THE INJURY SEVERITY SCORE: DEVELOPMENT AND POTENTIAL USEFULNESS

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ABSTRACT

A method for comparing death rates of groups of injured persons was developed, using hospital and medical examiner data for more than two thousand persons. The first step was determination of the extent to which injury severity as rated by the Abbreviated Injury Scale correlates with patient survival. Substantial correlation was demonstrated. Controlling for severity of the primary injury made it possible to measure the effect on mortality of additional injuries. Injuries that in themselves would not normally be lifethreatening were shown to have a marked effect on mortality when they occurred in combination with other injuries. An Injury Severity Score was developed that correlates well with survival and provides a numerical description of the overall severity of injury for patients with multiple trauma.

INJURIES ARE A SERIOUS PROBLEM common to all societies. Yet even within a single community, groups of injured persons differ as to the nature and severity of their injuries. The difficulty of adjusting for such variation has hampered scientific study of injured persons. Nevertheless, it is essential to take differences in severity of injury into account when comparing the morbidity and mortality of various groups for purposes of evaluating their emergency and subsequent care (1).

Two basic research approaches can be used in dealing with this problem. The first is to compare only persons with similar injuries. When feasible this is often the best approach, but the numbers of injuries of each specific type and severity are often too small to support statistically sound conclusions.

The second approach is to compare persons whose injuries, although not necessarily the same anatomically, are of the same severity. Combining patients into groups on the basis of severity of injury requires the use of scales such as the Abbreviated Injury Scale (AIS)(2,3) and the Comprehensive Research Injury Scale (CRIS), (3,4) which were developed to provide a method for rating and comparing injuries incurred in automotive crashes. The widely used AIS is the simpler of the two scales; the CRIS is a detailed extension of the AIS. These two scales were based primarily on the professional experience and judgment of the physicians who constructed them. The degree to which they relate to morbidity and mortality has remained conjectural despite the medical reasonableness of the scale themselves.

The AIS and CRIS pertain to individual injuries. Even though most deaths following automotive crashes involve injury to more than one part of the body, a scale for describing multiply injured patients has been lacking. Ryan and Garrett (5) converted a linear injury scale to one in which the injuries with the higher ratings were heavily weighted, and proposed that the weights for each injury could be added together to give a total injury score for an individual. However, the method involved an eight-class injury scale that has not been widely used, and the validity of the proposed weights was not tested.

The present study was undertaken to determine the extent to which AIS ratings correlate with mortality. The analysis led to development of a simple method -- based on the AIS -of adjusting for multiple injuries. This method, the "Injury Severity Score," makes possible a valid numerical description of the overall severity of injury in persons who have sustained injury to more than one area of the body.

METHOD

The study group included 2,128 motor vehicle occupants, pedestrians, and other road users whose injuries resulted in hospitalization or caused death. All such cases at eight Baltimore hospitals during the two-year period 1968-1969 were included. The eight hospitals were selected on the basis of having record systems that made it feasible to identify patients admitted because of vehicle-related injuries.

Seven of the hospitals were participants in the Professional Activity Study (PAS) and at these hospitals the coded PAS data were used. At the eighth hospital data were obtained from patients' charts. Patients transferred to other hospitals or extended care facilities were followed to determine their. status as of March, 1971.

Records from the Office of the Chief Medical Examiner of Maryland provided a second source of information for persons who died following hospital admission, and also made it possible to include persons who were dead on arrival (DOA) or who died in emergency rooms prior to admission -- deaths that might not appear in hospital admission or discharge records.

Injuries were categorized using the AIS modified for the present study in two respects. First and most important, the AIS codes 6 through 9, which are normally assigned to any atality occurring within 24 hours, irrespective of injury severity, were not used.* All such fatalities were coded as if the outcome were not known. Thus all injuries were rated by severity, irrespective of outcome, and the most severe injury code used was 5. Use of the fatal codes 6 to 9 would have made it impossible to compute meaningful death rates for the various severity codes, and in addition some details of the injuries themselves would have been lost. Second, facial injuries were separated from cranial and neck injuries -in part because facial injuries, being common in automobile crashes, might otherwise have overshadowed other head injuries, and in part because the disfigurement often associated with facial injuries may have influenced their AIS rating.

Using the AIS, each injury was categorized by body area (head or neck, face, chest, abdominal or pelvic contents, extremities or pelvic girdle, and general) and severity (l=minor; 2=moderate; 3=severe, not life-threatening; 4=severe, life-threatening, survival probable; 5=critical, survival uncertain). For injuries coded by the International Classification of Diseases, Adapted (ICDA) at the PAS hospitals, each ICDA code was translated into an AIS grade. For example, the ICDA code 835, denoting dislocation of the hip, was converted to "grade 3 injury, extremity."

*See article elsewhere in this volume which describes the subsequently revised AIS.

After grading all injuries for a given patient, each body area was categorized by the most severe injury in that area. For example, if a person had two chest injuries graded 1 and 3, his grade for chest injury was 3.

Autopsies had been performed on 74% of all persons who died. When information was available from both hospital and autopsy data, severity grading was based on the autopsy.

RESULTS

The overall ratio of hospital admissions to deaths (including DOA's) was 8:1. The ratios of admissions to deaths ranged from approximately 5:1 to 60:1 in individual hospitals -reflecting, in general, differences in the proportion of severely injured patients each received.

The largest number of cases was in the 20-29 year age group (Table 1), but there were major differences between hospitals in the age distribution of their patients. For instance, in two hospitals the 0-9 age group was largest. The proportion of patients age 60 and older ranged from 8% to 14% in individual hospitals.

Table 1 - Age Distribution of Patients Who Were Alive on Arrival

Age	#	%
0-9	317	16
10-19	382	19
20-29	408	20
30-39	239	12
40-49	233	12
50-59	197	10
60-69	126	6
70-79	85	4
80-89	28	1
Total	2,015	100

Table 2 shows the distribution of injury severity. It is important to remember that this distribution does not represent the entire spectrum of highway injuries, since many injuries, especially minor ones, do not result in admission to hospitals. The most severe injury was grade 3 for 49% of all the patients in the study. Hospitals differed as to the proportion of patients with very severe injuries: the proportion with injuries of severity grades 4 or 5 ranged from 6% to 31%.

The extremities and pelvic girdle were the most frequently injured body region. Forty-nine percent of all patients sustained injuries to extremities and/or pelvic girdle, and in 35% of all patients this was the most severely injured region. There were large differences between the hospitals in distribution of injuries. For instance, the face was the most severely injured part of the body in 17% of the cases at one hospital, compared to 2% at another hospital.

Table 2 - Outcome by AIS Grade of Most Severe Injury

	Outcome					
			"Admitted"			
AIS Grade Most Severe Injury	Dead on Arrival	Died Later	Survived	Unknown	Total #	%
1	0	0	80	1	81	(4)
2	0	2	437	1	440	(20)
3	6	23	997	20	1,046	(49)
4	13	30	229	3	275	(13)
5	93	80	97	3	273	(13)
Unknown	1	0	12	0	13	(1)
Total	113	135	1,852	28	2,128	(100)
%	(5)	(6)	(88)	(1)	(100)	

DATE AND TIME OF ARRIVAL - There was an association between severity of injury and weekend arrival. Among patients whose most severe injury was grade 1, only 21% arrived on Saturday or Sunday, but among patients whose most severe injury was grade 5, 39% arrived during this same 48-hour period. These figures exclude DOA's, 49% of whom arrived on Saturday or Sunday.

Hour of arrival was known for one hospital. There, only 50 out of 371 admitted patients (14%) arrived on a weekday between 8 AM and 4 PM. In other words, some 86% of the patients admitted as the result of highway injury arrived on weekend, nighttime, or evening shifts.

LENGTH OF HOSPITALIZATION - The median length of stay for admitted patients at the 8 hospitals was 10 days (i.e., half the patients were discharged or died within 10 days) (Table 3). The average length of stay was 17 days, reflecting the lengthy stay of some patients. Prolonged hospitalization was more common among the elderly.

Seventy-four patients spent additional time in other hospitals and extended care facilities; the 40 for whom length of stay was known spent an average of 4.8 months at the second institution. Thirteen (18%) of these 74 transferred patients were age 70 and older, although patients age 70 and older comprised only 6% of the entire study group.

Twenty-eight of the 74 transferred patients were lost to follow-up. It is unlikely that there was an appreciable number of deaths among the 28, because at least some of their names should have been on file at the Office of the Chief Medical Examiner if they had died from causes identified as related to injuries and sequelae. These 28 patients whose survival status was not known have been excluded from the remainder of the analysis.

Table 3 - Length of Hospital Stay in Days

Age Group	Number of Patients	Average	Median
0-49	1,549	16	9
50-69	315	20	13
70+	108	25	13
All ages	1,972	17	10

Table excludes 113 DOA's, 34 persons who died prior to admission, and 9 for whom length of stay was unknown.

FACTORS DETERMINING OUTCOME - The percentage of patients that died increased with severity of injury (Fig 1), as did the proportion of deaths that were DOA (Table 2).

The patients in each of the five severity groups had a wide spectrum of types and numbers of injuries. For instance, some patients whose most severe injury was grade 4 had no injury elsewhere, others had minor to severe injuries in additional regions of the body. Figure 2Ashows the death rates for all patients in whom the most severe injury was grade 4, separated by severity of injury in the second most severely injured region. The death rate increased with injury severity in the second region, ranging from 6% in persons with no injury or only a grade 1 injury in a second region to 60% of those with a second grade 4 injury. Similarly, for persons whose mos t severe injury was grade 5, death rates ranged from 22% to 100%, depending upon the degree of injury in the second most severely injured region (Fig 2B).

Comparison of Figures 2A and 2B shows that death rates were higher for some groups of patients whose most severe injury was grade 4 than for others whose most severe injury was grade 5. Such relationships pointed to the need for a method to derive, in each case, a summary of injury severity that would adjust for variations in mortality associated with the number of body regions involved and the severity of trauma in each. The authors of the AIS had cautioned against averaging the AIS ratings, stating that "The quantitative relationship of the AIS codes is not known and is almost certainly non-linear (3)." Evidence of non-linearity is illustrated by Figure 1, which shows that mortality increases disproportionately with AIS rating of the most severe injury. Additional non-linearity is demonstrated by comparison of Figures 2A and 2B: the death rate for persons with two injuries of grades 4 and 3 was not comparable to that of persons with two injuries of grades 5 and 2 (sum=7 in both cases).

The simplest non-linear relationship is quadratic. This led to investigation of the possibility that squaring the AIS grades for the most severe injury in each body area before adding them together would provide a valid adjustment for multiple injuries. When the AIS grades for each of the two most severely injured areas were squared and the two results added together, it was found that death rates were usually similar for comparable totals. For instance, for persons whose two most severely injured areas were graded 5 and 0 and for those graded 4 and 3 (sum of squares = 25 in both cases), death rates were almost identical (22% and 24%, respectively). Figure 3 shows that the grade of the third most severely injured area also influenced mortality.

When the AIS grades for each of the three most severely injured areas were squared and the results added together, comparable totals again proved to be associated with similar mortality rates and the correlation between total injury

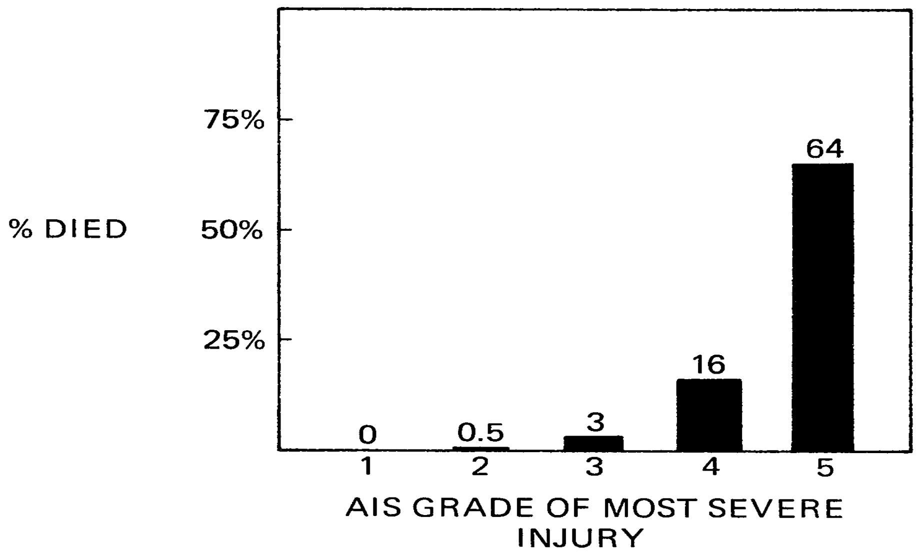

Fig. 1 - Mortality by AIS grade of most severe injury. DOA's included in calculations.

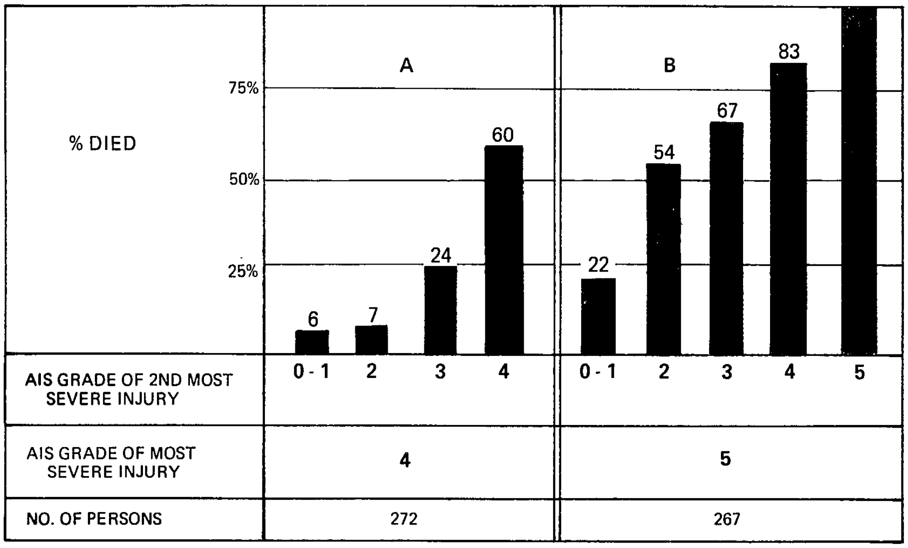

Fig. 2 - Mortality by AIS grade of second most severe injury: (A) when most severe injury was grade 4 and (B) when most severe injury was grade 5. DOA's included in calculations.

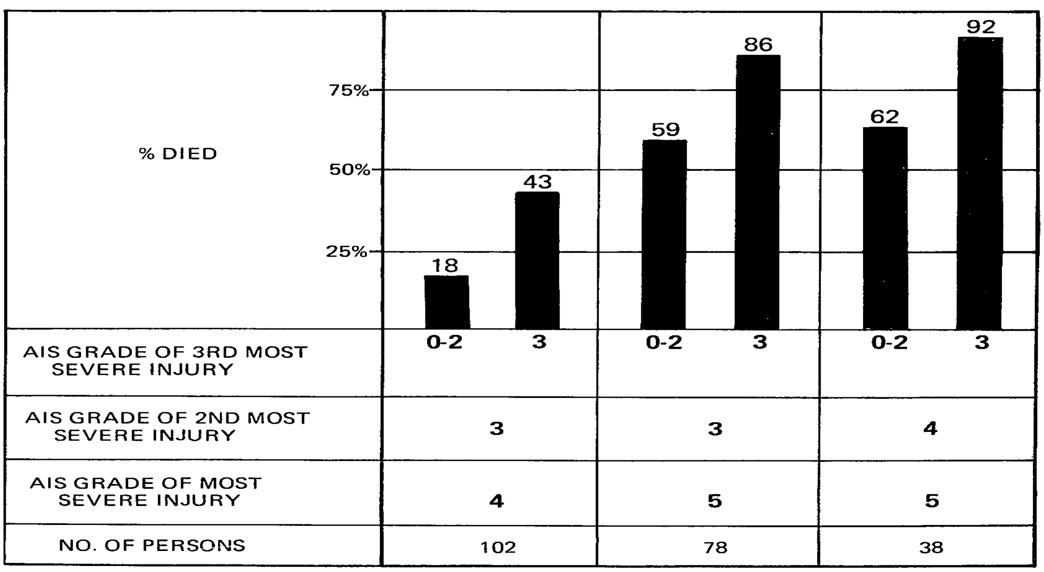

Fig. 3 - Mortality by AIS grade of third most severe injury. DOA's included in calculations.

severity and mortality was further improved. Including the grade of the fourth most severely injured area had no appreciable effect.

In view of the foregoing, an "Injury Severity Score" was defined as the sum of the squares of the highest AIS grade in each of the three most severely injured areas. In illustration, a person with a laceration of the aorta (AIS=5), multiple closed long bone fractures (AIS=4), and retroperitoneal hemorrhage (AIS=3), would have an Injury Severity Score of 50 (25+16+9). The highest possible score for a person with trauma to a single area is 25.

Use of the Injury Severity Score dramatically increased the correlation between severity of injury and mortality, as compared to using the AIS grade for the most severe injury. (Statistically, approximately half (49%) of the variance in mortality was explained using the Injury Severity Score to measure severity, compared to one-fourth (25%) using only the highest AIS grade.)

Figure 4 shows the observed relationship between Injury Severity Score and mortality. Death rates were higher for persons in the 50-69 year age group than for younger persons, and increased markedly for those age 70 and over. The ageassociated increase in mortality was especially pronounced

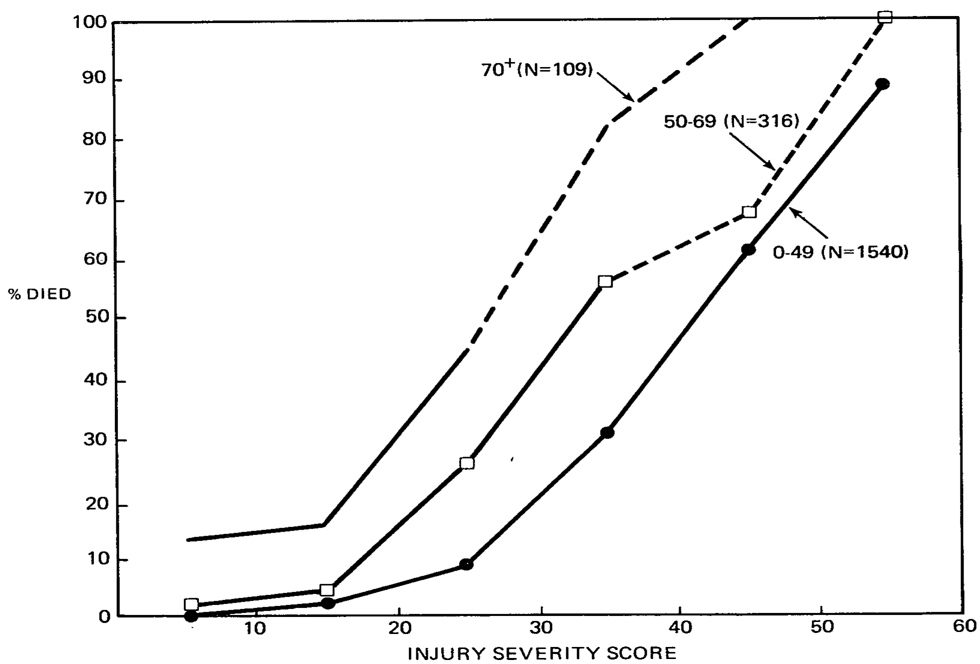

Fig. 4 - Mortality by Injury Severity Score for three age groups. DOA's excluded from calculations. Dotted lines connect points based upon less that 10 persons.

for <u>less</u> severe injuries. Figure 5 shows that the ratio of the death rate for age 70 and over to the death rate below age 50 increased exponentially as the Injury Severity Score <u>decreased</u> from 55 to 15. For Injury Severity Scores of 50 and higher there was almost no age difference in mortality, but for Scores of 10-19 the death rate for ages 70 and over was more than eight times the rate for persons less than 50 years old.

For Injury Severity Scores less than 10, there were no deaths at any time among patients less than 50 years old and no DOA's at any age (Table 4). The highest Score in a surviving patient was 50, in this particular series.

The association between age, time until death, and survival is shown in Figure 6. The figure illustrates the effect of age on probability of death as well as on time of death. Persons 50-69 had survival rates similar to younger persons for the first 24 hours, after which they fared progressively worse than younger persons. Compared with the two younger groups, persons 70 and older had lower survival rates, and the differences between this group and the other two increased as the interval between injury and death increased.

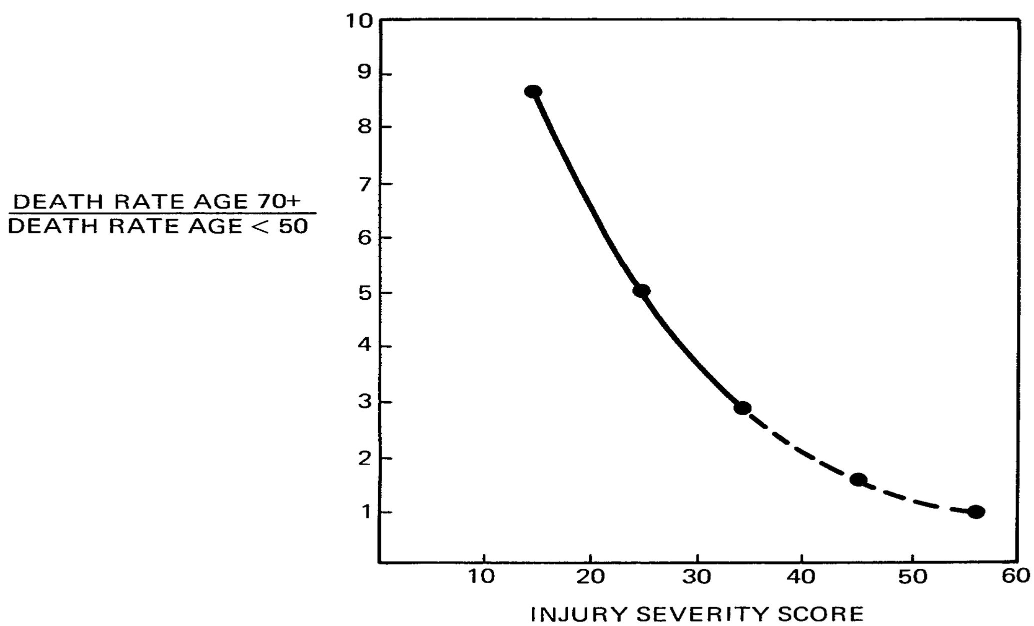

Fig. 5 - Age differential in mortality by Injury Severity Score. DOA's excluded from calculations. Dotted lines connect points based on less than 10 persons age 70+.

Among patients who died, the higher the Score the shorter survival tended to be (Fig 7). In illustration, among those with an Injury Severity Score below 20, half the deaths occurred over a week after injury and 18% over a month after injury. (No patients in the study were known to have died over three months after injury.) At the other extreme, when the Score was 50 or greater all deaths in this series occurred within a week of injury and three-fourths within the first hour.

Statistical correlation analysis indicated that, when the Injury Severity Score and age of patient were taken into consideration, survival was not significantly influenced by race or sex, or by whether a person was a vehicle occupant or pedestrian.

Table 4 - Injury Severity Score by Survival Status and Age of Patient

Age	Injury Severity Score	DOA	Died Later	Survived	Total
0-49	0-9	0	0	803	803
	10-19	2	8	431	441
	20-29	17	19	190	226
	30-39	17	16	36	69
	40-49	12	11	7	30
	50+	38	17	2	57
	Total	86	71	1,469	1,626
50-69	0-9	0	2	154	156
	10-19	0	4	92	96
	20-29	4	11	32	47
	30-39	2	5	4	11
	40-49	3	6	3	12
	50+	8	3	0	11
	Total	17	31	285	333
70+	0-9	0	6	42	48
	10-19	1	5	27	33
	20-29	0	9	11	20
	30-39	1	5	1	7
	40-49	1	1	0	2
	50+	6	2	0	8
	Total	9	28	81	118

Table excludes 28 persons whose survival status was unknown and 23 whose Injury Severity Score was unknown.

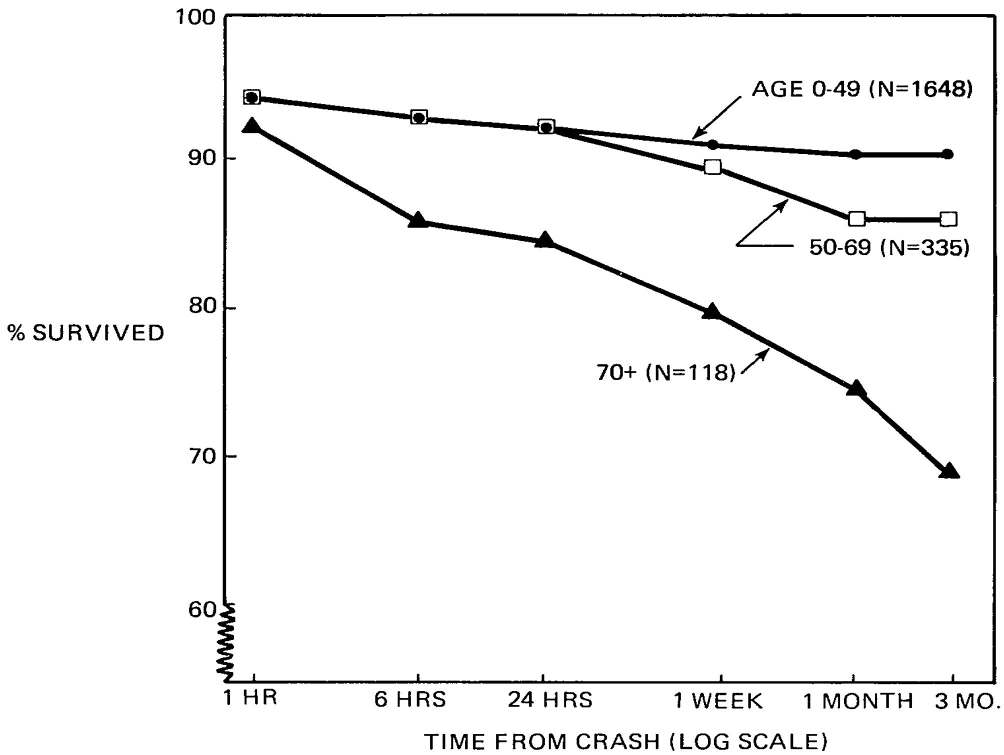

Fig. 6 - Survival curves for three age groups, DOA's included in calculations.

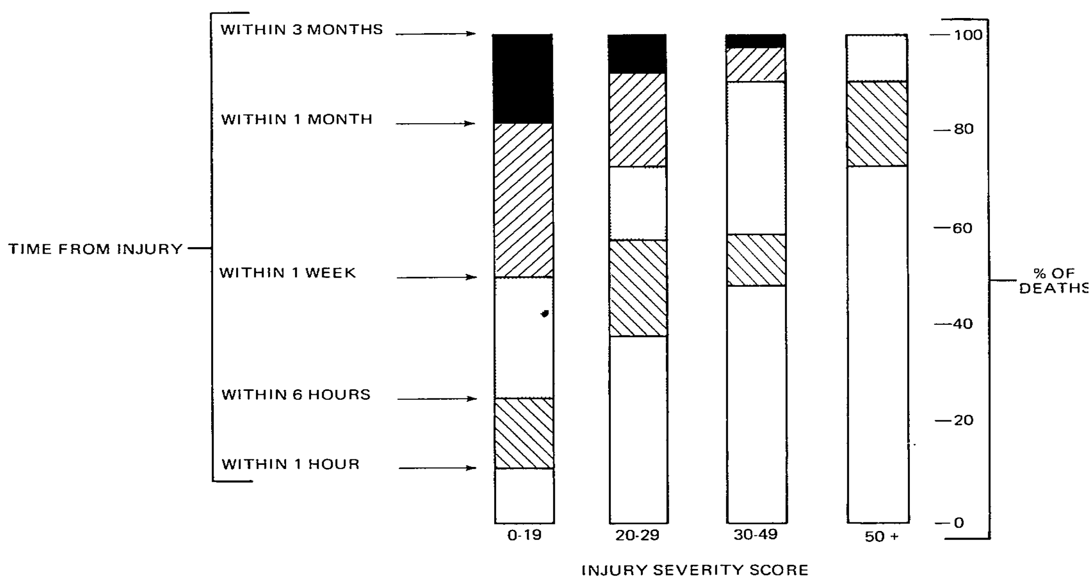

Fig. 7 - Length of time from injury until death by Injury Severity Score. Includes all deaths.

DISCUSSION

The results demonstrate that death rates increase in the presence of injuries in a second or third body area (Fig 2,3), even when the additional injuries would not normally, in themselves, be life-threatening. That patients with substantial injuries to multiple body areas have worse prognoses has long been known, but not previously quantified to a similar extent. This effect of additional injuries on mortality underscored the need for a method of summarizing the overall severity of injury.

Although the results show that the AIS, modified by nonuse of ratings over 5, does correlate substantially with death rates,* they also confirm the belief of the authors of the AIS that adding or averaging the ratings for various injuries will not adequately adjust for multiple injuries.

The score produced by adding together the squares** of the AIS ratings for each patient's three most severely injured body areas proved to correlate even more closely with death rates than did the AIS itself. Because of its much higher correlation with mortality and its solution to the problem of summarizing multiple injuries, this "Injury Severity Score" was used for analysis of additional factors in relation to mortality.

AGE - Results of the present study reflect the well-known fact that elderly patients, compared with younger persons similarly injured, have worse prognoses. Use of the Injury Severity Score made it possible to determine that this increased mortality in the elderly is most pronounced when the injuries are least severe (Fig 4,5). The magnitude of the effect of age on mortality and the difference between hospitals

*The more recent Comprehensive Research Injury Scale (CRIS) was not available when this investigation was initiated. Comparison of CRIS threat-to-life grades and AIS grades show that for 87% of injuries the two are the same or only one grade apart. This correlation suggests, first, that the Injury Severity Score can be based on this threat-to-life scale as well as on the AIS and, secondly, that results of the present investigation validate both scales. It is expected that further research would demonstrate that death rates correlate even more closely with CRIS threat-to-life grades (and Injury Severity Scores derived from them) than with AIS grades.

**The quadratic relationship between AIS grades and the threat to life of injuries in multiple body areas may reflect fundamental aspects of response to injury that should be the subject of research on changes over time in basic biochemical and physiological variables.

in the age distribution of their patients underscore the necessity of adjusting for age whenever two series of patients are to be compared.

If one were interested in using the Injury Severity Score as a tool to predict the experience of one or more groups of the injured, an adjustment for age could be incorporated into the calculation; however, separate consideration of age and injury severity is possible only when the Injury Severity Score itself is not age-adjusted. It is noted that there is no apparent need for consideration of either the patient's sex or race or whether vehicle user or pedestrian, since (in the present series, at least) once Injury Severity Score and age were taken into account survival did not vary with these factors.

For the individual patient, recognition of the poor prognosis for elderly persons may influence decisions in the early post-injury period. Therefore consideration should be given to incorporating an estimate of the injured person's age into clinical evaluation systems or indices for use in the immediate post-injury period, to help determine the need for especially prompt and comprehensive emergency response.

SURVIVAL TIME - Improvements in survival rates are especially achievable among persons who survive long enough to make possible the initiation of medical treatment. (An investigation of 33 deaths due to abdominal injuries revealed that none of the patients died within an hour of injury, and that approximately half the deaths might have been prevented with prompt and proper diagnosis and treatment) (6). The association between severity of injury and rapidity of death (Fig 7) suggests that patients with Injury Severity Scores below 50 may have the greatest potential for improved survival rates, since the majority who died with Scores below 50 were still alive an hour after injury.

POTENTIAL USES OF THE INJURY SEVERITY SCORE - Since patients with Scores below 10 rarely die, survival rates for groups with Scores between 10 and 50 may prove to be important evaluative indices. This group includes the patients whom Waller (7) suggests provide the real key to evaluating the emergency care system: those who are sick enough to be adversely affected by poor care, but not so sick that they will not survive even with optimum care. It is important to note, however, that certain patients whose Injury Severity Scores would be well in excess of 50 may survive if promptly treated by pertinently trained specialists who have at their disposal all necessary resources. Therefore, evaluation of emergency response systems should include patients throughout the range of the Injury Severity Score.

The Injury Severity Score can easily be added to data coded for research purposes, and to the hospital chart itself. This description of injury severity would enhance the value of patient records **--** from the simplest records to those in the Trauma Registry (8). After grouping patients on the basis of overall injury severity, any given emergency room, hospital, region, or country could describe the proportion of its trauma population that is injured to a specified extent.

Ability to compare groups of patients classified by overall injury severity makes it possible to evaluate methods of treatment, identify problem areas, and document progress. Professional service review organizations wishing to compare various institutions that provide care to the injured may also find the Injury Severity Score useful. For example, mortality rates for a trauma unit such as the Maryland Institute for Emergency Medicine, where the typical patient has sustained multiple severe injuries, cannot be compared meaningfully with mortality rates for all admitted injured patients at another hospital; however, a comparison based on comparable Injury Severity Scores would be useful.

METHODOLOGICAL CONSIDERATIONS - The present study does not include all vehicle-related injuries and deaths from a defined geographic area. This would be important if overall injury death rates were under consideration. However, a major advantage of the Injury Severity Score is that even when biases are present or suspected, valid comparisons can usually be made between the death rates of sub-groups with similar Injury Severity Scores and age distributions, provided followup information is available for both groups for corresponding time periods.

The appropriateness of including DOA's in calculation of mortality rates will depend upon the objectives of an investigation. DOA's should be included, for example, in studies focusing on types of vehicles or in calculation of the total death rate for a geographic area. On the other hand, when evaluating hospital care it is not realistic to include cases that were dead on arrival. The latter situation is complicated by the fact that a patient who would be pronounced DOA at one hospital might not be pronounced dead at another hospital until some time had been spent in resuscitative attempts. Resolution of this dilemma might require that each facility use the same objective criteria for vital status at the moment of arrival.

MAJOR CURRENT NEEDS - Further improvement in ability to evaluate the effectiveness of emergency response systems and medical care of the injured depends upon developing the ability both to classify the injured patient before and after admission and to measure his outcome. Other indices, including clinical signs and biochemical measurements, (9) could be used either in conjunction with or as an alternative to injury severity rating systems based on clinical diagnosis. Nor should the measurement of outcome be limited to analyses of mortality rates. For example, other outcome measurements suggested by Gibson (10) for use in studying emergency medical systems include disability days, residual impairment, and symptom scores 6 and 12 months after injury. For some evaluative purposes such measurements are more sensitive than death rates and need to be studied in relation to severity of injury.

Another major need is for revision of the International Classification of Disease trauma codes. At present, conversion of ICDA codes to AIS grades (and therefore Injury Severity Scores) is difficult because the ICDA index for trauma is extremely limited, especially in the classification of blunt injury. Only 15 whole numbers, of the 159 assigned to trauma by the ICDA, describe internal injuries to the head, chest, and abdomen. Thus, less than 10% of the codes describe those injuries that account for the majority of trauma deaths. If the potential usefulness of the ICDA injury codes is ever to be realized, it is imperative that they be revised to provide greater detail in describing the wide spectrum of damage resulting from the physical hazards of man's environment. Furthermore, since the most basic categorization of injuries is in terms of the kinds of energy transfers that produce them -- for example, mechanical, thermal, electrical, ionizing, chemical (11-13) -- we believe that subdivision of this type is necessary to rationalize such codes.

Most patients in this study had been injured by excessive transfers of mechanical energy. The findings reported cannot, therefore, be generalized to injuries due to transfer of other kinds of energy. Similarly, since the AIS and hence the Injury Severity Score based on it are oriented to the types of mechanical energy damage that commonly result from road crashes, extrapolation of the findings beyond this major group may be inappropriate except where similar injuries are involved. For example, injuries sustained in falls might be suitably so scored, but gunshot wounds might not. Rating systems analogous to the AIS and Injury Severity Score need to be developed and applied to the full range of human injury to help bring the science of this relatively neglected area of human wastage to the breadth and quality its importance demands (14).

CONCLUSION

Results of this investigation indicate that the Injury Severity Score represents an important step in solving the problem of summarizing injury severity, especially in patients with multiple trauma. The Score is easily derived and is based on a widely used injury classification system, the Abbreviated Injury Scale. Use of the Injury Severity Score facilitates comparison of the mortality experience of varied groups of trauma patients, thereby improving ability to evaluate care of the injured.

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