Defining Brain Damage after Head Injury

BRYAN JENNETT, MD, FRCS

Professor of Neurosurgery,
Institute of Neurological Sciences and University of Glasgow

Whether or not the victim of a head injury lives or dies, and whether a survivor recovers or remains permanently disabled, depends in many cases on good decision-making by doctors in the early stages. These decisions derive mostly from the clinician's assessment of the likely outcome—the probability of recovery or of complications. Factors affecting outcome include the starting odds of the patient before injury; his age and psychosocial status, for example. But the most important determinant is the degree of brain damage, both that sustained at impact and that due to secondary events that occur in the first 24 hours or so after injury. The dilemma that confronts the doctor soon after injury is to decide which patients require skilled management, either because, although relatively mildly injured, they are at risk of developing early complications, or because, although they are severely injured, they have potential for recovery. Implicit in this is the recognition that there are injuries so mild that recovery will occur regardless of how little is done, and others so severe that, no matter how much is done, the victims will die or be badly disabled.

This is an example of triage for treatment, a term which became common usage among the American forces in Korea and Vietnam; under pressure of large numbers of casualties only those likely to benefit from treatment were dealt with. Many large British hospitals admit 1,000 head injuries a year, while throughout the country a million patients come to Accident and Emergency Departments after recent head injury (Jennett *et al.*, 1977). It is therefore realistic to consider the logistics of dealing with this prevalent condition in military terms. Moreover, there is good evidence that informal decision-making in this field has unsatisfactory consequences: the unnecessary admission to hospital of thousands of mildly injured patients, and the prolonged application of intensive therapy to patients who either die or remain hopelessly crippled. We have also calculated that in 50 per cent of deaths in hospitals after head injury there are avoidable factors in management contributing to the fatal outcome (Rose *et al.*, 1977; Jennett and Carlin, 1978)—better decision-making might prevent some of these deaths.

For more than 10 years we have been studying in Glasgow the problem of predicting outcome after severe head injury. One purpose was to provide reliable predictions soon enough after injury to form a basis for management decisions about individual patients. But it was also hoped that such predictions could be used to evaluate alternative methods of treatment for patients in coma; some regimens are elaborate and expensive, yet their efficacy has not been critically assessed. The latter require comparisons to be made between series of patients with equally 'severe' injuries; that is, patients predicted to have a similar outcome if similarly treated. When outcome is claimed to have been better in one series of patients there are, of course, several explanations other than improved treatment: the initial severity was over-estimated; the degree of ultimate disability was under-estimated; hidden variables have influenced outcome; there was a statistical error in the comparison, which is therefore invalid. However, failure to match the severity of brain damage sufficiently rigorously in different series seems to be the most common reason for misleading claims for the efficacy of particular therapeutic regimens.

Brain damage of the diffuse type that results from most head trauma in civilian life is characterised clinically by reduced responsiveness, amounting to coma when sufficiently severe. The challenge was to make the description of coma both computer compatible and clinically practical. Responsiveness has three components—arousal, activity and awareness. While these are dimly discernible in previous, traditional ways of recording information about patients in coma, the data were customarily in analogue form, usually as the illegible handwriting of nurses and doctors. We have converted this to a digital three-part scale that defines the level of responsiveness in three modalities—eye opening, motor response, and verbal response (Teasdale and Jennett, 1974). Formal observer-error tests were carried out to determine which terms were least ambiguous, particularly when used by non-neurological, and also by non-English-speaking, medical and nursing staff (Teasdale *et al.*, 1978). The resultant system can be displayed as a bedside chart (Fig. 1) and it has proved its worth by its remarkably rapid adoption in many countries and in many translations. It is even used in some American states by paramedical technicians and ambulance personnel at the scene of the accident.

Each level of response has been assigned an ordinal

INSTITUTE OF NEUROLOGICAL SCIENCES, GLASGOW
OBSERVATION CHART

NAME

RECORD No.

DATE — 26 OCT, 27 OCT, 28 OCT, 29 OCT, 30 OCT

TIME

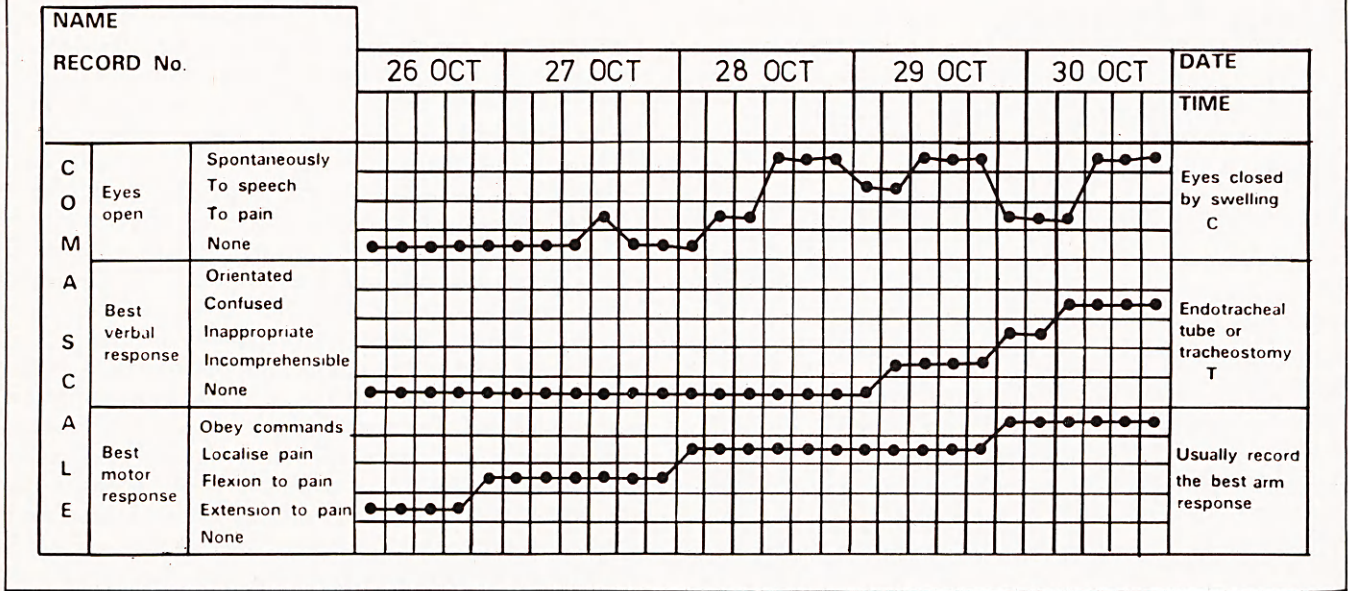| COMA SCALE			
Eyes open	Spontaneously		Eyes closed by swelling — C
	To speech		
	To pain		
	None		
Best verbal response	Orientated		Endotracheal tube or tracheostomy — T
	Confused		
	Inappropriate		
	Incomprehensible		
	None		
Best motor response	Obey commands		Usually record the best arm response
	Localise pain		
	Flexion to pain		
	Extension to pain		
	None		

Fig. 1. *Coma chart for bedside recording. Only five motor responses are included in this simplified scale; abnormal flexion (see Table 1) is recorded as 'flexion'.*

number, high for normal and low for abnormal, which allows responsiveness to be expressed in numbers (Table 1). Thus, $E/M/V = 1/5/2$, means no eye opening, localising painful stimulus, uttering sounds but no words.

Table 1. Glasgow Coma Scale.

Eyes open		Motor response		Verbal response	
Spontaneous	4	Obeys commands	6	Orientated	5
To speech	3	Localises	5	Confused	4
To pain	2	Flexor withdrawal	4	Inappropriate words	3
Never	1	Abnormal flexion	3	Sounds only	2
		Extends	2	Nil	1
		Nil (flaccid)	1		
Score or sum =		$E + M + V = 3\text{-}15$			

This is in fact the highest level of responsiveness that we accepted for our definition of 'coma'. It is also possible to add these numbers to give a score or sum; by our definition all patients scoring 7 or less are in coma, and those with 9 or more are out of coma; about half of those with a score of 8 in the acute stage after injury prove to be in coma by this definition. The coma score shows a continuous relationship with outcome (Fig. 2), but for practical and statistical purposes it is useful to group together patients in different bands of this score. However, this involves a sacrifice of predictive power; indeed, even quoting a score, rather than its composition

in terms of its E, M and V components, involves some loss of information (Fig. 3).

Other aspects of coma have also been expressed as a series of hierarchial scales: of eye movements (spontaneous and reflex), pupil reactions, and the motor response pattern in all four limbs. Severity factors (or predictive criteria) have so far been limited to clinical data, and are independent of special investigations usually available only to patients in special centres. We have also identified certain factors which were previously believed, on intuitive grounds, to have an important influence on outcome but which prove to have little effect. In this way we have reduced the number of items needed to define severity (that is to make a prediction) to manageable proportions. Even so, with 4-6 levels of response possible for each of ten indicants, and each of these assessed during 1, 2 or 3 epochs within the first week (according to duration of survival) the number of possible combinations is still formidably large.

Our system has been adopted informally over recent years by other centres (particularly in the USA), and there are now reported series of cases, comparing outcome with the first 1,000 patients in our collaborative study (Jennett *et al.*, 1979). Scrutiny of these reports indicates that if severity comparisons are to be valid it is important to standardise the time at which assessment is made. The clinical status of patients changes within each epoch during the first week, and particularly within the first 24 hours; to deal with this our system records both the best and the worst states during each period. If a given level of responsiveness was the worst state in a given period, then a better outcome would be predicted than if
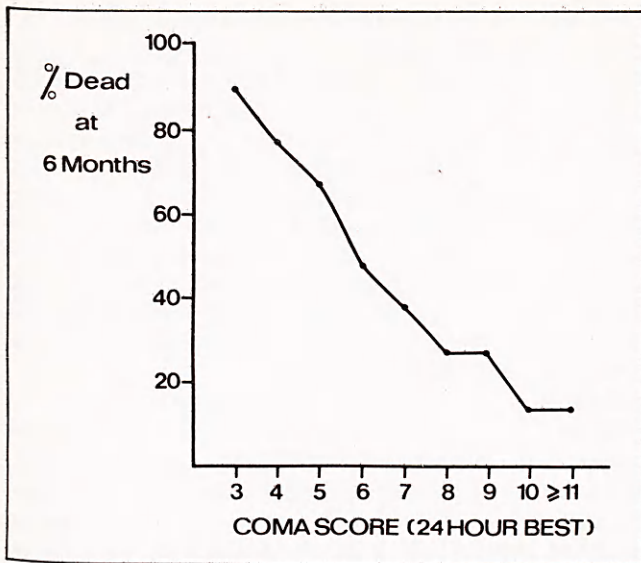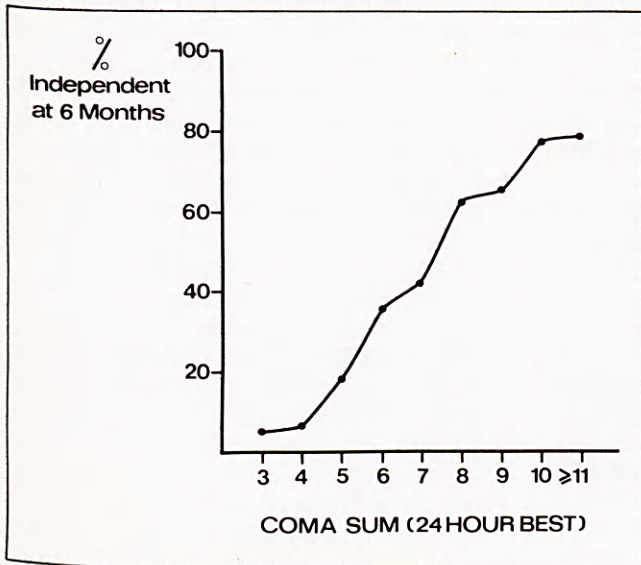
Fig. 2. *Outcome at 6 months for patients with different coma scores (as 24 hours best state).*

Fig. 3. *Information yield (Z) of coma data, as separate components (E, M & V), or as a score (sum of* E + M + V*). There is more predictive information as time passes (in the first week); at all times* E, M *and* V *yields more than the score. Expressing the score in 4, 3 or 2 bands still further reduces the information yield (Teasdale et al., 1979). Z (Outcome/Data) = H[(Outcome)−H (Outcome/Data)]−H (Outcome).*

that same degree of dysfunction represented the patient's best state (Table 2). All the results that we have published have been related to the 'best' state within various periods (usually during the first 24 hours). Moreover, we have reported that several severity signs are much more frequently found when account is taken of the worst rather than the best state in this period (Table 3). Most series published by others for comparison with the collaborative study have been based on the patient's state 'on admission', which in most cases is worse than the '24 hour best'.

Using data of this kind to assess alternative treatment regimens can be done in three ways. One is to review the outcome of similarly severe injuries which happen to have been differently treated. For example, during the data collection of the first 1,000 cases to our data bank no attempt was made to standardise treatment; in the event
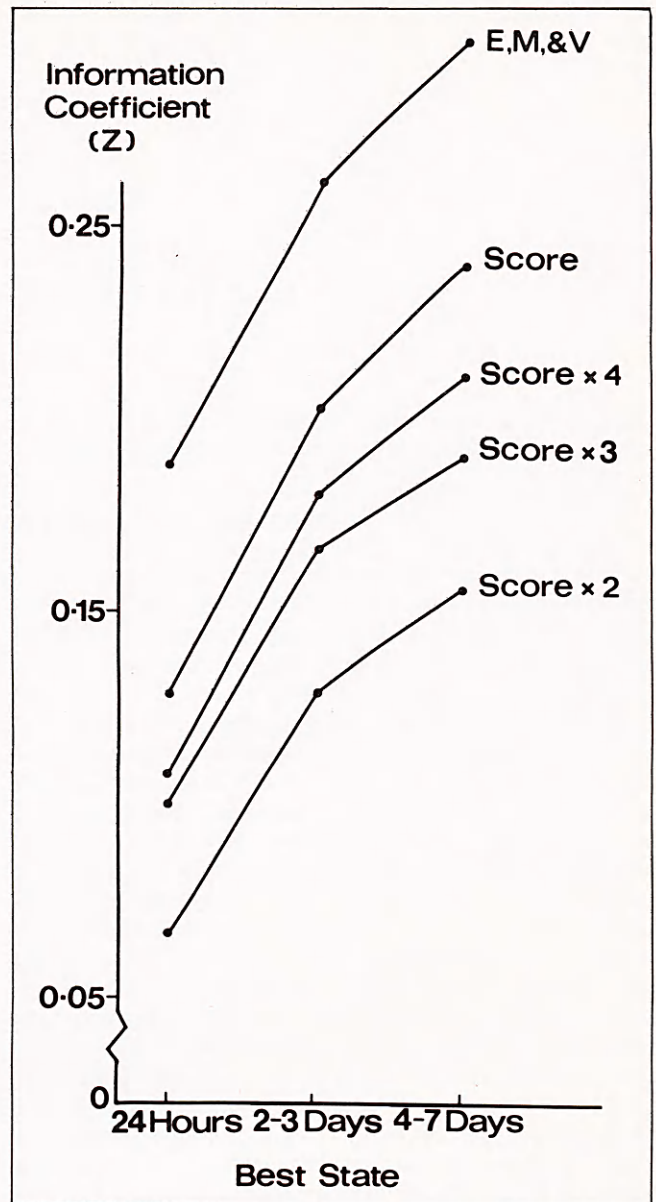
this varied considerably between the centres (e.g. tracheostomy, mechanical ventilation and corticosteroid administration were each used more frequently in one or other centre than in the other two). The initial severity of the series was similar in each centre and so was the mortality at six months (Jennett *et al.*, 1979). Even when statistical manipulations were carried out in order to take account of the more frequent use of certain treatments in more severely affected patients, we could still detect no

Table 2. Comparison of prognostic implications of a given level of responsiveness if it is 'best' or 'worst' state during 2-3 day epoch.

Coma Score (sum)	% dead or vegetative at 6 months	
	Best state in 2-3 day epoch	Worst state in 2-3 day epoch
3/4	97%	75%
5	79%	48%
6	61%	30%
7	41%	21%
8	28%	5%

Table 3. Signs of severe brain dysfunction in first 24 hours — difference in frequency of occurrence when based on 'best' or 'worst' state.

Severity sign	Frequency as best state	Frequency as worst state
Coma sum 3/4	19%	49%
Non-reacting pupils	23%	44%
Absent/impaired eye movements	23%	34%
Abnormal motor response pattern	41%	62%

benefit from the use of a number of methods currently advocated. That is not to deny that there may be some specific sub-sets of the population of head injuries which might benefit from one or other of these methods; nor is it to preach a doctrine of therapeutic nihilism—indeed, the recovery to independence of 80 per cent of the survivors of these severe injuries is testimony to the effectiveness of their general management.

Another approach would be formal controlled trials, with randomisation, making use of the knowledge gained about severity factors to balance the different groups of patients. However, there is now an ethical tide turning against randomised studies of conditions associated with a high mortality rate (*Lancet,* 1979). The need for rapid decisions soon after head injury would make it almost impossible to comply with requirements for informed consent, which with comatose patients would have to come from relatives who would seldom be immediately available.

There is therefore renewed interest in the use of historical controls, provided that sequential series of patients are assessed in a sufficiently standardised way to make comparisons valid; 'bias can then be observed and estimated rather than submerged by randomisation' (*British Medical Journal,* 1979). For severe head injuries

the data bank provides the kind of well-standardised data required for this approach. The predictive system that we have evolved makes it possible to make the historical control a more critical basis of comparison (Jennett *et al.,* 1975; Jennett *et al.,* 1976). To evaluate a new therapeutic regimen, the outcome in patients who receive it would be compared with the outcome predicted for those individual patients on the basis of cases in the data bank who had been treated with the conventional therapy previously available. Evidence of efficacy would depend on a statistically significant proportion of patients achieving a more favourable outcome with the new treatment than had been predicted.

As well as providing a tool for assessing the efficacy of treatment, predictions of outcome can form the basis for several management decisions about individual patients. If a severely injured patient is predicted to have potential for recovering independence, it is important to institute intensive therapy. If a less badly affected patient is predicted to have a risk of developing complications (e.g. intracranial haematoma or traumatic epilepsy), observation or prophylaxis is appropriate. After the acute stage has passed the predictions need to be updated, according to the degree of recovery so far; if this revised prognosis indicates little chance of a reasonable recovery it is right to consider the scaling down of intensive therapy or, in the later stages, the withdrawal of active rehabilitation. Decisions of this kind are never easy, but clinicians might make them more confidently if they had access to estimates of the probability of various degrees of recovery.

This article is based on a paper read at the Conference on Clinical Decision-Making: Picking the Best Test, held at the Royal College of Physicians in June 1979.

References

British Medical Journal (1979) **1,** 288.

Jennett, B. and Carlin, J. (1978) *Injury,* **10,** 31.

Jennett, B., Murray, A., McMillan, R., Macfarlane, J., Bentley, Cecily and Hawthorne, V. (1977) *Lancet,* **2,** 696.

Jennett, B., Teasdale, G., Braakman, R., Minderhoud, J. and Knill-Jones, R. (1976) *Lancet,* **1,** 1031.

Jennett, B., Teasdale, G. M. and Knill-Jones, R. P. (1975) *Journal of the Royal College of Physicians of London,* **9,** 231.

Jennett, B., Teasdale, G., Braakman, R., Minderhoud, J., Heiden, J. and Kurze, T. (1979) *Neurosurgery,* **4,** 283.

Lancet (1979) **1,** 534.

Rose, J., Valtonen, S. and Jennett, B. (1977) *British Medical Journal,* **2,** 615.

Teasdale, G. and Jennett, B. (1974) *Lancet,* **2,** 81.

Teasdale, G., Murray, G., Parker, L. and Jennett, B. (1979) *Acta Neurochirurgica,* **1,** Suppl. 28, 13.

Teasdale, G., Knill-Jones, R. and Van der Sande, J. (1978) *Journal of Neurology, Neurosurgery & Psychiatry,* **41,** 603.