EVALUATION OF THE AIS AS A MEASURE OF PROBABILITY OF DEATH

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ABSTRACT

The Abbreviated Injury Scale, or AIS, has become the chief system for evaluating the severities of injuries incurred in automobile accidents and in human tolerance studies. The Scale was first published in 1971 by the Joint Committee on Injury Scaling, and it was intended to replace and unite the wide variety of injury scales that existed at that time. To make the AIS as broad and useful as possible, it was based on five criteria: energy dissipation, threat to life, permanent impairment, treatment period, and incidence.

There are difficulties, however, in using the AIS to examine a single aspect of automobile injuries. For instance, AIS codes, and combinations of codes, can not be related directly to a probability of death. A single injury of AIS 3 to the head may be much more life threatening than an AIS 3 injury to a leg.

In this paper, AIS will be evaluated as a scale of probability of death. Data will be obtained from the National Accident Sampling System (NASS) to evaluate the correlation between the 3 most severe injuries in a case and the probability of death. A study will also be made to examine the dependency of probability of death on the the body regions in which injuries occurred.

BACKGROUND

Before development of the AIS, various groups used different injury scales based on their specific interests in accident investigations and injury studies. Most of these scales based injury severity on threat-to-life, a criteria which the Joint Committee on Injury Scaling considered to be subjective [12]. The Abbreviated Injury Scale was designed to meet the needs of all of these groups with one unified code. To extend the usefulness of the scale, it was based on five criteria rather than just one or two. The current Abbreviated Injury Scale, AIS 1984, represents the third revision of the original injury code. (Most of the codes in this paper are based on AIS 1980, the second revision.) The continuing evolution of the scale is necessary to list more specific injury definitions and to eliminate ambiguity [1].

The AIS has proven to be a convenient scale for individual injuries, but, because most crash victims are multiply injured, it is beneficial to formulate a code to describe the overall condition of a victim. Since the inception of the AIS, several researchers have sought to define such a code.

The best known formula for an overall injury assessment is the Injury Severity Score. Developed in 1974 by Baker, et al, the Score was devised as a code by which emergency and other care facilities might be evaluated [3,2]. To calculate this Score, the body is considered to be made up of six regions. The ISS is the sum of the squares of the highest AIS code in each of the three most severely injured regions. The highest possible ISS is 75, as injuries coded AIS-6 are automatically assigned an ISS of 75. The quality of care at various facilities may be compared via comparison of the morbidity and mortality rates of groups of injured persons with similar ISS codes.

In a 1980 study [10], Susan Partyka investigated the societal cost of traffic accidents. Using regression methods and data from NCSS, National Crash Severity Study, she calculated fatality rates for injured persons as a function of first and second AIS codes. As a further refinement to the model, she included age as a factor in mortality. Fatality rate was also expressed as a function of ISS, and then of ISS and age. When the models were compared to initial NCSS data, the formula using the pair of two highest AIS codes showed the best correlation. The formulae were further verified on the National Accident Sampling System, NASS data, and it was found that both the AIS pairs model and the ISS model predicted fatality rates well. Application of the formulae to FARS, Fatal Accident Reporting System, showed similar results.

A 1980 study by Eppinger and Partyka [6] used the AIS pairs model calculated in Partyka's study [10]:

$$\text{fatality rate} = \frac{(6.567)^{AIS1} * (1.230)^{AIS2}}{43673}$$

A method was proposed whereby these fatality rates could be used to evaluate the effectiveness--reduction in fatalities--of various vehicular safety improvements. By identifying the injuries that could be prevented by safety improvements, the number of fatalities prevented may be calculated.

Susan Partyka extended the investigation of injury consequences of traffic accidents by applying modeling methods to calculate length of hospital stay as a function of the two most severe injuries [11]. Regression equations calculated from NCSS were applied to NASS data for verification. Models were found to be reasonably accurate in prediction of hospital stay.

In a more recent study, Ronald L. Somers introduced a Probability of Death Score, of PODS [13,14]. Using a stepwise logistic regression program, he calculated values for the parameters β and α of the linear logistic model:

$$\ln(\text{odds of death}) = \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \alpha$$

where the x_i's are independent variables, and α is constant. For Somer's research, odds of death, the ratio of the probability of death to the probability of survival, was a more significant mathematical value than probability of death. Somers also advanced the PODS as a measure of lives saved by vehicular safety improvements [15].

In recent studies at Folksam Insurance Company [7,8], societal cost of injuries resulting from traffic accidents was considered. A rating system for Risk of Serious Consequences (RSC) due to injuries was developed as a result. Rather than consideration of only threat to life as a serious consequence of injuries, another unacceptable consequence, permanent disability, was also considered. A formula was created to calculate the probability of either death or permanent disability. The risk value is based on the following equation:

$$RSC = r_f + [(1 - r_f) * (1 - \prod^{i} (1 - r_{id}))]$$

where

r_f = risk (probability) of death based on ISS value

r_{id} = risk (probability) of permanent disability for body region i, based on AIS value.

RSC and MRSC, Mean Risk of Serious Consequences for a certain group, represent a more general risk than is calculated by ISS. The RSC can be used to evaluate the value of vehicle safety improvements by calculating the reduction of all permanent consequences of injury.

Evaluating the four studies which relate AIS and probability of death, only Somers gives a clear probability of death value for all combinations of three AIS injury numbers. Also, the words "Minor", "Moderate", "Serious", etc., used in the AIS code, have not been related to probability of death in any of these studies. It is for these reasons that this study was undertaken.

PROCEDURE AND RESULTS

The goal of the present study is to relate combinations of three injuries to mortality rates. First, the combinations of three AIS codes from a large data base will be evaluated to determine mortality rates. Then, the mortality rates will be calculated for the injury combinations when they occur in specific body regions. The mortality rates of the specific regions will be compared to the mortality rates of the entire data base to evaluate the applicability of the fatality rates calculated over the entire data base. An effort will be made to relate AIS codes to their descriptors in AIS-80 [12].

AIS Code	Severity Code Descriptors
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury virtually unsurvivable in AIS-80

Data for this study was obtained from NASS, the National Accident Sampling System. Data collection is conducted from a number of carefully selected Primary Sampling Units across the country. Because accidents in the NASS data base comprise only a small sampling of the accidents which occur in the U.S. each year, NASS data must be weighted to estimate national statistics for accidents and injuries.

NASS contains a great deal of data about each accident, the vehicle or vehicles involved, the driver or drivers, and the injuries to occupants and non-occupants involved in the accident. Up to 10 injuries are recorded for each person. For each injury, the severity (AIS), body region, both by OIC, Occupant Injury

Classification, and by ISS region, the injury aspect, the type of lesion, and the system or organ involved are listed [9]. The result of the injuries, called "treatment", is also recorded.

OVERALL 3-AIS

For the first part of this study, general data was obtained from NASS files for 1979 through 1983. The data was divided by the three highest AIS codes into the 56 categories listed in Table 1. Other injuries listed in NASS were neglected (1) because consideration of more injuries would have subdivided the data into more and smaller categories, and (2) to provide some consistency with the standard severity scale, the ISS, which uses three injury severity values. Mortality rates were calculated from the number of injured persons and the number of fatalities. Raw data is shown in Table 1 and plotted in Figure 1. There was significant scatter in the data, but this was anticipated: 1) because of small quantities of data for some 3-AIS combinations and 2) because the ordering, 1 through 56, was chosen by logical sequence and does not indicate an actual order of severity. For example, an injury combination 3 3 3 is more serious than 4 0 0. To adjust for scatter and severity ordering, the data was logistically regressed by sets, one set for each of the highest injury severity

TABLE 1 -- 3-AIS Rankings and Raw Data

INDEX	3-AIS RANKING	INJURED	DEAD	MORTALITY RATE (%)	INDEX	3-AIS RANKING	INJURED	DEAD	MORTALITY RATE (%)
1	1 0 0	7917	4	0.0505	29	4 3 3	109	31	28.4404
2	1 1 0	5031	1	0.0199	30	4 4 0	0	0	--
3	1 1 1	8845	24	0.2713	31	4 4 1	4	3	75.0000
4	2 0 0	387	6	1.5504	32	4 4 2	14	5	35.7143
5	2 1 0	527	5	0.9488	33	4 4 3	47	21	44.6809
6	2 1 1	2359	19	0.8054	34	4 4 4	24	17	70.8333
7	2 2 0	84	3	3.5714	35	5 0 0	11	4	36.3636
8	2 2 1	653	9	1.3783	36	5 1 0	3	1	33.3333
9	2 2 2	250	14	5.6000	37	5 1 1	38	8	21.0526
10	3 0 0	91	2	2.1978	38	5 2 0	2	1	50.0000
11	3 1 0	123	0	0.0000	39	5 2 1	13	3	23.0769
12	3 1 1	585	8	1.3675	40	5 2 2	7	1	14.2857
13	3 2 0	47	0	0.0000	41	5 3 0	4	2	50.0000
14	3 2 1	344	12	3.4884	42	5 3 1	14	4	28.5714
15	3 2 2	254	18	7.0866	43	5 3 2	30	6	20.0000
16	3 3 0	30	3	10.0000	44	5 3 3	50	23	46.0000
17	3 3 1	147	1	0.6803	45	5 4 0	0	0	--
18	3 3 2	229	11	4.8035	46	5 4 1	7	4	57.1429
19	3 3 3	198	23	11.6162	47	5 4 2	11	4	36.3636
20	4 0 0	16	5	31.2500	48	5 4 3	42	24	57.1429
21	4 1 0	13	1	7.6923	49	5 4 4	38	28	73.6842
22	4 1 1	51	6	11.7647	50	5 5 0	1	0	0.0000
23	4 2 0	6	1	16.6667	51	5 5 1	0	0	--
24	4 2 1	34	4	11.7647	52	5 5 2	2	0	0.0000
25	4 2 2	27	2	7.4074	53	5 5 3	14	7	50.0000
26	4 3 0	6	0	0.0000	54	5 5 4	32	24	75.0000
27	4 3 1	29	2	6.8966	55	5 5 5	22	19	86.3636
28	4 3 2	49	9	18.3673	56	6 - -	192	192	100.0000

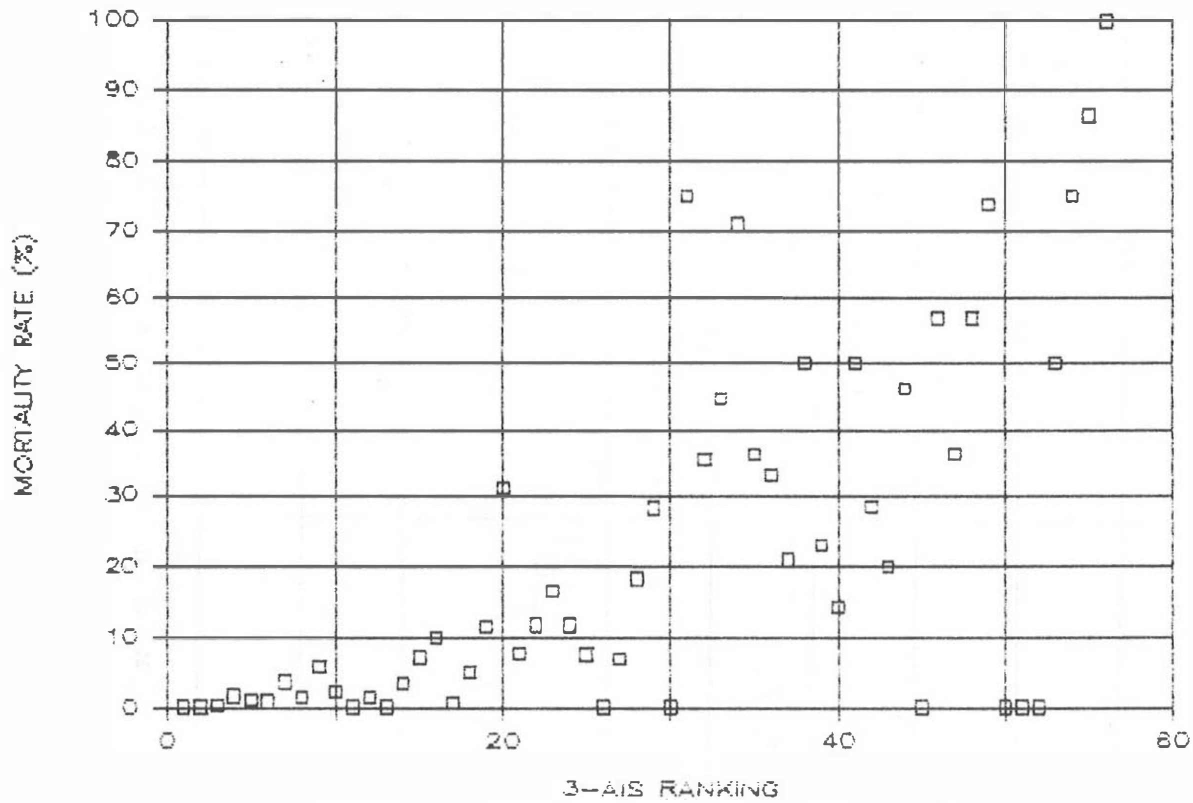

FIGURE 1 -- Raw Data From NASS 1979-1983

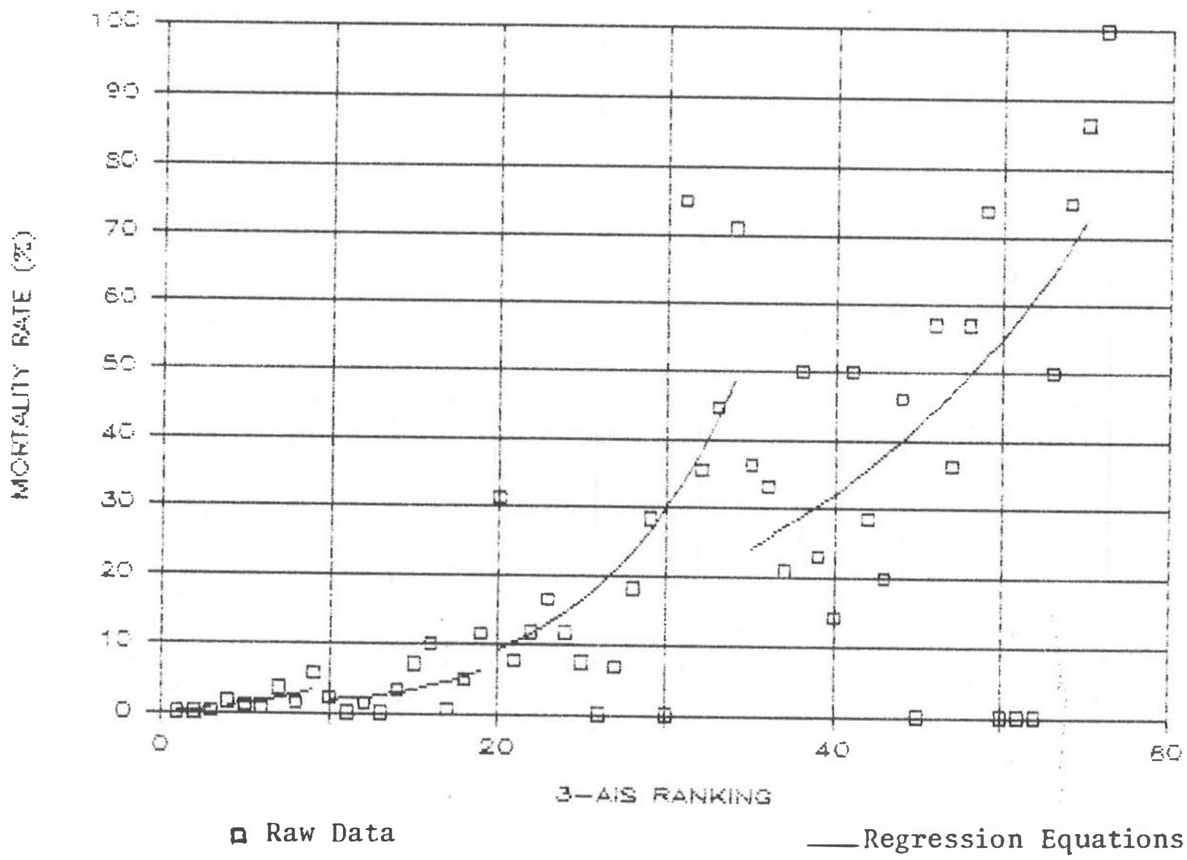

FIGURE 2 -- Regression Equations and Raw Data

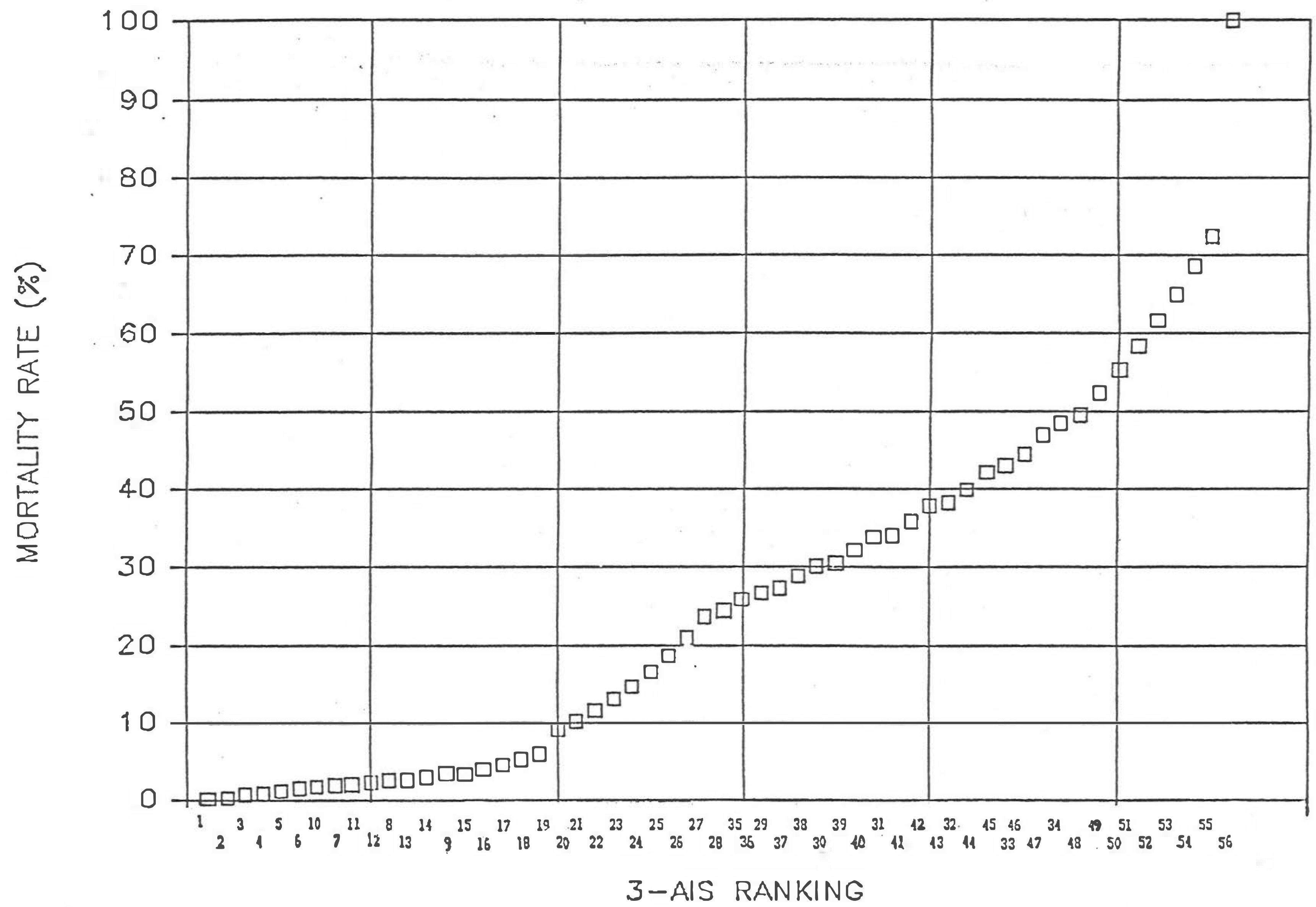

FIGURE 3 -- Regression Data, Re-Ordered

codes, 1-5. (Severity codes of 0 and 6 are considered to correspond to mortality rates of 0% and 100% respectively.) Correlation between the regression equations and the data was fair -- the correlation coefficient was 0.63 or better for four of the five groups and 0.4 for the group of AIS 3's. A plot of the regression equations with the raw data is shown in Figure 2. Data was re-ordered by increasing mortality rate as determined by the five regression equations. The re-ordered data is plotted in Figure 3. It can easily be seen in Figure 3 that the 3-AIS combination of 4 4 1 (3-AIS combination number 31) is more likely to cause death than a combination of 5 2 0 (number 38). Better correlation of the regression equations with the NASS data should be achieved by regressing data divided into groups by the two highest AIS codes, but this division would have led to 20 data sets, 5 of which contain only one point.

The ISS has been applied to various data sets to demonstrate its usefulness. A plot from the 1976 report, "The Injury Severity Score: An Update," [2] is reconstructed in Figure 4. The plot relates mortality rates to Injury Severity Scores for an American study [3] and a British study [4]. The points on this plot were converted to the 3-AIS combinations which they represent in Figure 5. The ISS numbers on the plot represent the data from Bull [4] and Baker [3]. Mortality rates represented by the ISS numbers are generally higher than those occurring in the NASS data for ISS of 50 or higher. This is most likely due to differences in data collection procedures. The ISS studies used data from hospitals and medical examiners. The NASS collects data on police-reported accidents from selected sites across the U.S., utilizing unofficial information, interviews from persons involved in the accident, emergency medical service

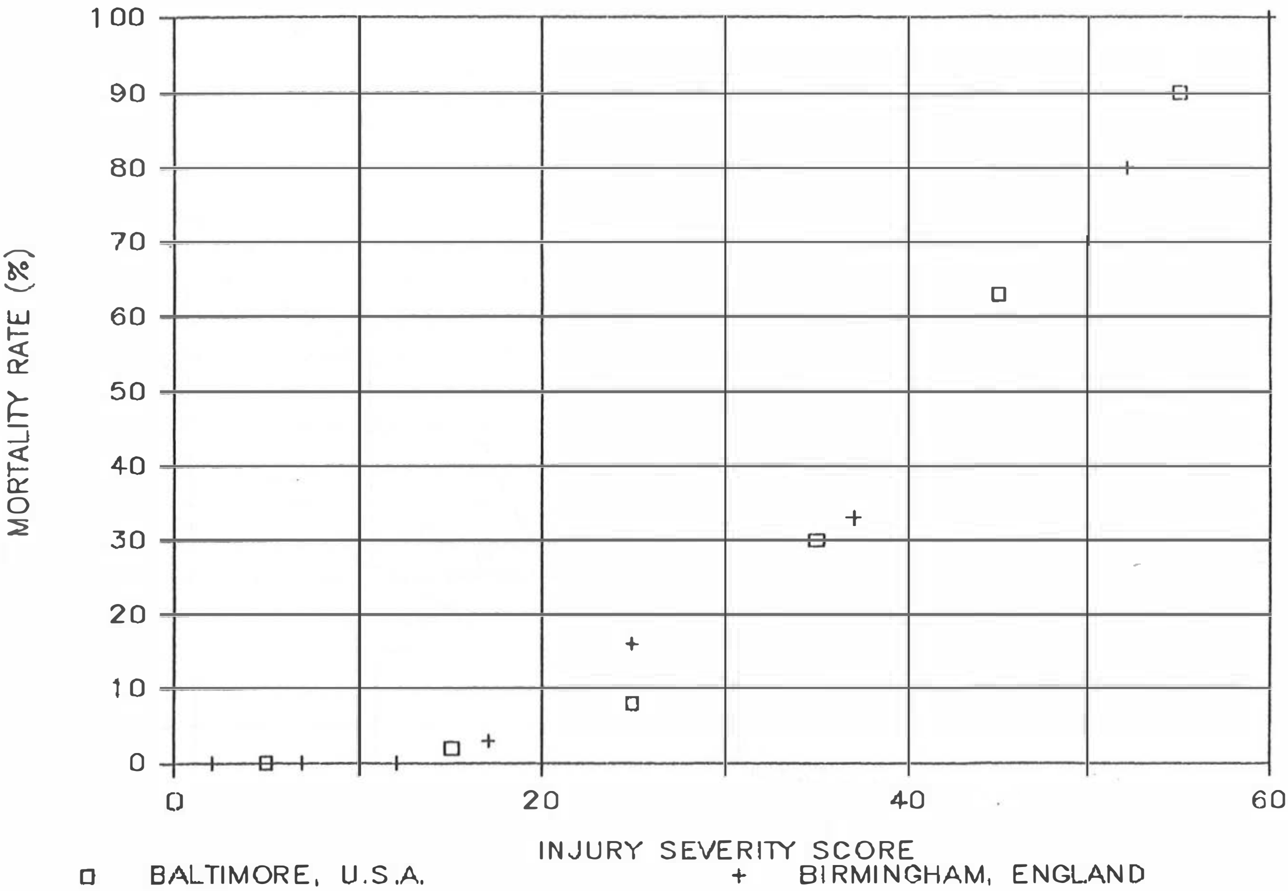

FIGURE 4 -- Mortality Rates by ISS From Studies by Bull [4] and Baker [3]

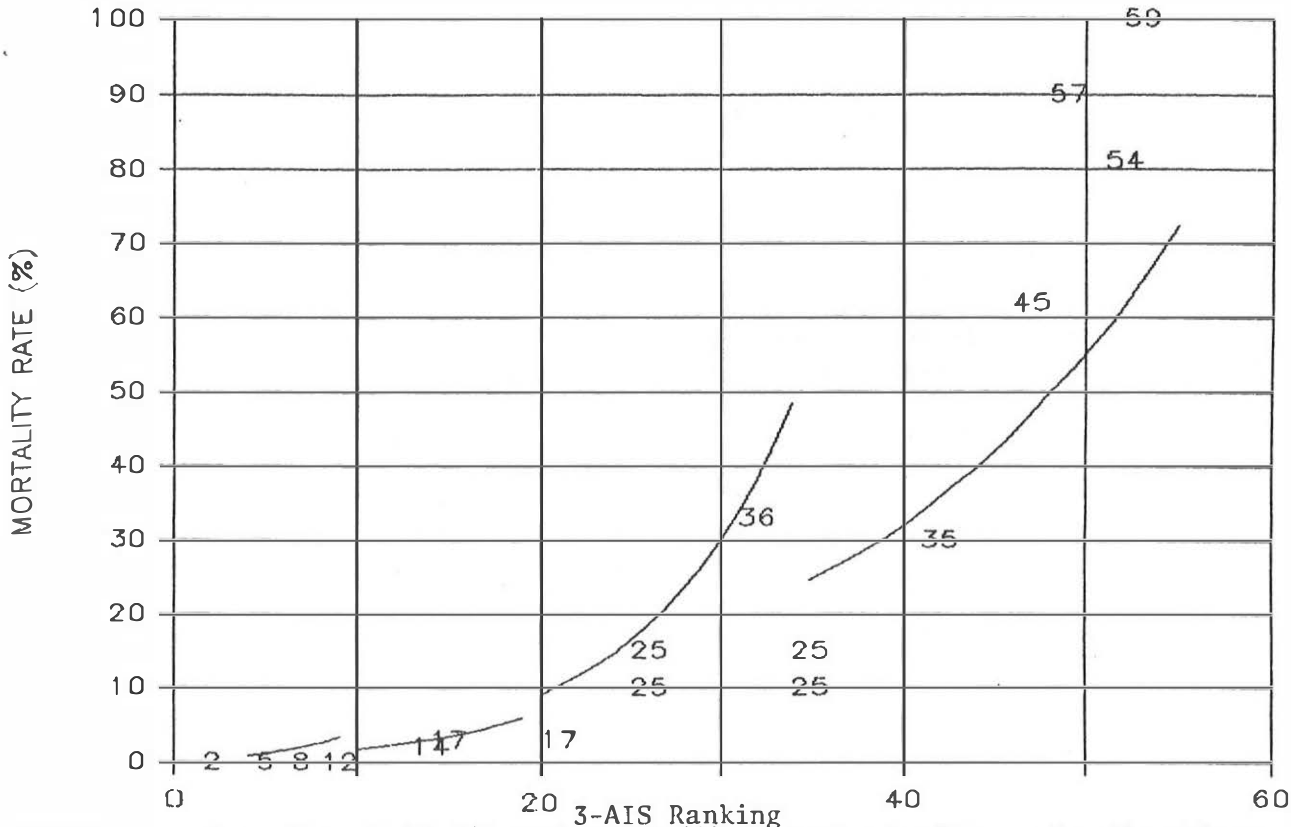

FIGURE 5 -- Data From Bull [4] and Baker [3] Compared to Regression Equations

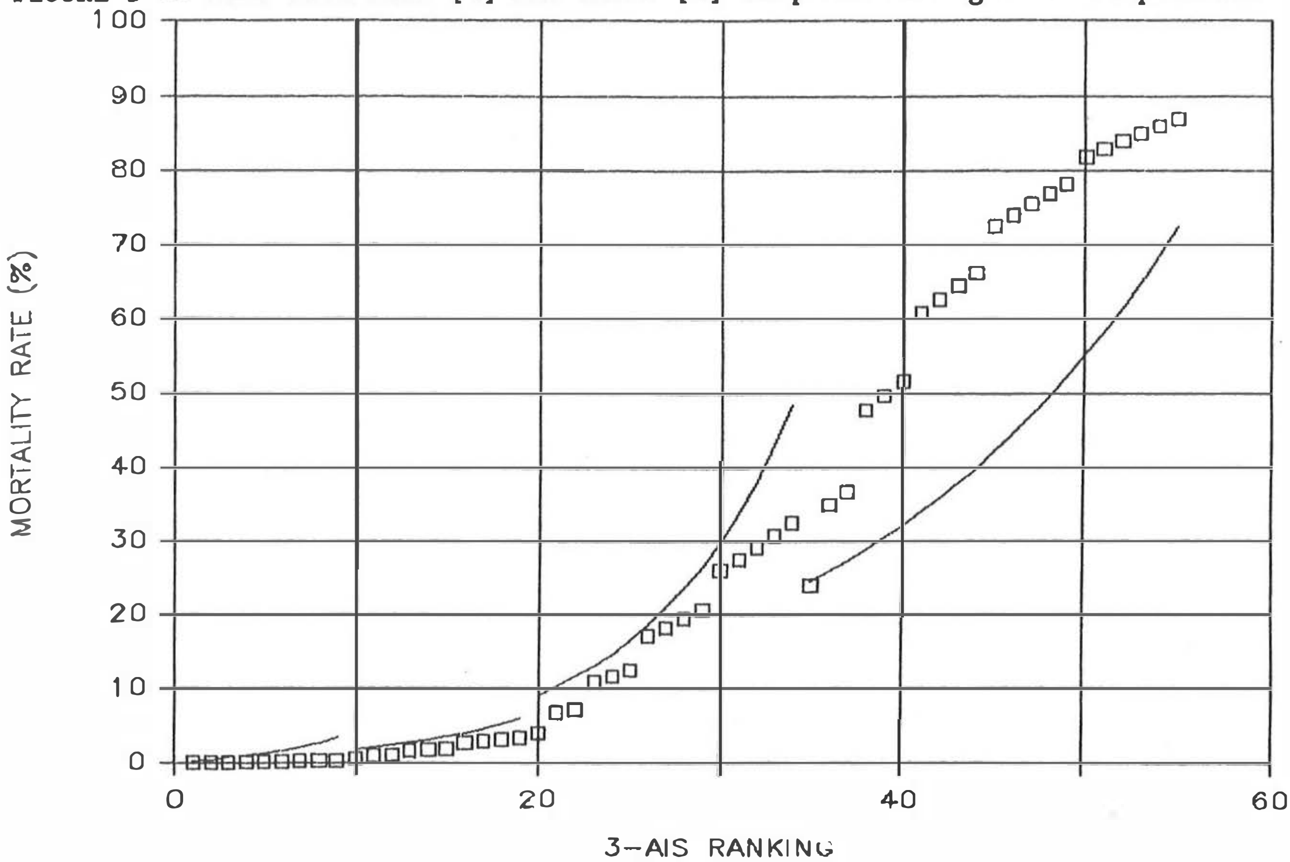

FIGURE 6 -- PODS Compared to Regression Equations

records, and police reports, as well as official medical data [10]. NASS records a death as an accident fatality only when the death occurs within a limited time period after the accident. Baker's study recorded fatalities that occurred months after a crash. These two differences, use of unofficial data in NASS and dissimilar time periods for inclusion of fatalities may explain the differences in data.

The fatality rates calculated with Somers PODS may also be compared to the data of this study. In Figure 6, the regression equations calculated from NASS are compared with the probability of death--calculated from odds of death--determined by the model Somers formulated from the NCSS, National Crash Severity Study. At low injury severities, the PODS predicts NASS mortality rates fairly accurately. In injury combinations in which the most severe injury is an AIS 5, PODS predicts higher mortality rates than are predicted by the regression equations. Somer's curve flattens out with increasing injury severity whereas the regression equations (and the raw data) indicate a steepening of the curve at high injury severity levels (Figure 2).

EVALUATION OF AIS BY BODY REGION

To verify the applicability of mortality rates associated with the 56 1- or 2-digit descriptors to all body regions, more specific injury data were obtained from NASS. These data covered the years 1981 through 1984. Data was divided into 5 categories: chest, head, abdomen, neck, and extremities. "Chest" data included only those cases in which the three most severe injuries were to the chest. Persons with less than three injuries were included if all of the injuries were to the chest. "Neck" and "abdomen" injuries represent similar sets. "Head" injuries are much like the other categories, except that a facial injury might be included if it were the third most severe injury. All injuries to arms, legs, hands, feet, shoulders, and bony pelvis were included in "extremities". It should be noted that this method, which uses cases in which the three most severe injuries are in the same body region, is opposite to calculation of the ISS, which uses injuries in three <u>different</u> body regions.

The numbers of injuries and deaths for each subset of the data are shown in Table 2. It is apparent from Table 2 that categorizing the data by body region and by the 56 3-AIS combinations creates some subdivisions which are so small as to make the information statistically insignificant. In categories containing only one or two cases, a single death makes the difference between 0 and 100 per cent mortality rates. This makes it difficult to evaluate the 3-AIS code mortality rates by body region at this time.

Because data is extremely limited, especially at high injury severity levels, it is necessary to group the data into larger sets. The data may be grouped by the highest severity injury to show trends in mortality rate with increasing AIS. The probabilities of death for each body region by first injury are shown in Table 3. It can be noted that mortality rates for chest injuries are similar to the overall mortality rates (data from Table 1) for injury combinations 1 0 0through 2 2 2. At greater injury severities, chest injuries generally have a higher mortality rate than injuries to any other region of the body. This could be due to the critical need for immediate treatment of the massive hemorrhaging that frequently occurs with chest injuries.

TABLE 2 -- Data From NASS 1981-1984 by Body Region

3-AIS		CHEST			HEAD			ABDOMEN			EXTREMITIES			NECK		
INDEX	RANKING	INJURED	DEAD	%	INJURED	DEAD	%	INJURED	DEAD	%	INJURED	DEAD	%	INJURED	DEAD	%
1	1 0 0	308	0	0.00	1098	0	0.00	57	0	0.00	3018	0	0.00	1450	1	0.07
2	1 1 0	24	0	0.00	114	0	0.00	1	0	0.00	1451	0	0.00	16	0	0.00
3	1 1 1	17	0	0.00	78	1	1.28	0	0	--	1533	0	0.00	0	0	--
4	2 0 0	28	0	0.00	106	3	2.83	0	0	--	216	0	0.00	17	4	23.53
5	2 1 0	5	0	0.00	39	1	2.56	0	0	--	115	0	0.00	0	0	--
6	2 1 1	5	0	0.00	92	1	1.09	0	0	--	278	0	0.00	0	0	--
7	2 2 0	1	0	0.00	4	0	0.00	0	0	--	38	0	0.00	1	0	0.00
8	2 2 1	0	0	--	18	0	0.00	0	0	--	100	1	1.00	0	0	--
9	2 2 2	2	1	50.00	6	1	16.67	0	0	--	82	1	1.22	3	0	0.00
10	3 0 0	4	0	0.00	9	3	33.33	1	0	0.00	44	0	0.00	6	1	16.67
11	3 1 0	2	0	0.00	1	0	0.00	2	0	0.00	28	0	0.00	0	0	--
12	3 1 1	4	0	0.00	21	0	0.00	2	0	0.00	70	0	0.00	0	0	--
13	3 2 0	7	0	0.00	2	0	0.00	0	0	--	18	0	0.00	0	0	--
14	3 2 1	4	0	0.00	11	0	0.00	0	0	--	40	0	0.00	2	1	50.00
15	3 2 2	1	1	100.00	8	1	12.50	0	0	--	81	5	6.17	0	0	--
16	3 3 0	0	0	--	0	0	--	1	0	0.00	13	1	7.69	1	0	0.00
17	3 3 1	0	0	--	2	0	0.00	0	0	--	36	0	0.00	0	0	--
18	3 3 2	2	0	0.00	7	3	42.86	0	0	--	92	6	6.52	0	0	--
19	3 3 3	0	0	--	5	3	--	3	0	0.00	79	1	1.27	0	0	--
20	4 0 0	1	1	100.00	8	3	37.50	6	0	0.00	1	0	0.00	0	0	--
21	4 1 0	0	0	--	3	0	0.00	0	0	--	1	0	0.00	0	0	--
22	4 1 1	0	0	--	3	0	0.00	0	0	--	1	1	100.00	0	0	--
23	4 2 0	1	0	0.00	1	0	0.00	0	0	--	0	0	--	0	0	--
24	4 2 1	0	0	--	6	0	0.00	0	0	--	1	0	0.00	0	0	--
25	4 2 2	0	0	--	2	1	50.00	0	0	--	0	0	--	1	1	100.00
26	4 3 0	0	0	--	0	0	--	1	0	0.00	0	0	--	0	0	--
27	4 3 1	0	0	--	2	0	0.00	0	0	--	0	0	--	0	0	--
28	4 3 2	1	0	0.00	7	2	28.57	0	0	--	0	0	--	0	0	--
29	4 3 3	3	2	66.67	10	7	70.00	7	1	14.29	0	0	--	0	0	--
30	4 4 0	0	0	--	0	0	--	0	0	--	0	0	--	0	0	--
31	4 4 1	0	0	--	1	0	0.00	0	0	--	0	0	--	0	0	--
32	4 4 2	1	0	0.00	1	0	0.00	0	0	--	0	0	--	0	0	--
33	4 4 3	2	1	50.00	10	6	60.00	5	2	40.00	0	0	--	0	0	--
34	4 4 4	2	1	50.00	4	3	75.00	2	1	50.00	0	0	--	0	0	--
35	5 0 0	3	3	100.00	6	1	16.67	0	0	--	--	--	--	1	0	0.00
36	5 1 0	0	0	--	2	0	0.00	0	0	--	--	--	--	0	0	--
37	5 1 1	0	0	--	1	0	0.00	0	0	--	--	--	--	0	0	--
38	5 2 0	0	0	--	0	0	--	0	0	--	--	--	--	2	1	50.00
39	5 2 1	0	0	--	2	0	0.00	0	0	--	--	--	--	0	0	--
40	5 2 2	0	0	--	3	1	33.33	0	0	--	--	--	--	0	0	--
41	5 3 0	0	0	--	0	0	--	0	0	--	--	--	--	0	0	--
42	5 3 1	0	0	--	2	0	0.00	0	0	--	--	--	--	0	0	--
43	5 3 2	0	0	--	4	1	25.00	0	0	--	--	--	--	1	0	0.00
44	5 3 3	1	1	100.00	8	6	75.00	2	0	0.00	--	--	--	0	0	--
45	5 4 0	0	0	--	0	0	--	1	0	0.00	--	--	--	0	0	--
46	5 4 1	2	2	100.00	2	2	100.00	0	0	--	--	--	--	0	0	--
47	5 4 2	0	0	--	3	2	--	0	0	--	--	--	--	0	0	--
48	5 4 3	4	2	50.00	4	3	75.00	5	2	40.00	--	--	--	0	0	--
49	5 4 4	3	3	100.00	1	1	100.00	4	2	50.00	--	--	--	0	0	--
50	5 5 0	1	1	100.00	0	0	--	0	0	--	--	--	--	0	0	--
51	5 5 1	0	0	--	0	0	--	1	0	0.00	--	--	--	0	0	--
52	5 5 2	0	0	--	0	0	--	0	0	--	--	--	--	0	0	--
53	5 5 3	1	1	100.00	2	2	100.00	2	1	50.00	--	--	--	0	0	--
54	5 5 4	0	0	--	0	0	--	3	1	33.33	--	--	--	0	0	--
55	5 5 5	3	3	100.00	0	0	--	2	0	0.00	--	--	--	0	0	--
56	6 - -	--	--	--	--	--	--	--	--	--	--	--	--	-		--
TOTAL		443	23	5.19	1719	58	3.37	108	10	0.09	7336	16	0.22	1501	9	0.60

TABLE 3 -- Mortality Rates by Body Region

Injuries	All (1979-1983)	Chest	Head	Abdomen	Extremities	Neck*
1 0 0 - 1 1 1	0.00	0.00	0.08	0.00	0.00	0.07
2 0 0 - 2 2 2	1.30	2.44	2.26	---	0.24	19.05
3 0 0 - 3 3 3	3.80	8.33	19.70	0.00	2.59	22.22
4 0 0 - 4 4 4	24.90	45.45	37.93	19.05	---	100.00
5 0 0 - 5 5 5	47.80	88.89	47.50	30.00	---	25.00

*Too little data for significant results.

It might be expected that mortality rates for head injuries should be similar to mortality rates for chest injuries, but this is not the case. For injuries 3 0 0 to 3 3 3, the mortality rates for head injuries are higher than the mortality rates for chest injuries and the overall mortality rates. At AIS-5, the mortality rate for chest injuries is twice the mortality rate for head injuries. Head injuries may have lower fatality rates at AIS-5 because deaths that occur long after the accident may not be identified with the injury.

Mortality rates for abdominal injuries were lower than overall fatality rates at each AIS level. Extremity injuries very closely matched the overall fatality rate to a maximum severity of AIS-3. Mortality rates above this level were not compared for extremities because there are very few extremity injuries above the AIS-3 level. Neck injury fatality rates were mostly higher than overall rates, but they fluctuated randomly. This is due to the scarcity of neck injuries of severity AIS-4 and higher.

The data grouped by maximum AIS groups indicates some discrepancies with the application of AIS to different body regions. The discrepancies are more apparent if injury groups 1 0 0 through 2 2 2 are eliminated and the remaining data are grouped by body region and compared. The mortality rate for chest injuries is 41%. For head injuries, the mortality rate is 31%. Abdominal injuries have a 20% mortality rate. The mortality rate for injuries of extremities is lower, about 3%, and neck injuries have a 29% mortality rate. The data of Table 1 indicates a 12% mortality rate for all injury combinations 3 0 0 to 5 5 5. It is obvious that AIS does not relate the same to mortality rate in each body range. The discrepancies are not entirely problems with scale itself, but they may result from the way the scale is applied in NASS. The limited information which is available to accident investigators may lead to inaccurate and incomplete coding of injuries.

DISCUSSION

Age was not considered in this study. Age has been considered in most of the other studies involving the AIS [3,6,10,11,13,14]. In these studies, it is apparent that age of the injured occupants does effect mortality rate. Age is not available, however, for each case in NASS. This would have further reduced the amount of usable data for this study. Inclusion of all cases, regardless of age, produces an averaging effect. Mortality rates are probably representative of a 16-45 age group because this is the group most likely to be injured or killed in automobile accidents.

Current injury evaluation formulae are useful to varying degrees in predicting the probability of death of persons injured in automobile accidents. The ISS is very easy to calculate, but it is very difficult to use as a probability of death scale because it was not designed exclusively for that use. Instead, it was designed as a scale by which morbidity and mortality of different groups of injured persons might be compared. Each ISS value is not associated with a single, specific mortality rate, but each may be related to a different mortality rate for each data set to which the ISS is applied. A general plot of mortality rates obtained in Baker's [3] and Bull's [4] studies was shown in Figure 4. The information available is insufficient to determine whether the points shown indicate direct data points, or whether the points represent average results over a range. Because some points are plotted at ISS values which are impossible to achieve -- 15 for example -- the latter is more likely. Because of a lack of understanding and definition of the plot reconstructed in Figure 4 as it pertains to all combinations of 3-AIS injuries, it was difficult to use.

The PODS is also simple to use, but different coefficients and constant are needed for different data sets. The plot shown in Figure 6 was determined from NCSS data. As discussed previously, the PODS data differs substantially from the data of this study at high severity levels. It is difficult to represent mortality rates of the entire range of 3-AIS injury severities with a single formula. The PODS does not account for the discontinuities observed in NASS data, for example, between 2 2 2 and 3 0 0. Also, as already mentioned, NASS data and Baker and Bull indicate a sharp rise in mortality rate at high injury severities, whereas PODS predicts a leveling off.

The RSC is a new method which may come into greater use in the future. Use of RSC is more complicated than use of either ISS or PODS. Values for the RSC equation must be obtained from a table of ISS and mortality rate and a table of probability of permanent disability associated with various injury severities (AIS) in different regions of the body. The RSC utilizes data from Baker and Bull without justification that the Swedish data agree with the Baltimore and Birmingham studies with regard to mortality rates.

The 3-AIS ranking, as defined in this study, is a look-up method rather than a formula. Table 4 lists the AIS injuries and mortality rates. Calculation of the mortality rates for the 3-AIS rankings requires five formulae rather than just one to better take into account the importance of the most severe injury in the effect of second and third injuries. Though current correlation to raw data is fair, better correlation -- and perhaps new formulae -- will result as more data is obtained. This makes Table 4 very useful for formulae like the RSC.

An overall evaluation of AIS codes with respect to the severity descriptors can best be made by considering injury cases in which there is a single injury. Table 5 lists the AIS codes, the descriptors, and the mortality rates. When only a single injury is considered, the mortality rates are somewhat lower than might be suggested by the code descriptors, but most accident victims are multiply injured. Second and third injuries will have a greater effect on an accident victim with a most severe injury of AIS-5 than they will on a victim with most severe injury of AIS-3. The overall mortality rate for persons with injuries 3 0 0 to 3 3 3 is 3.8%. For persons with injuries 5 0 0 to 5 5 5, the overall mortality rate is 47.8%. This better justifies the assignment of the description "critical" to an AIS-5 injury.

TABLE 4 -- 3-AIS Rankings and Mortality Rates Calculated From Regression Equations

INDEX	3-AIS RANKING	CALC. MORTALITY RATE (%)	INDEX	3-AIS RANKING	CALC. MORTALITY RATE (%)
1	1 0 0	0.1502	29	4 3 3	26.7080
2	1 1 0	0.3481	30	4 4 0	30.0853
3	1 1 1	0.8068	31	4 4 1	33.8896
4	2 0 0	0.9379	32	4 4 2	38.1750
5	2 1 0	1.2140	33	4 4 3	43.0022
6	2 1 1	1.5713	34	4 4 4	48.4399
7	2 2 0	2.0339	35	5 0 0	24.5181
8	2 2 1	2.6327	36	5 1 0	25.8821
9	2 2 2	3.4077	37	5 1 1	27.3220
10	3 0 0	1.8198	38	5 2 0	28.8420
11	3 1 0	2.0789	39	5 2 1	30.4465
12	3 1 1	2.3750	40	5 2 2	32.1403
13	3 2 0	2.7133	41	5 3 0	33.9283
14	3 2 1	3.0997	42	5 3 1	35.8158
15	3 2 2	3.5412	43	5 3 2	37.8083
16	3 3 0	4.0456	44	5 3 3	39.9117
17	3 3 1	4.6218	45	5 4 0	42.1321
18	3 3 2	5.2800	46	5 4 1	44.4759
19	3 3 3	6.0320	47	5 4 2	46.9502
20	4 0 0	9.1459	48	5 4 3	49.5622
21	4 1 0	10.3025	49	5 4 4	52.3194
22	4 1 1	11.6052	50	5 5 0	55.2300
23	4 2 0	13.0727	51	5 5 1	58.0236
24	4 2 1	14.7258	52	5 5 2	61.5461
25	4 2 2	16.5879	53	5 5 3	64.9700
26	4 3 0	18.6855	54	5 5 4	68.5844
27	4 3 1	21.0483	55	5 5 5	72.3999
28	4 3 2	23.7099	56	6 - -	100.0000

TABLE 5 -- Mortality Rates for Single Injuries

AIS Codes	Severity Code Descriptor	Mortality Rate (%)
1 0 0	Minor	0.2
2 0 0	Moderate	0.9
3 0 0	Serious	1.8
4 0 0	Severe	9.1
5 0 0	Critical	24.5
6 0 0	Virtually Unsurvivable	100.0

The AIS was originally based on five criteria to make the scale as useful as possible to all researchers and accident investigators. The five criteria are energy dissipation, threat to life, permanent impairment, treatment period, and incidence. The AIS is most frequently used as a measure of threat-to-life. In general, there is a relationship between the AIS codes and probability of death. As can be observed in Table 5, the mortality rate does rise from cases with an injury of AIS-1 to cases with an injury of AIS-5. The AIS is most useful as a threat-to-life scale. Energy dissipation was intended to aid in recommendations for vehicle safety improvements, but it is difficult to define and measure. Treatment period and likelihood of permanent impairment are somewhat related criteria. They are good measures of injury severity, and should be developed as a separate scale as has been done by Chi Associates [5]. Incidence can be used as a weighting factor in scales to emphasize the overall importance of specific injuries.

CONCLUSIONS

1. The look-up Table 4 proposed for determining mortailty rates for all 3-AIS combinations is simple, accurate, and easy to use.

2. The AIS Number Codes have been defined in Table 5 in terms of mortality rates for single injuries.

3. The AIS code descriptions in Table 5 may not be representative of the mortality rates shown.

4. The AIS codes may represent different mortality rates depending on the body region injured.

5. The data retrieved from NASS for only neck injuries and for only chest injuries show unusual numbers of deaths at low injury severity levels.

6. The AIS should be redefined to represent threat to life only, with a new separate code for disability.

7. Incidence of occurrence should be a separate weighting factor.

8. NASS was found to be a very useful data base for this study and is necessary for future refinements.

ACKNOWLEDGEMENTS

This work was supported by the Vehicle Research and Test Center, National Highway Traffic Safety Administration, U.S. Department of Transportation. The authors acknowledge their appreciation to Mr. Howard Pritz for his technical assistance in this project.

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