 3 assaults
Injury Severity Score	17.9 ± 1.2
Abbreviated Injury Scale	
Head and neck	2.4 ± 0.2
Thorax	1.4 ± 0.2
Abdomen	0.7 ± 0.1
Extremities	0.9 ± 0.1
BRI	
Head and neck	52 (63%)
Thorax	40 (49%)
Abdomen	24 (29%)
Extremities	33 (40%)
Number of BRI	1.8 ± 0.1
Stay (days)	24.4 ± 2.5
Complications	
Number per patient	0.8 ± 0.1
Cardiac	19 (23%)
Pneumonia	18 (22%)
Vent ≥ 5 days	16 (20%)
Sepsis	5 (6%)

M = male; F = female; MVA = motor vehicle accident; BRI = body regions injured.

Results

Geriatric Population

The characteristics of the population are provided in Table 1. The population had a mean age of 75.8 ± 0.8 years and a moderate overall level of injury with a mean ISS of 17.9 ± 1.2. All patients had blunt injury secondary to falls (48%), motor vehicle accidents (33%), pedestrian–motor vehicle accidents (16%), or assault (4%). Men outnumbered women nearly 2:1. Twenty-three patients (28%) had an ISS of 25 or more. The head and neck region was most frequently injured (64%), and 49 patients (60%) had multiple body regions injured. Most patients had pre-injury cardiac or pulmonary disease (72%). Half of the patients required surgery after trauma, and surgery was emergent in two-thirds of these cases. The types of operations performed are listed in Table 2.

Complications developed in 35 patients (43%), with a mean number of complications per patient of 0.8 ± 0.1. Cardiac complications (23%) and pneumonia (22%) were most frequent. Sixteen patients (20%) required assisted mechanical ventilation for 5 days or longer. Systemic sepsis occurred in only five patients (6%). More than one complication developed in 18 patients (22%) which included 11 with prolonged ventilatory assistance and pneumonia.

Seventeen patients died during hospitalization, yielding a mortality rate of 21%. Table 3 depicts the characteristics of survivors and nonsurvivors. Nonsurvivors were older (81.7 ± 2.1 *vs.* 74.3 ± 0.8 years, $p < 0.001$), had more severe overall injury (ISS: 26.7 ± 2.8 *vs.* 15.8 ± 1.1, $p < 0.001$), and had more severe head and neck

TABLE 2. *Surgery in 82 Geriatric Trauma Victims*

	No. of Patients
Surgery	42 (51%)
Emergent	29 (69%)
Delayed	13 (31%)
Type of operations performed	
Central nervous system	18 (43%)
Abdomen	9 (21%)
Orthopedic	10 (24%)
Thorax	2 (5%)

TABLE 3. *Comparison of Survivors and Nonsurvivors*

	Survivors (N = 65)	Nonsurvivors (N = 17)	
Age	74.3 ± 0.8	81.7 ± 2.1	*
Sex	44 M/21 F	10 M/7 F	NS†
Mechanism of injury	31 falls/31 at MVAs/3 assaults	8 falls/9 MVAs	NS†
ISS	15.8 ± 1.1	26.7 ± 2.8	*
AIS			
Head and neck	2.1 ± 0.2	3.5 ± 0.5	‡
Thorax	1.3 ± 0.2	1.6 ± 0.5	NS†
Abdomen	0.8 ± 0.2	0.4 ± 0.2	NS†
Extremities	0.9 ± 0.2	1.0 ± 0.3	NS†
Number of BRI	1.8 ± 0.1	1.8 ± 0.2	NS†
Stay (days)	25.2 ± 2.5	21.5 ± 7.6	NS†
Complications			
Number per patient	0.6 ± 0.1	1.8 ± 0.3	‡
Cardiac	10 (15%)	9 (53%)	‡
Pneumonia	12 (19%)	6 (35%)	NS†
Vent ≥ 5 days	9 (15%)	7 (41%)	‡
Sepsis	2 (3%)	3 (18%)	NS†

* p < 0.01.
† NS = not significant, p > 0.05.
‡ p < 0.05.
MVA = motor vehicle accident; BRI = body regions injured; M = male; F = female.

trauma (AIS: 3.5 ± 0.5 *vs.* 2.1 ± 0.2, p < 0.025). There was no difference in AIS values between survivors and nonsurvivors for trauma that did not involve the head and neck, number of body regions injured, mechanism of injury, incidence of surgery (emergent or delayed), or length of hospital stay.

TABLE 4. *Comparison of Patients Ages 65 to 79 with Patients 80 Years Old and Older*

	Ages 66–79 (N = 58)	Age ≥ 80 (N = 24)	
Sex	15 M/9 F	39 M/19 F	NS*
Mechanism of injury	30 falls/25 MVAs/3 assaults	9 falls/15 MVAs	NS*
Injury Severity Score	17.4 ± 1.3	19.3 ± 2.5	NS*
Abbreviated Injury Scale			
Head and neck	2.2 ± 0.3	2.8 ± 0.4	NS*
Thorax	1.5 ± 0.2	1.0 ± 0.3	NS*
Abdomen	0.8 ± 0.2	0.5 ± 0.2	NS*
Extremities	0.9 ± 0.2	1.0 ± 0.3	NS*
Number of BRI	1.9 ± 0.1	1.7 ± 0.1	NS*
Stay (days)	23 ± 2.9	27.9 ± 4.7	NS*
Complications			
Number per patient	0.6 ± 0.1	1.5 ± 0.3	†
Cardiac	6 (10%)	13 (54%)	†
Pneumonia	9 (16%)	9 (36%)	NS*
Ventilator ≥ 5 days	7 (12%)	9 (36%)	†
Sepsis	3 (5%)	2 (8%)	†
Mortality rate	10%	46%	‡

* NS = not significant, p > 0.05.
† p < 0.05.
‡ p < 0.01.
BRI = body regions injured; M = male; F = female; MVA = motor vehicle accidents.

Complications were more frequent in nonsurvivors. Complications developed in 82% of nonsurvivors compared with 33% of the survivors (p < 0.05). Nonsurvivors had a higher incidence of cardiac complications (53% *vs.* 15%, p < 0.05) and ventilator dependence for 5 or more days (41% *vs.* 14%, p < 0.05). Four of 11 patients (36%) with the combination of pneumonia and assisted ventilation for 5 or more days died.

If mortality rate after trauma in geriatric patients is indeed primarily related to advanced age, patients older than 80 years may be at increased risk. Twenty-four patients (29%) were 80 years or older. The mortality rate in this age group was more than fourfold greater than for patients ages 65 to 79 (46% *vs.* 10%, p < 0.01, see Table 4). There was no difference in number of body regions injured, ISSs, AIS values for any body region, or length of hospital stay between these two age groups. However, there were more complications in patients who were 80 years and older (1.8 ± 0.3 *vs.* 0.6 ± 0.1, p < 0.001). In the older group prolonged mechanical ventilation (36% *vs.* 12%, p < 0.025) and cardiac complications (54% *vs.* 10%, p < 0.01) were more frequent and there was a trend toward a higher incidence of pneumonia (36% *vs.* 16%, p < 0.06). Thus, advanced age or more frequent complications may contribute to an increased mortality rate in patients older than 80 years old, although injury severity was not greater. However, severe overall injury in the older group appears to denote a particularly poor prognosis. Of 10 patients older than age 80 with ISSs greater than or equal to 25, eight died and the two survivors required permanent nursing home care.

Discriminant Analysis

Discriminant analysis revealed that outcome was related to four variables: ISS, age, and the presence of cardiac (CARDIAC) or septic (SEPSIS) complications (0 = no complication, 1 = complication) *via* the following discriminant function:

$$\text{Discriminant score} = (0.086)\text{AGE} + (0.064)\text{ISS} + (1.49)\text{SEPSIS} + (1.06)\text{CARDIAC} - 7.96$$

The canonic correlation coefficient was 0.63 (p < 0.001). Survivors had a mean discriminant score of −0.4, whereas nonsurvivors had a mean score of 1.55. Classification of each individual case based on its probability of group membership, as if survival were unknown, revealed that 85% of the cases were correctly classified by the discriminant function (Table 5). This percentage was not increased significantly if other variables were added to the discriminant analysis.

Test Population

To test the accuracy of the discriminant function, we prospectively reviewed the cases of 61 additional consecutive blunt trauma victims older than the age of 65

TABLE 5. *Analysis of the Predictive Value of the Discriminant Function: Predicted Outcome (Based on the Discriminant) was Compared with the Actual Outcome for the 82 Patients in the Original Population and for the 61 Patients in the Test Population**

	Predicted Survival	Predicted Death
Original patients (N = 82)		
Actual		
Survival	54	11
Death	1	16
Test population (N = 61)		
Actual		
Survival	50	1
Death	4	6

* Overall, 85% of the original patients were classified correctly by the discriminant function. In the test population, 92% were correctly classified.

admitted to our Trauma Service during the 1985 calender year. The characteristics of the test population are listed in Table 6. The mean age and incidence of cardiac complications and sepsis in the test population were similar to those of the original population. The mean ISS and mortality rate were somewhat lower, however. Despite these differences in the test population's characteristics, the discriminant function predicted outcome correctly in 92% of the test cases (Table 5).

Geriatric Trauma Survival Score and Mortality

Most errors in classification of individual cases as survivors or nonsurvivors occurred in patients with discriminant scores in the middle range (*i.e.*, discriminant score between 0 and 1.5). The mortality rate for patients scoring in this range is significantly less than 100% and greater than zero (Fig. 1). Because the mortality rate associated with each discriminant value in the test population was strikingly similar to the respective mortality rate in the original population (Fig. 1), we combined the two groups in an attempt to derive a clinically useful formula for assessing the mortality rate of geriatric patients with trauma admitted to our institution. First, we performed an algebraic transformation of the original discriminant function to obtain a Geriatric Trauma Survival Score (GTSS):

$$\text{GTSS} = 0.9(\text{AGE} - 65) + 0.6(\text{ISS}) + 14.9(\text{SEPSIS}) + 10.6(\text{CARDIAC})$$

As in the discriminant formula, SEPSIS and CARDIAC refer to the presence or absence (score = 1 or 0, respectively) of septic and cardiac complications. The GTSS differs from the original discriminant function in that all values are greater than zero. The range of possible GTSSs includes a minimum score near zero. Although the theoretic maximum GTSS is greater than 100, this would require extreme age and an ISS near the maximum possible score of 75. The calculated GTSSs in the 143 patients studied ranged from 3.9 to 58.4, with a mean GTSS of 21.7 ± 12.4 (standard deviation [SD]). The mean GTSS for survivors was 18 ± 9.5 (SD) and for nonsurvivors 37.8 ± 2 (SD).

TABLE 6. *Characteristics of the 61 Prospectively Reviewed Geriatric Patients with Trauma Constituting the Test Population*

Age (years)	76.3 ± 0.9
Injury Severity Score	10.0 ± 0.9
Complications	
Cardiac	15%
Sepsis	3.3%
Mortality rate	16%

Having derived a GTSS that is easier to calculate than the original discriminant function, we examined the mortality rate associated with values of the GTSS. The GTSS values for all patients were ranked in ascending order and arbitrarily divided into 15 roughly equal subgroups with consecutive scores. The mean GTSS and mortality rate for each subgroup were determined and plotted (Fig. 2). An iterative least-square logistic curve fitting model[9,10] was used to determine the best curve relating GTSS and mortality rate. In order to provide an accurate assessment of the curve, we assumed that patients with a near-maximum GTSS of 100 had a mortality rate of 100%. Thus, the asymptote of the curve converged on a 100% mortality rate for high GTSSs. This assumption appears reasonable, because a GTSS of 100 requires a near-maximum ISS and the mortality rate in younger patients with injury of this severity approaches 100%. The best fit relationship was:

$$\text{Mortality (\%)} = 100 - 100/(1 + [\text{GTSS}/32.8]^{5.2})$$

The correlation coefficient for the curve fit by the above formula was 0.99 ($p < 0.001$). The GTSS associated with

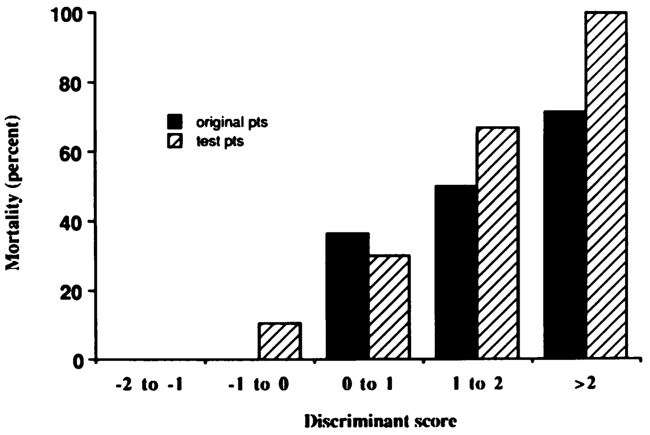

FIG. 1. Mortality rate associated with increasing values of the discriminant score. The mortality rates of patients in the original and test populations for a given discriminant score were similar. Most errors in classification of patients as survivors or nonsurvivors were in cases with discriminant scores in the middle range.

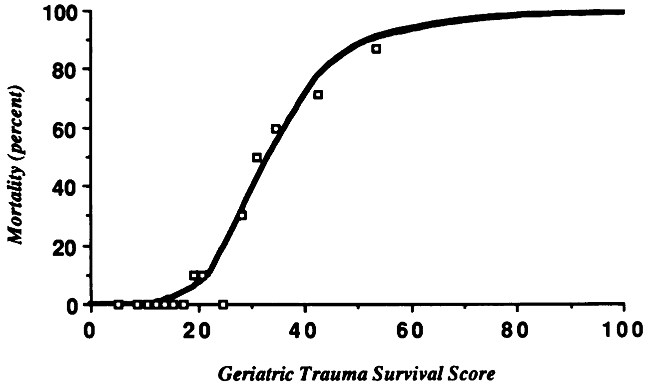

FIG. 2. Mortality rate associated with increasing values of the GTSS in the total population of 143 patients. There was a strong correlation between GTSS and mortality rate ($r = 0.99$, $p < 0.001$) with the use of the least-squares logistic analysis. A GTSS of 32.8 led to a predicted mortality rate of 50%, and the mortality rate of patients with GTSSs greater than or equal to 50 was 89%.

a 50% mortality rate was 32.8, with a 20% mortality rate was 25.5, and with an 80% mortality rate was 43.7. The curve predicts a 95% mortality rate for patients with a GTSS of 62.8.

Discussion

Elderly persons are seriously injured less frequently than any other segment of the population.[11] However, the mortality rate of elderly patients after trauma is higher than for any other age group.[11,12] Despite their lower injury rate, the elderly patients consume nearly one-third of all health care resources expended on trauma care.[13] Furthermore, the geriatric segment of the population is growing rapidly. The elderly population is projected to increase by 18% over the next 10 years[14] and by more than 50% within 50 years.[15] Clearly, trauma in elderly patients will become an increasingly important health care issue in the future.

Few studies have examined why the mortality rate is increased in geriatric patients after trauma.[1,16] Furthermore, comparison of such studies is potentially difficult. Many injured elderly persons have relatively minor trauma (*i.e.*, hip fractures resulting from falls), and high morbidity and mortality rates have been reported in this situation, presumably as a result of severe intrinsic disease.[17,18] Including these debilitated patients in a study of trauma would inevitably bias the outcome. Because we were primarily interested in previously healthy, independent patients with major trauma,[1,16] we defined our population carefully. We included only patients admitted to the trauma service and excluded those with isolated orthopedic injuries. Because nearly all of our patients were living independently before injury,[2] these criteria probably excluded most debilitated patients. Thus, we feel the study population is representative of previously independent elderly persons admitted to most trauma centers.

The mortality rate in our patients was high despite moderately severe injuries. In one of the few previous studies that has examined factors related to mortality rate in geriatric patients, Oreskovich et al.[1] in Seattle reported that nonsurvivors had an increased frequency of head trauma and thermal injury. However, they found no difference in age or injury severity as measured by ISS between patients that survived and those that died. In contrast, our data suggest that both of these factors contribute to mortality rate. The reasons underlying these conflicting results are unclear. A possible explanation may be found in the revisions of the ISS since its introduction in 1976. We used the 1985 revision of the ISS[5] that includes physiologic modifications added after the original version used by Oreskovich et al.[1] Thus, the updated ISS may be more useful than previous versions in predicting mortality rate.

In the Seattle study,[1] most nonsurvivors were characterized by hypotension upon arrival, prehospital intubation, prolonged mechanical ventilation, and pulmonary sepsis. However, this nonsurvivor profile is difficult to interpret, because the mortality rate associated with each factor was not reported. For example, although all nonsurvivors required prolonged ventilatory assistance, the overall mortality rate of patients in whom this complication developed was not reported. In our series, 44% of patients requiring prolonged ventilatory assistance died and six of nine that survived eventually returned home after hospital discharge.[2] Clearly, the need for prolonged ventilatory assistance is not an indication for withdrawing support.

Mortality rate in geriatric patients with trauma is difficult to predict based solely on the ISS.[12] Oreskovich et al.[1] found no difference in ISSs between survivors and nonsurvivors. Although our nonsurvivors had a higher ISS than survivors and ISS was correlated with outcome, the ISS alone was a poor predictor of survival rate. For this reason, we used a multivariate analysis to determine factors related to mortality rate. Discriminant analysis determined that survival rate was primarily related to age, ISS, and the presence of cardiac or septic complications in the original population, and the importance of these factors was confirmed in 61 additional prospectively reviewed patients. Algebraic transformation of the discriminant function yielded a Geriatric Trauma Survival Score, or GTSS, that was easier to calculate than the original equation.

Although the GTSS was strongly related to mortality rate, its clinical utility is difficult to determine. The GTSS appears to be a good predictor of mortality rate in geriatric patients at our institution, but its predictive value for other institutions has not been tested. Clearly, the GTSS should not be used to predict the mortality rate of geriatric trauma victims or the futility of resuscitation because the number of patients with high GTSS values in our study was small. Furthermore, the GTSS is unlikely to be helpful in determining whether or not resuscitation of an elderly patient in the emergency room should be continued, because complications, which are important contributors to the GTSS, are often not early events. In this study we have not examined prehospital variables (*i.e.*, prehospitalization endotracheal intubation, hypotension on arrival, *etc.*): doing so may have increased the predictive value of the GTSS.

The futility of geriatric trauma care is not supported by our data. Although the small group of patients with GTSSs over 50 had a high mortality rate, it is clear that further study is required before aggressive care of these patients is deemed hopeless. At the present time, the GTSS is likely to be most useful for trauma centers to evaluate their own experience with geriatric patients and for comparing the results of different institutions. The GTSS may also be useful for evaluating the effect of changes in treatment protocol at an individual institution. For example, routine invasive cardiac monitoring for patients with trauma who are older than 80 years old may decrease the mortality rate associated with cardiac complications and shift the curve relating GTSS to mortality rate to the right.

The data demonstrate the important role of complications in deaths of geriatric trauma victims. Cardiac complications in particular may reflect the severity of underlying disease, and many authors have suggested that the mortality rate is difficult to predict in this population because of intrinsic disease that may be clinically silent before injury.[1,12] Interestingly, the presence of previously diagnosed cardiopulmonary disease was not related to mortality rate. Thus, the lack of significant medical history should not be used as a criterion for intensive care unit admission and invasive monitoring in patients with moderate overall injury. Notably, of the factors related to survival determined by discriminant analysis, only the complications might be avoided with more aggressive care. Routine aggressive treatment of geriatric trauma victims, including intensive care unit admission, early invasive cardiac monitoring, and aggressive pulmonary therapy, might prevent complications in these patients and decrease mortality rates. Thus, our data indicate that routine aggressive care for elderly patients with moderate overall injury is appropriate, particularly because the survivors had a good prognosis for functional recovery.[2]

In summary, our data suggest that geriatric patients with trauma who are older than 80 years old, have severe overall injury (ISS $\geq$ 25), or have severe head and neck trauma have an increased mortality rate. Nearly half of the patients older than the age of 80 died after trauma, with no increase in injury severity in this group. The mortality rate is also increased in patients with complications, particularly cardiac complications and ventilator dependence. Cardiac and pulmonary complications were more frequent in patients who were older than 80 and this may contribute to the increased mortality rate in this group. Patients older than the age of 80 who had severe overall injury and patients with GTSSs greater than or equal to 50 had an extremely poor prognosis. Aggressive care of patients in this group may be futile, but further study is required to confirm this result. Because complications are potentially avoidable and contribute to increased mortality rates, routine aggressive care for geriatric patients with moderate overall injury is indicated.

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