Measuring the severity of injury[1]

Professor H B Stoner MD FRCPath **D F Heath** DPhil
D W Yates MChOrth FRCS **K N Frayn** PhD
MRC Trauma Unit, University of Manchester, Manchester M13 9PT

Summary: Attempts have been made to improve the Injury Severity Score (ISS) system of Baker *et al.* (1974) using plasma lactate data obtained from 277 patients shortly after injury and before treatment. The ISS is based on the Abbreviated Injury Scale (AIS) values of the individual injuries, being the sum of the squares of the values for the three most severely injured regions. Log (plasma lactate concentration) is positively related to ISS over its whole range. It was not possible to vary the AIS values, either on clinical grounds or using a computer, in such a way that the variance of the log (plasma lactate concentration) about its regression line with ISS was significantly reduced. With a score based on the sum of the squares of the AIS values for all the patient's injuries, some improvement to the AIS values could be made but it was not statistically significant. At the present time Baker's ISS method would seem to be the best way of grading injuries for acute studies.

Introduction

For serious work on injured patients, be it clinical, epidemiological or biochemical, one must have some way of measuring the severity of their injuries. However, it is difficult even to allocate patients to the three categories – minor, moderate and severe – and any attempt to separate them into those with and those without 'shock' would be quite impractical. During World War II a system was devised which depended on an assessment of the blood loss (> 2 pints, 1140 ml, severe) and of the amount of injured tissue, measured in fistfuls (> 2 severe), together with measurement of blood pressure and pulse rate (Grant 1941, Grant & Reeve 1941, 1951). This system was used successfully on battle casualties (Green *et al.* 1949). However, it is a crude system without a numerical scale, difficult to apply to burns and to injuries of the head, chest and abdomen, and to peace-time civilian injuries since these are mostly closed, making it hard to assess the amount of tissue damage. These drawbacks led us to seek other methods.

The Injury Severity Score (ISS)

We chose the Injury Severity Score (ISS) devised by Baker *et al.* (1974) using the Abbreviated Injury Scale (AIS) booklet (1976). In this method the body is divided into 6 regions: (a) head and neck, (b) face, (c) chest, (d) abdominal and pelvic contents, (e) extremities, shoulder and pelvic girdles, and (f) general (external). The injuries in these regions are graded, in increasing severity, from 1 to 5 according to the AIS code. The ISS is then calculated as the sum of the squares of the highest AIS values in each of the three most severely injured regions of the body. This gives a discontinuous scale of 0–75.

We were favourably impressed by our earlier use of the method (Stoner *et al.* 1977, Yates, 1977). Although the ISS scale is a discontinuous one, this does not prevent it being used for statistical purposes. Bull (1975, 1978) has used it in probit analysis to show the importance of age in determining mortality. Since ISS values are not normally distributed, correlation coefficients cannot be calculated, but regression analysis can be used (Armitage 1971). This has been discussed elsewhere (Stoner *et al.* 1979).

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Application of ISS

The ISS system has been used to interpret biochemical data from 277 patients investigated shortly after injury and before treatment (Stoner *et al.* 1979). The concentrations of some plasma constituents (lactate, glucose) were positively related to severity over the whole ISS range, whereas those of others (cortisol, non-esterified fatty acids, glycerol) were only positively related to severity over part of it. The values of these variables at any one ISS were widely scattered and this led us to try to improve the ISS system, particularly for its use as a measure of severity during the first 24 hours after accident.

Improvement of ISS – first attempt

In our attempts to improve the ISS system we have used plasma lactate data from the 277 patients mentioned earlier and in whom there was a positive relationship between log (plasma lactate concentration) and ISS over the whole range (Stoner *et al.* 1979). Plasma lactate was chosen because it is widely considered to be itself a measure of the severity of injury (Broder & Weil 1964, Peretz *et al.* 1965, Vitek & Cowley 1971).

In our first attempt the principle of the ISS system, i.e. the score being the sum of the three squares, was retained and the AIS values were altered on clinical grounds. From current and previous observations it seemed that injuries to the pelvis and lower limbs, particularly if bilateral, caused greater biological disturbance than injuries to the upper limbs and our proposed changes (Table 1) were intended to reflect this.

Table 1. Possible changes in Abbreviated Injury Scores (AIS) for the calculation of the Injury Severity Score (first attempt)

Injury	Original AIS	New value
Patella, dislocation	3	2
Hip, dislocation with or without fracture	3	4
Knee, dislocation	3	4
Ankle, dislocation with fracture of posterior malleolus	3	4
Femoral fracture, shaft	2●	3●
Femoral fracture, supracondylar	2●	3●
Femoral fracture, both legs	2●	5
Hip, dislocation both	3	5
Pelvis, fracture pubic rami, multiple	3	2
Scapula, fracture	2	2●
Arm-forearm-hand, multiple long bone fracture in same extremity	4	3
Radius, ulna, carpus, metacarpus, fracture	2●	2

● Add 1 for open and/or displaced and/or comminuted

These proposed new AIS values reduced the ISS values for some patients and increased those for others. This gave a better spread of the patients over the ISS scale, but its effect on the distribution of the log (plasma lactate concentration) was purely cosmetic. It did not, as hoped, reduce their variance about the regression line. Subsequent computer studies (see below) indicated that it was unlikely that this variance could be reduced enough to warrant altering the AIS values.

Improvement of ISS – second attempt

In a further attempt to improve the ISS system for pathophysiological and metabolic studies during the first 24 hours, we investigated the possibility that a score based on the sum of the squares of the AIS values for all the patient's injuries would be better. For this we used the log (plasma lactate concentration) in 198 of the 277 patients already referred to who had not been consuming ethanol before the accident. Ten aberrant values in patients with scores near the mean for the groups were eliminated on statistical grounds. The AIS values for the 188 remaining patients were altered as follows: on clinical grounds 1 was added to the score for

bilateral injuries to the extremities; fractures of the tibia and fibula in the same leg scored 0.5 more than fractures of either alone; head, neck and face injuries were combined.

A Monte Carlo search for the 'best' AIS values was then carried out with the following restrictions.

(1) Scores of 1 were not varied since plausible changes would barely affect the variance.

(2) An AIS value was only varied if there were at least 4 cases of the injury among the 188 patients. Besides reducing the number of scores to be varied this also guarded against spurious 'improvements' which might arise if the only patient with a particular injury had a very deviant plasma lactate concentration.

(3) Variations in the scores were in steps of 0.5, to a maximum of ± 1 in Run 1 and ± 0.5 in Run 2; e.g. in Run 1 if the original score was S, only values of $S-1$, $S-0.5$, S, $S+0.5$ and $S+1$ were tested, and similarly in Run 2 only values of $S-0.5$, S and $S+0.5$ were tested. This is equivalent to saying that the original values were not grossly in error.

(4) Random assignment of values on this basis could go against clinical judgment in grading injuries of the same type, e.g. by inverting AIS values of 3 and 4. This was not allowed. It was assumed that the clinical ranking of severity was correct and no two adjacent grades were allowed to become closer than 0.5.

With these restrictions the Monte Carlo search was, in effect, trying to find the best assignment to 26–27 variables of 5 possible values of each in Run 1 and of 3 of each in Run 2. While it is very unlikely that the best possible combination would be found, a Monte Carlo search should be highly effective at discovering whether any significant improvement is possible and can also give some indication of the biggest improvement possible within the restrictions applied.

In each run the program (BASIC; Nova 8400 computer) first calculated the mean variance of log (plasma lactate concentration) from the least mean squares straight line of best fit to the ISS and to the sum of the squares of the AIS of all the injuries using the original AIS values. A random number generator then assigned new values to all the scores and recalculated the variances. This process was repeated 16 400 times. Each reduction in variance was printed out along with the scores that gave it and this set then acted as a new baseline. None of the improvements (Table 2) was statistically significant (F test), but those using the total score system were large enough to suggest that the variance could be reduced significantly, i.e. down to about 190 for $P=0.05$.

Table 2. Variances ($\times 10^4$) of log (plasma lactate concentration (mmol/l)) from line of best fit

	ISS method	'Total injury score' method
Initial estimate	242	238
Best of Run 1	230	203
Best of Run 2	230	207

It is interesting to see how the improvements were achieved. Variance was reduced by increasing scores for fractures and dislocations below the knee and elbow by about 0.5 and by decreasing the scores for the more serious femoral fractures by about the same amount. The regularity of these findings exceeded chance in a χ^2 test: $P<0.001$ for the first and $P<0.005$ for the second. In interpreting these somewhat unexpected proposals it is important to remember that the principle for the total injury scores method is different from that for the ISS. Injuries below the knee and elbow are often a patient's only injuries, whereas a serious fracture of the femur is often part of multiple injuries and, hence, only makes a part contribution to the 'total injury score'. In the ISS method, injuries to the extremities and their girdles, no matter how many, can only make one contribution to the final score so that the weighting has to be different to take account of the probability of multiple injuries.

Most AIS values were unchanged and the only other significant alterations were a decrease of 0.5 for dislocation of the hip and an increase of 0.5 for lacerations of the head, neck and face ($P<0.05$ in both cases). Scores for head injuries in living patients involving the central nervous system were possibly over-expanded, i.e. a score of 2 was rather too low, of 3 about right, and 4 and 5 rather too high. This could be related to the frequent coexistence of other injuries with the more severe head injuries. Difficulties in applying the current AIS definitions for head injury in the ISS method have probably been overcome by the proposed changes to that part of the AIS list (E Petrucelli, personal communication).

Discussion

While it may be possible to develop a method for measuring the severity of injury based on the sum of the squares of the scores for all the injuries, which would be better for metabolic and other studies during the first 24 hours after the accident, at present one cannot improve on the ISS method and existing AIS values. Baker's ISS method has the advantage of being widely employed and, since one has only to decide the three most severely-injured regions and the most severe injuries in them, it is much easier to use than any method which depends on the cataloguing of all the injuries.

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