Brain Failure and Resuscitation

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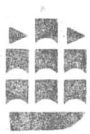

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Preface

Following the introduction of intensive care units (ICUs) and the breakthrough of cardiopulmonary resuscitation in recent decades, the 1970s demonstrated an escalating scientific interest in resuscitation of the failing and arrested brain. We may now observe an increasing number of specialty ICUs in major hospitals and notice the growing importance of high-level general ICUs for the management of multiple organ failure patients who necessitate the joint efforts of many medical and surgical specialists, frequently coordinated by a critical care physician serving as a medical director of the unit. The most important goal for the management of these critically ill patients is survival with intact human mentation.

Modern medical technology has made it possible for crippled individuals to return to a functional life with the help of artificial organs, used intermittently or continuously, or through organ transplantation. However, the brain cannot be replaced artificially. Furthermore, society now agrees with medical science that the individual is dead when the entire brain permanently ceases to function. Thus, it is important to avoid the development of irreversible brain damage, not only to reduce mortality, but also to increase the quality of survival from critical illness.

The purpose of this volume is to provide the practitioner of critical care medicine with relevant, up-to-date information on brain-oriented resuscitation and life support. The variable backgrounds of this book's authors reflect the need for multidisciplinary teams in research, teaching, and care delivery programs concerned with multiple organ failure, which includes brain failure.

The first chapter is authored by Jennett, who skillfully draws on his vast experience with head injuries. He explains the important difference in the quality of survival after a medical or surgical insult to the brain compared to insult to other organs in the body, since the patient with a significant deficit in brain function is usually unable to compensate for such loss by artificial means.

The unique properties of brain metabolism and the many problems related to energy and transmission failure of the brain are succinctly described by Rehncrona and Siesjö in a variety of conditions commonly seen in the critically ill. Garcia and Conger demonstrate the pattern of structural and biochemical changes, pointing out the difference in the final outcome after ischemic brain injury, depending on the length of time of the ischemic period, as well as the patient's condition prior to and immediately following the ischemic episode and whether the attack was focal or global.

Caronna reports on the clinical findings of the comatose patient with emphasis on neuro-ophthalmologic examination following a succinct description of the differen-

tial diagnostic problems of coma. Greenberg and associates present the different forms, indications, and clinical values of monitoring intracranial pressure and neuroelectrical activity, with emphasis on evoked potentials. This report is followed by Zimmerman's chapter on radiology of the brain, which includes an illustrative series of cerebral angiograms and computerized tomography scans illuminating these radiologic findings.

Todd and colleagues offer a futuristic discussion of techniques for and current results of cerebral blood flow (CBF) measurements in different disease states involving the brain. The equipment for determination of CBF is becoming smaller and less cumbersome, indicating clinical availability in the near future. CBF measurements will also make it possible to study metabolism of the brain. The authors offer several examples where such measurements could be used to determine optimal treatment in cases of severe brain failure.

The chapter on resuscitation after ischemic brain insults by Safar is a report of laboratory and clinical research results over the past decade. It presents a description of present trends and future possibilities in maximally restoring threatened brain function, particularly after cardiac arrest, i.e. extending the period of reversible clinical death.

Teasdale and Galbraith provide information on the frequencies of head trauma and intracranial hemorrhage. They outline the practical management of these two conditions, providing indications for surgical intervention and detailed data on short- and long-term outcomes. Newfield and Cottrell consider pharmacologic aspects on brain failure and discuss the pros and cons of drugs used perioperatively, e.g. the effect of vasodilators on intracranial pressure, and other concerns of drugs used prior to, during, and after neurosurgical procedures. In addition, specific and important intraoperative problems in neuroanesthesiology, such as air embolization, are considered in this chapter.

Finally, the chapter by Powner and colleagues deals with the many moral, ethical, religious, legal, and medical issues involved in certifying brain death based on irreversible cessation of all brain function and discusses the withdrawal of treatment when the outcome is hopeless and when continued therapy will only prolong suffering for the patient and/or the relatives. These considerations enable us to accompany brain resuscitation advances with critical care triage, a necessity in a world of finite resources where society claims to be compassionate and reasonable.

If this book leaves the reader with the impression that the brain has emerged from its "black box" status and has become the target organ of critical care medicine, the authors and editors have attained their goal. Little does it matter what the condition of the other vital organs are, if at the same time the brain is in a severe permanent state of failure, i.e. consciousness with severe neurologic dysfunction and suffering or unresponsiveness with persistent vegetative state—the extreme of which is brain death. Therefore, the protection and salvage of cerebral neuronal function must always be the top priorities in the care of critically ill or injured patients.

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Scope and Magnitude of the Problem

Bryan Jennett

INTRODUCTION

Technology now makes it possible for doctors to rescue many patients from acute, life-threatening situations that arise when one or more organs fail. The failure may be the result of congenital malformation, progressive disease, or a single episode of organ damage. While it may seem profitless to argue whether one organ is more "important" than another, because full health and normal life clearly requires that all systems be functioning fully, physicians and philosophers agree that the brain is in a class of its own. Its peculiarities present those concerned in critical care with both biological problems and ethical dilemmas that are, at best, difficult and, at worst, insoluble.

These problems apply when decisions are being made in the acute stage, and again when the immediate threat has been averted but continued intensive care is being considered. Moreover, the brain's dependence on other organ systems means that even when the original crisis affected another system (e.g. cardiac, respiratory, or hepatic), the main issue may rapidly become one of brain failure or damage. To this extent, it may be said that the primary object of all critical care is to preserve and restore brain function. The problem of brain damage, therefore, looms much larger in intensive care than would be anticipated from the prevalence of primarily neurological conditions that demand critical care. It follows from this that, at least in the acute stage, the management of brain failure must often be in the hands of those whose knowledge and skills are not in the fields of medical or surgical neurology.

It is difficult to ascertain the incidence of brain failure—partly because there is no clear definition of this, and partly because policies and practices vary so much between different areas of a country, let alone between nations that have contrasting systems of medical care. For head injury, however, reliable data are beginning to emerge, indicating that in Britain about 10 cases of head injury producing coma for several hours occur per million population per year.[13] By extrapolation from data for certain areas of the United States, it seems likely that the rate there is at least twice as great.

Figures for nontraumatic coma are much more difficult to calculate, for the condition is heterogeneous both in its cause and in its distribution through different parts of the hospital system. In the English general hospital (Royal Victoria Infirmary, Newcastle-upon-Tyne), which took part in an Anglo-American study of nontraumatic coma, about half the cases dealt within a year were due to drug overdose; almost half the remaining cases were due to stroke, and half as many again were the result of cardiac arrest "successfully" resuscitated.[4] Of all cases of stroke admitted to that hospital, about one-fourth were in coma. However, 75 percent of the stroke

victims taken into British hospitals are over the age of 65 years, and it could be that some of these would not go to large teaching hospitals such as this one; on the other hand terminal brain failure in the elderly is perhaps beyond the scope of this book. A hospital with an aggressive program for cardiac arrest rescue, or one with an active open heart surgery unit, might have a different mix of cases.

PECULIARITIES OF BRAIN FAILURE

The time scale for the infliction of damage to the brain is much shorter than for most other organs. The brain's vulnerability to oxygen deprivation is such that irreversible structural damage is inflicted on the cerebral cortex in a matter of minutes. Such oxygen lack, whether due to a lack of supply or a mismatch between supply and demand, is the final common factor leading to serious brain damage after many insults, other than those that are primarily ischemic or hypoxic. This derives from another peculiarity of the brain: its enclosure within an unyielding body compartment. The cerebral circulation is therefore vulnerable, not only to the physiological fluxes that influence blood flow in all tissues, but is also liable to be reduced, either locally or generally, by raised intracranial pressure. Moreover vasodilatation, the normal protective response to hypoxia or hypercapnia, may induce a further rise in intracranial pressure if compensatory mechanisms are already exhausted; the net effect may then be to aggravate the oxygen lack to the brain.[16]

The time scale of these secondary intracranial events can also be very rapid, and it may, therefore, be difficult for the clinician—faced with a patient in coma within half an hour or so of a sudden brain insult (whether traumatic or ischemic)—to determine how much of the damage is primary and, therefore, probably irreversible and how much is due to secondary processes that may still be influenced favorably. Yet another feature that adds to the complexities of assessing the acutely brain damaged patient is the susceptibility of brain function to systemic influences, such as hypotension and hypoxia, as well as to alcohol and other drugs. Even when these are not serious enough to cause structural damage, they may combine to depress the activity of the brain temporarily; this is more likely to occur if a degree of structural damage has already been inflicted by a recent traumatic or ischemic insult.

Yet another problem is epilepsy, which may be precipitated by the initial brain insult and may immediately aggravate the brain dysfunction. This may be a temporary affair, but nonetheless confusing in that the patient is seemingly much worse for a time. But of more importance is that the convulsion (or particularly a succession of these) may initiate a change in intracranial dynamics, and precipitate a sequence of rising intracranial pressure on the basis of vascular engorgement. These various factors make it particularly difficult, soon after an episode of brain damage, to determine how serious the insult suffered has been, and, therefore, to know just what the likelihood is of recovery, with or without various kinds of intervention.

Once the acute stage is over and the patient has survived, the brain damaged patient is again often different. The previously healthy patient who suffers a head injury or cardiac arrest is not subject to progressive disease or further episodes, such as threaten many patients with cardiorespiratory, hepatic, or renal failure.

The victim of stroke on the other hand may well have another stroke or develop myocardial infarction. One consequence of this is that patients who are left disabled after a single episode of brain damage may remain handicapped for many years.

After an episode of organ failure it is much less easy to assess the reserve of residual function in the brain than it is to determine the biochemical or physical capabilities of other organs by appropriate laboratory tests. Partly this is because of the relatively slow pace at which neurological and mental function are restored after severe brain damage. But, it is also made difficult by the importance of mental handicap in contributing to the total disability due to brain damage. Those who tell tales of the heroism of patients left with crippling physical disability, whether from quadriplegia, arthritis, or cardiorespiratory incapability, are relating examples of the resilience of the human spirit. Some such patients reveal unexpected reserves of courage, resolution, and ingenuity in response to their disabilities, as a result of which they are able to cope—in collaboration with their families and the professionals caring for them. When the brain is damaged, it is different. The patient's intellectual capacity, his emotional integrity, and the very fabric of his personality are all too often so eroded by the brain damage that he is quite unable to deal even with situations previously well within his grasp, let alone devise solutions for, and adapt to, circumstances never before encountered—often much more difficult and taxing than any he formerly had to face. He may reject the efforts of his advisers and his family to help him, while even his closest relatives may reject him on account of his new, unrecognizable and irrevocably changed personality.[3,17]

There is another aspect of the critical care of the acutely brain damaged that can make it difficult always to make wise decisions. The patient himself is, by definition, in coma; and because such events are usually sudden and unheralded, it is often impossible to make contact with relatives for some time. Consent for treatment cannot, therefore, be formally obtained, and, in particular, it is often impossible to secure the kind of informed consent required for randomizing treatment in the context of a controlled trial. Added to this may be the discovery of a living will in which the patient has declared a wish not to be subjected to extreme life-supporting measures in certain circumstances. While most persons expressing such sentiments and wishes have in mind the discomfort and indignity of extraordinary efforts made in the last weeks of terminal illness, it is clear that some of them are concerned about being left with crippling mental and physical disability after brain damage—disability that may let them live for many years. All of these factors makes it unusually difficult for the physician in the critical care unit to deal with acute brain failure, either in the patient's best interests in the long term, or in the pursuit of knowledge about the effect of different therapeutic regimens.

TYPE OF BRAIN FAILURE

While the brain, in common with other organs, has only a limited repertoire of responses to insults that depress its function, the significance of the resulting clinical state of "brain failure" varies greatly in different circumstances. The two dominant variables are the kind of damage inflicted on the brain, and the kind of brain that has suffered damage. The brain may initially suffer local or diffuse

damage, but if the focal damage is sufficiently severe, it may lead to secondary intracranial processes (e.g. raised pressure) that result in diffuse brain damage. Dysfunction that is initially functional (e.g. hypoxia) may, if it is serious and prolonged, lead to structural damage, and what was a retrievable situation becomes irreversible. It is the supposed frequency, rapidity, and intensity of these secondary processes that has led clinicians, faced with a patient whose brain is failing, to intervene without delay, with measures designed to forestall, to limit, or to reverse the harmful effects of these dynamic developments. The difficulty that confronts them is to recognize reliably which of the less severely affected patients are really at risk from such developments, and to balance this risk with the possible hazards of aggressive therapy.

The quantum of damage that a brain has suffered is difficult to determine, especially in the first few hours or days. Laboratory measures of functional brain damage (CT scan, evoked responses, biochemical markers) are of very limited value. For the most part, it is possible only to assess the degree of dysfunction, as reflected in the altered consciousness, in the pupils and eye movements (spontaneous and the oculocephalic and oculovestibular reflexes), and in the response pattern of movement in the limbs.[2,5,8,15]

More readily recognized is the kind of brain that has been damaged, because this depends on factors operating before the damaging episode. The most obvious is the patient's age. Young children tend to respond to acute brain insults by reverting more readily to primitive activity in the nervous system (e.g. decerebrate rigidity). This is often short-lived, but it can result in an overestimate of the severity of he degree of brain damage, if assessment is made too soon. Even when there has undoubtedly been serious structural brain damage, as evidenced by coma persisting for several days, the young brain seems better able to recover functionally. It is not known whether this power of recovery is based on residual developmental plasticity in certain parts of the brain, enabling undamaged areas to take over the function of those no longer working; or whether damaged brain can itself actually recover function more readily in the young; or whether recovery is a reflection only of the capacity of the young brain to learn (or to relearn). On the other hand, the young brain may react more unfavorably in a structural sense to certain insults. For example, neuropathologists commonly find diffuse edema of the brain, without a major focal lesion (cortical contusions or intracranial hematoma), after brain injury only in those patients under the age of 16 years. In younger adults, local swelling around such lesions is a frequent development, but CT scanning has shown that edema is a much less prominent feature after trauma than with tumor or abscess, or even after a hypoxic incident.

The brain of older patients (over 50 or 60 years) is probably somewhat less at risk from raised intracranial pressure, not only because edema develops less often, but because the natural ageing process has left a somewhat smaller brain with larger subarachnoid spaces. These benefits are, however, usually much less important than the reduced reserve of the older brain, which may suffer not only from the normal effects of aging but may have structural damage due to small infarcts secondary to vascular disease, even when there is no history of stroke. If there is hypertension, diabetes, or chronic alcoholism, then some degree of brain damage should be assumed; such patients will also be liable to suffer recurrent brain

damage in the future, even if the present episode is survived and recovered from. They are also liable to failure of other organs in the future. These factors combine with older age to make the outlook much less good than for victims of head injury, who are usually young and otherwise healthy.

Not only the kind of brain damaged, but the kind or person it belongs to, may have a significant influence on how satisfactorily the patient can be rehabilitated in the social sense. The young person with attentive parents may fare better than the older patient without close relatives; on the other hand, the frustrations and difficulties of adolescence may complicate the recovery process. Many victims of head trauma are found to have been psychosocially maladjusted prior to injury—indeed, this may have contributed to their accident—which may make it more difficult for them to cope socially with an incomplete physical recovery associated with attendant organic mental handicap.

Enough has perhaps now been said about the complexity of brain damage and its immediate and long-term effects to deter physicians from making facile judgements about the outcome of such episodes. Large numbers of such patients, with reliable data painstakingly analyzed, are required before it is possible to construct a body of knowledge that can be used as a secure base for future decision-making about newly presenting patients, or for judging the efficacy of newly evolved regimens of management.

MEASURING SUCCESS IN THE TREATMENT OF BRAIN FAILURE

Because the process of organic recovery and social adaptation after an episode of serious brain damage takes so long, it is particularly difficult for those who work in critical care to know what the ultimate outcome has been of their exceptional efforts in the acute stage. If valid data are to be collected and reliable comparisons made between different series, a standardized method for assessing outcome, and an agreed-upon interval after injury when this assessment should be made, are required.

The state of patients, months or years after head injury or stroke, has been classified in a variety of ways, and using terms that had no agreed definition. Some of these, such as "practical," "useful," and "worthwhile" recovery, prove on closer examination to be euphemisms for persisting serious disability. Other scales, particularly those devised by geriatricians for elderly victims of stroke, are mainly concerned with analyzing the degree of independence regained in relation to various activities of daily living (ADL), such as feeding, toileting, and dressing. These may be less appropriate for the victim of head injury, whose average age is less than 30 years and for whom the crucial question is whether he is socially independent as a whole—able to get through all day and every day without the practical assistance of another person. Other features of the quality of life, significant for the young disabled person, are his ability to organize his day-to-day life, mobility by public transport, the possibility of social relationships with his peers (rather than only with his parents or other protectors), and of leisure activities of his choice. Moreover, he is concerned not only with the short-term goals of present satisfaction but with future prospects.

To encompass these social effects of the combination of mental and physical

disability within a simple categorization, the Glasgow Outcome Scale was devised,[11,17] primarily for formal studies on patients who survived episodes of coma due to head injury or nontraumatic conditions (mostly stroke). The *vegetative state* has been described by Jennett and Plum,[14] and is regarded as an end-state of survival rather than a stage on the way to more satisfactory recovery. *Severe disability* applies to the person who, because of either physical or mental handicap (often a combination of both), needs the help of someone else every day. *Moderate disability* describes patients who are independent but disabled. *Good recovery* requires that all normal activities can be undertaken, although minor deficits may persist. This scale deliberately eschews reference to the occupational status, as this can be misleading: patients who are well recovered may, for a variety of reasons, not return to work (or indeed not have a formal job), while some patients back at work prove to have very protected employment (or considerate employers) that conceals the true degree of their disability. Experience of many different workers has indicated that the degree of disability is also readily underestimated, if too much emphasis is placed on physical recovery and enquiries do not extend to questioning relatives about changes in the personality and the intellectual capabilities of patients.

Although patients may take long periods to gain the maximum degree of recovery after severe brain damage, systematic study of large numbers of patients has made it clear that the capacity for recovery becomes clear within the first few months. Indeed, on the simple scale described above, almost two-thirds of those who eventually make a good recovery, or are only moderately disabled, have reached this degree of recovery within 3 months after the episode of brain damage; 90 percent have done so within 6 months. Patients still severely disabled after 3 months are unlikely to be better than moderately disabled after that time. This is not to deny that patients who remain in the same outcome category may not improve within it; but much of the "improvement" reported after a year or more proves more often to reflect acceptance of, and adjustment to, a relatively fixed disability rather than a marked restoration of function. For these reasons, it would seem reasonable to assess the outcome of treatment for brain failure after 6 months.

It is obvious that to secure survival in the vegetative state is no better than a fatal outcome—it is no more than death deferred. There is evidence, from large scale enquiries among professionals and others, that a consensus is emerging that survival in a severely disabled, but conscious, state should also be regarded as a failure; indeed it may be much worse for the patient, because he is aware of his plight.[6,7] While most vegetative patients die within the first year, one-third may live for 3 years or more, and 18 years' survival has been recorded. Most severely disabled survivors are under the age of 30, and they face 30 years or more of disability, because life-expectancy is reduced by only 5 years in the next 20 years.[21] In Britain, about 30 patients per million population leaving the hospital each year have permanent brain damage after head injury; half of them will never work again. In the United States, the rate is probably about 70 such victims per million population, because serious head injury is more than twice as common. Because most are young, the accumulating pool of permanently brain damaged people is very considerable. After stroke, there are also many disabled survivors, although the length of survival is much less because such patients frequently succumb to another stroke or to cardiac or renal events.

The mark of success in the treatment of brain failure is to restore the patient at least to independence, even if he is disabled. This should be borne in mind when basing decisions about the initiation or continuation of various levels of therapeutic or life-supporting endeavors, as is discussed more fully in Chapter 11. It is inevitable that even with good triage, and with humane restriction of technology, some patients will remain vegetative or severely disabled. These must be accepted as the price of securing a reasonable recovery for others.[7] But if there are too many failures in proportion to success, then that price is too high.

PREDICTION OF OUTCOME AFTER BRAIN FAILURE

The central role of prediction, both in making management decisions and in assessing the efficacy of alternative treatment methods, is not sufficiently appreciated. Every decision to employ this or that therapeutic technique (or not to do so), should be based on an assessment of the likely outcome, with or without this particular component of therapy. Unless it is known what course a case (or series of patients) is likely to take *without* a certain therapy, it is impossible to know whether the outcome that follows its use has occurred because of it, or in spite of it.

It has long been held to be very difficult to make a reliable prognosis after an episode of acute brain damage, but recent studies in both traumatic[18] and non-traumatic[2,20] coma indicate that the outcome can be predicted within a day or two of injury in many cases, on the basis of clinical data that are always available. But in order to make such predictions, the clinical evidence of severity has to be expressed in a standardized fashion, as described by Dr. Caronna in Chapter 4. It is important to ensure that the degree of brain dysfunction recorded is valid, and is not unduly influenced by extracranial factors, such as systemic disorders (hypotension or hypoxia) and drugs (especially alcohol). Assessment of the severity of brain damage very soon after the insult, particularly in traumatic cases, is often misleading for these reasons. There is a tendency for doctors to believe that the accumulation of more and more data about a patient is likely to lead to a more accurate prediction. Fortunately this is not so, and the use of a small number of items of readily collected and reliably interpreted factors can prove more powerful, if appropriate statistical methods are used.[9,23]

The studies of prediction already completed[2,18,20,23] have identified features that determine the outcome. From a knowledge of these, it is possible to state the features that should be similar in two series of patients, if they are to be differently managed, and their outcomes then compared to discover which method is the more effective. This would enable prospective randomized trials to be carried out with greater efficiency than if factors influencing outcome were not known. Very large series of patients have to be accumulated for all of these factors to balance out by randomization. However, the consistency in the outcome in series of patients with injuries of defined severity is such that it seems possible that rigorous trials of alternative treatment methods might be feasible using suitable matched historic controls.[19] This would obviate the difficulties of randomization and of informed consent, which can be formidable in these unconscious patients who require urgent intervention.[10]

But the possibility of making early predictions in individual cases opens the way

for a different and novel approach to assessing the efficacy of new methods of treatment. It is widely recognized that, with rare exceptions, such new therapies are unlikely to make a very marked difference in outcome, and that this benefit is likely to be confined to patients whose outcome is not already predestined to a high degree by the amount of brain damage sustained. Those not very seriously affected will likely recover well with conventional treatment; those with overwhelming damage will likely die, whatever is done. Unless these cases are excluded from a trial, their presence may obscure the benefits of treatment in the small number of patients whose outcome can be influenced favorably. We propose that these latter patients should be identified by predictive methods, and trials of new therapies limited to them. Such trials could be by conventional randomizing or by treating all such cases and then calculating whether a significant proportion had a better outcome than had been predicted from patients conventionally treated.

AUDITING ACTION AGAINST BRAIN FAILURE

When failure has to be faced as the final fruit of all our efforts to rescue a patient from brain failure, we should always question why the outcome did not turn out better. Harvey Cushing taught that the doctor should ask himself each time he encounters a patient, what can I do for him and what can I learn from him? The patient's management should be scrutinized to discover whether there were points during the evolution of his fatal illness when better decisions might have been made, or when actions might have been taken more rapidly. When this was done for a series of head injured patients who had died in a neurosurgical unit, about half were found to have at least one adverse factor in their management that might have been avoided.[12,22] These were also frequent in patients who survived but who remained disabled.

The most common factor was a delay in the management of a complication that had consequently caused secondary brain damage—such as intracranial hematoma or systemic hypotension hypoxia. It is not suggested that any system of medical care could completely eliminate such factors—some are dependent on the chance of where the crisis happens, the distance from skilled help, the personnel who happen to be available, and so on. That does not detract from the importance of identifying such factors for the lessons they teach us, rather than attempting to attach blame for their occurrence.

Even when clinical features are carefully reviewed, it is often difficult to determine the balance between primary damage and secondary events in contributing to death after acute brain damage unless an autopsy is done, the brain fixed before dissection, and a proper neuropathological examination carried out.[1] Even in a patient who has been in coma continuously after head injury, autopsy may reveal that impact damage was limited and recoverable, but that secondary processes accounted for the fatal outcome.

Unfortunately, such a systematic autopsy is all too seldom done, partly for forensic reasons and partly because these cases are of limited interest to most neuropathologists. Consequently, it is not easy for those dealing with the management of patients with brain failure to have accurate feedback about the effectiveness of what they have done, so that they may modify their line of action in the

future. When this is done, however, it becomes possible to recognize, by the judicious study of clinicopathologic correlations as well as by using the predictive techniques described, the signs of irrecoverable damage. This makes it possible to withold or to withdraw treatment from such cases, which makes it more likely that the effectiveness of any new management method will become evident sooner, because it is being used in cases with potential for recovery.

CONCLUSION

Achieving acceptable recovery after threatened brain failure is the most difficult, but when successful can be the most rewarding, challenge in the field of critical care. The stakes are high because of the price exacted not only from the victims who survive with severe brain damage but from their families, and from the society that has to support them. The need is therefore to try to reduce inconsistent decision-making and to monitor carefully the results of what we do in order to make a better judgment next time. The aim is to identify those patients for whom maximal efforts are appropriate; this entails protecting other patients from diagnostic and therapeutic endeavors from which they cannot benefit and which will divert valuable and scarce resources from those whose outcome may depend on them.

REFERENCES

1. Adams JH, Graham DI, Scott G, Parker L, Doyle D 1980 Brain damage in non-missle head injury. Journal of Clinical Pathology 33: 1132–1145
2. Bates D, Caronna JJ, Cartlidge NEF, Knill-Jones RP, Levy DE, Shaw DA, Plum F 1977 A prospective study of non-traumatic coma: methods and results in 310 patients. Annals of Neurology 2: 211–220
3. Bond MR, Brooks DN 1976 Understanding the process of recovery as a basis for the investigation of rehabilitation for the brain injured. Scandinavian Journal of Rehabilitative Medicine 8: 127–133
4. Cartlidge NEF 1980 Personal communication
5. Jennett B 1976 Assessment of the severity of head injury. Journal of Neurology, Neurosurgery and Psychiatry 39: 647–655
6. Jennett B 1976 Resource allocation for the severely brain damaged. Archives of Neurology 33: 595–597
7. Jennett B 1977 The cost of rescue and the price of survival. In: Phillips CI, Wolfe JN (eds) Clinical Practice and Economics, Pitman Medical, London p 46–55
8. Jennett B 1979 Defining brain damage after head injury. Journal of the Royal College of Physicians, London 13: 197–200
9. Jennett B 1980 Comments on paper by Stablein DM et al. Neurosurgery 6: 246–248
10. Jennett B 1981 Efficacy efficiency and adequacy in neurosurgery. In: Rice-Edwards JM (ed) Topical Reviews in Neurosurgery, Wright and Sons, London (In press)
11. Jennett B, Bond M 1975 Assessment of outcome after severe brain damage. Lancet 1: 480
12. Jennett B, Carlin J 1978 Preventable mortality and morbidity after head injury. Injury 10: 31–39
13. Jennett B, MacMillan R 1981 Epidemiology of head injury. British Medical Journal 282: 101–104
14. Jennett B, Plum F 1972 Persistent vegetative state after brain damage. Lancet 1: 734–737
15. Jennett B, Teasdale G 1977 Aspects of coma after severe head injury. Lancet 1: 878–881
16. Jennett B, Teasdale G 1981 Dynamic pathology. In: Management of Head Injuries. FA Davies, Philadelphia
17. Jennett B, Bond MR, Snoek J, Brooks DN 1981 Disability after severe head injury. Journal of Neurology, Neurosurgery and Psychiatry (In press)
18. Jennett B, Teasdale G, Braakman R, Minderhoud J, Heiden J, Kurze T 1979 Prognosis of patients with severe head injury. Neurosurgery 4: 283–288
19. Jennett B, Teasdale G, Fry J, Braakman R, Minderhoud J, Heiden J, Kurze T 1980 Treatment for severe head injury. Journal of Neurology Neurosurgery Psychiatry 43: 289–295