Clinical Advances in the Evaluation of Deep Coma* **

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Today, 1974, in large medical centers, evaluation of the patient in coma is almost a daily necessity, and the need to evaluate the patient in deep coma arises once or twice every week. Even in smaller hospitals the problem is not uncommon. This has come about because many laymen and most medical personnel are now well trained in methods of cardiorespiratory resuscitation (1, 2). Persons are not allowed to die easily and once resuscitated, are moved to intensive care units where life is maintained. Fortunately, if they do not die of their underlying disease, such as trauma or myocardial infarction, many patients thus rescued recover completely; that more do not is due to the fact that the brain is such a tender organ—only a few minutes without oxygen and neurons die or are damaged—only a short while without blood flow and, apparently, the cerebral blood does not flow again. On the other hand, neurons, silenced completely by drugs for hours or even days, may recover and soon be alive and well.

A proper decision as to the cause and degree of brain damage may lead to useful treatment and recovery or, if the brain is dead, may allow other organs to be used for transplantation and relieve the family, as well, of hours of anguish and added expense. In 1966, Plum and Posner (3) outlined in an orderly fashion the various clinical observations necessary for the evaluation of the ordinary comatose patient. They did not, however, give special attention to the patient in deep coma or the problem of possible brain death. The problem of diagnosing deep coma and determining brain or cerebral death became more urgent with the advent of widespread organ transplantation. Although at first, the problem of evaluation of deep coma was approached by each specialist from his own area of expertise, a combination of clinical examination and laboratory tests has now been developed which promises to allow routine and relatively rapid diagnosis and prognosis. Impetus for such an approach in the United States first came in 1968 from the report of the ad hoc committee of the Harvard Medical School (4) to examine the definition of brain death. These so-called "Harvard Criteria" were primarily a combination of clinical examination and electroencephalogram recording. Standards for acceptable electroencephalographic recording were further studied and summarized by an ad hoc committee on "EEG Criteria for a Demonstration of Cerebral Death" (5) of the American Electroencephalographic Society published in 1970. While these and other studies (6, 7) emphasized the usefulness of the EEG in the evaluation of deep coma, investigators in Europe demonstrated the usefulness of cerebral arteriography and the assessment of cerebral blood flow as prime criteria for the determination of brain death (8–10). Further refinements of the clinical and EEG evaluation of deep coma will soon be available in the report of the National Institutes of Health Collaborative Study on Cerebral Survival (11). This study of over 500 patients also emphasizes the clinical examination and the electroencephalographic study; however, it will include the report of an ancillary study on a rapid bedside method of assessing cerebral blood flow by the injection of radio isotopes—the Bolus technique (12).

At the Medical College of Virginia, we became interested in the problem of acute bedside recording in the mid-1960's, particularly in relationship to patients with seizures and strokes. We were espe-

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cially interested in changes in patients with cerebral emboli who often presented with continuous focal seizures (13). This interest was expanded to include patients in deep coma, primarily for the purpose of making decisions related to organ transplant. For over five years, we have maintained regular 24-hour EEG coverage in the Medical College of Virginia Hospitals. Beginning in 1971, we took part in the National Institutes of Health Collaborative Study on Cerebral Survival (11). From this experience, and a survey of recent literature, comes the following assessment of our present approach to the diagnosis of the patient in deep coma. The main items of importance in the process are presented below.

Clinical Examination. Responsiveness to stimuli is basic to the definition of coma. Persons in deep coma do not respond to the spoken word at all; they do not respond in any purposeful manner but only by reflex movement to other stimulation. With deep pain, they may respond not at all or respond by reflex movement such as decorticate or decerebrate posturing. In some cases, eye blinks, either spontaneous or to stimulation, may occur and occasionally chewing movements. Any easily elicited response, particularly of a purposeful nature to any stimuli, suggests that the patient is not in deep coma.

The presence or absence of spontaneous respiration is, of course, a critical point in the evaluation of deep coma. With brain death, including the cerebral cortex as well as the brain stem, there will be no spontaneous respiration. With cerebral cortex damage alone, but with brain stem function intact, respiration may be nearly normal. This accounts for the rare situation of a patient showing electrocerebral silence on EEG with some loss of other cranial reflexes who surprisingly breathes spontaneously after the mechanical respirator is disconnected. These are the patients who may survive for months or years with an EEG showing electrocerebral silence. This also indicates the necessity of carefully testing all cranial reflexes before cerebral death is pronounced. In general, the absence of spontaneous respiration is a bad prognostic sign in patients with structural lesions, such as cerebral hemorrhage or trauma, and to a considerable degree in patients with cerebral anoxia. Patients in coma from overdose, however, may not have spontaneous respiration for a considerable period of time and still completely recover.

The Harvard criteria emphasize the absence of all reflexes, both cranial and spinal, and the lack of spontaneous respiration as the prime elements in the clinical examination. Experience in the Collaborative Study on Cerebral Survival (11) has confirmed the importance of cerebral reflexes. In this regard, the pupillary reflexes are the most important since fixed dilated pupils (not necessarily maximally dilated) and absence of respiration are the most common clinical accompaniment of brain death. The presence of oculocephalic reflexes indicates that brain stem structures are still alive. The presence of oculovestibular reflexes also suggests the presence of functioning brain stem structures, but this reflex seems to persist longer than the oculocephalic reflex. The response of eye blinks, either as a reflex or spontaneously, also indicates some brain stem function and since this is routinely recorded in the electroencephalogram, it serves as a reminder to the electroencephalographer that brain stem function persists, even though the recording may show electrocerebral silence otherwise (Fig. 1).

It may be noted that the examination of the optic fundi is not included as an important factor in determination of cerebral death. Although examination of the optic fundi may help in the etiological diagnosis of coma, it is of little direct help in prediction of the level of coma or its outcome. Information of the presence or absence of blood flow in the retinal vessels is not sufficiently accurate to serve as a criterion of brain death.

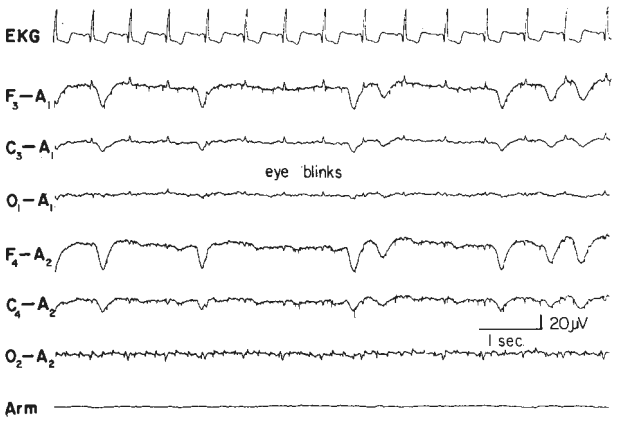

Fig. 1—This record shows eye blink, muscle, and EKG artifacts. After succinylcholine injection the muscle and eye blink artifacts were abolished and no evidence of cerebral activity remained. Despite this fact, the patient is still alive, nine months after cardiorespiratory arrest. The patient still remains in coma but breathes spontaneously.

One result of our experience in the cerebral survival study is the understanding that spinal reflexes are completely unreliable in the prediction of brain death or of the outcome of coma. Although the paper outlining the Harvard criteria is not exactly clear on this point, it suggests the absence of spinal reflexes as part of the criteria; this is one part of the Harvard criteria that may definitely be discarded. Although spinal reflexes are often absent, patients in deep coma may show some degree of reflex movement as well as actual muscle stretch reflexes and even Babinski signs. Such reflexes, of course, may be suppressed in patients with drug overdose, and yet the patient may still recover completely.

Convulsions or myoclonic jerks are common during the 12–24 hours immediately following cerebral damage from anoxia due to cardiac arrest. During this time, the EEG may indeed show no clear activity except the artifacts produced by such movements. With the use of succinylcholine or Valium®, the cerebral discharges alone can be recorded. The occurrence of convulsions or diffuse rhythmic myoclonic jerks can be taken as proof of some brain function.

Blood pressure, as such, is of little value in the evaluation of the patient in deep coma. It is true, however, that a sudden fall of blood pressure is often a terminal event in a patient with brain death maintained on a respirator for a long period. It is also apparently true that in patients with cerebral trauma or cerebral hemorrhage, the presence of excessively high blood pressure is a bad prognostic sign (14). Thus, excessive alteration, either up or down, of the blood pressure is a sign of poor prognosis (15).

Temperature is of importance mainly because extremely low temperature may alter cerebral activity and be associated with electrocerebral silence in the patient who eventually survives. Slight lowering of temperature does not seem to have this effect. In the ordinary case of deep coma, therefore, temperature is of no major importance.

In summary, of all the clinical observations of the patients with deep coma, those having to do with cranial reflexes, particularly the pupils, and with respiration, are the most important.

Tests for Drugs and Metabolic Abnormalities. Since recovery from deep coma in patients with electrocerebral silence on the EEG is seen almost exclusively in patients whose coma is due to drug overdose or metabolic derangement, the diagnosis of toxic and metabolic factors in coma is of great importance. Experience in this regard suggests that tests for metabolic derangement, at least ordinary metabolic derangement, are rapidly and easily obtained. The same is not true of toxicology. Even in large medical centers, it is often difficult to obtain rapid, reliable, quantitative tests for drugs and toxic substances. While it is true that drug levels are not important in cases of clear trauma or of anoxia secondary to cardiac disease, occasionally the two conditions may coincide. For this reason and because of the legal implications, improvement of our services in this area is urgent (16). Even though rapid toxicology reports may become available in large medical centers, it will remain a difficulty for some time in smaller hospitals. Fortunately, evidence at this point suggests that usually the patient in deep coma can have an adequate evaluation without knowing the actual drug levels. For instance, in our experience, no patient with dilated pupils and electrocerebral silence on the electroencephalogram has survived. Since such a case might exist, however, due to drug overdose, this is an area in which the use of a rapid simple test of cerebral blood flow would help give a final answer concerning cerebral death without reference to drug levels (10).

Another recurring problem of patients in deep coma, particularly with anoxic coma, has to do with the fact that many present with convulsive or myoclonic seizures. Such patients are often treated with rather large doses of anticonvulsant drugs which are also sedatives. Obviously, it is not appropriate to accept clinical and EEG evidence of brain death in the patient who has just been given large doses of such drugs. Quantitative drug levels are necessary before final decisions can be made.

Electroencephalogram. The importance of the electroencephalogram in the evaluation of coma has escalated in direct proportion to the 24-hour availability of such recordings, the excellence of the recording technique, and the experience of the electroencephalographer. When these criteria are met, the electroencephalogram is indispensable in the diagnosis and prognosis of deep coma.

Meticulous technique is the mark of the excellent EEG technician and the true electroencephalographer. The model of such meticulous technique was established by Hans Berger (17) in his extensive studies to prove that the oscillations

of his recorders were due to cerebral activity and not to artifact. Modern electroencephalographers have retraced Berger's steps with the opposite intent, namely to prove that the oscillations *are* artifact and not cerebral activity.

Fortunately, with present equipment, excellent artifact-free records may be obtained in even the most chaotic intensive care unit. Adequate technical recording requires that records be made at a very high amplification with portions of the record being recorded with an amplification of two microvolts per millimeter. It is then necessary that all deflections of the recording be clearly identified either as artifact or as cerebral activity. Common artifacts come from the electrocardiogram, from mechanical respirators, from cardiac monitors, and from other monitoring equipment. Any slight movement of the bed or patient may present a problem. When these artifacts cannot be eliminated, they can at least be monitored as a part of the actual recording. Figure 2 shows respirator artifact and electrocerebral silence when the respirator is briefly stopped. Figure 3 shows the monitoring of the respirator cycle by an accelerometer actually attached to the respirator instrument.

The most consistently bothersome artifact is that of muscle activity. Even in deeply comatose patients and even in patients without brain stem function, some muscle activity may remain. Fortunately, since such patients are on respiratory support, the use of succinylcholine given intravenously to abolish muscle artifact is an extremely useful procedure. This is particularly true since in a review of our records on patients in deep coma, the type of record which was most consistently thought to be technically inadequate was the record with muscle artifact. Particularly records with low amplitude artifact due to muscle alone may be thought to show low-fast brain activity. Figure 4*A* shows such a record and the recording after succinylcholine (Fig. 4*B*).

As regards the Harvard criteria (4), our studies have shown that all patients with a single record of thirty minutes of electrocerebral silence with no spontaneous respiration and with dilated fixed pupils have died. A recent report of Jorgensen (18, 19) from Copenhagen reaches this same conclusion, except that he adds to the criteria the loss of spontaneous maintenance of systemic blood pressure.

Aside from the usefulness of the electroencephalogram in the recording of electrocerebral silence in cases of brain death, experience in a great variety of patients with lesser degrees of coma has given a new appreciation of certain distinct EEG patterns (13, 20–27). Such distinctive EEG

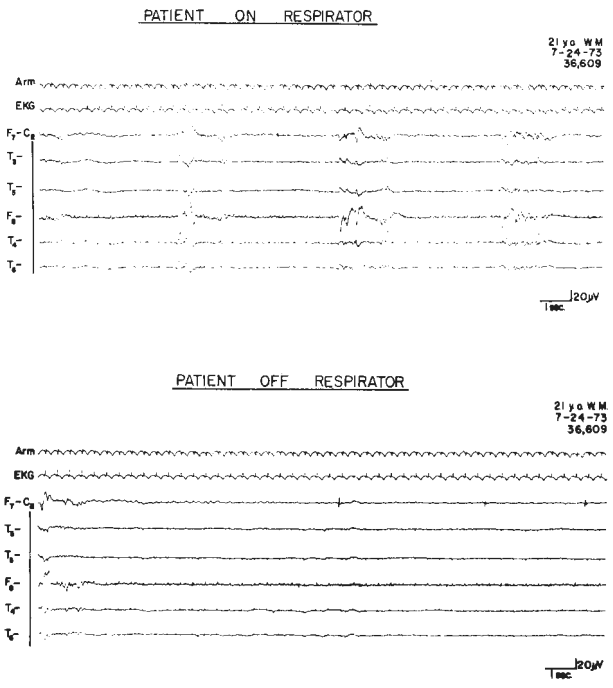

Fig. 2—The first record shows regular, recurring respirator artifact. The second record shows the disappearance of this artifact when the respirator is stopped. Though some very slight muscle artifact remains, the record after the respirator is stopped is essentially that of cerebral silence.

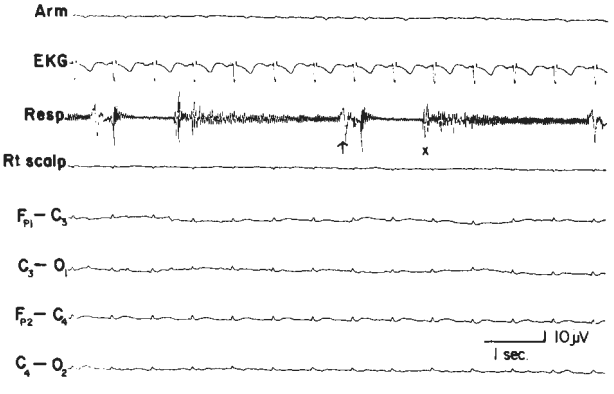

Fig. 3—Monitoring of the respirator cycle by an accelerometer is demonstrated in Channel 3. Although the recording is that of electrocerebral silence and no marked respirator artifact appears, a slight swaying of the baseline in time with the respiration can be detected in Channels 5 & 6.

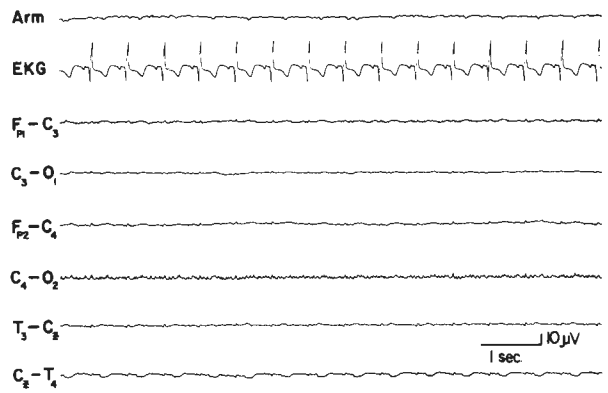

Fig. 4*A*—This record shows low amplitude fast activity in the sixth channel from electrodes C_4 and O_2. This might be considered cerebral activity.

patterns seen in patients in coma are presented below.

Electrocerebral Silence. As recorded in the electroencephalogram, electrocerebral silence consists of no deflections above a millimeter with the machine set at an amplification of two microvolts per millimeter. Actually, some older machines have a background noise level of two-to-three microvolts, and in this situation, some leeway will have to be given for determination of electrocerebral silence. In the newer machine with everything in order, a record without deflections beyond a one-millimeter range should be obtainable. Nevertheless, it is usually impossible, except by special subtraction or computer techniques, to remove all of the EKG artifact from the record (28). This usually appears as a regular deflection which can be monitored and determined to be directly synchronous with the EKG (Fig. 5).

Low Amplitude-Fast Activity (Muscle) Abolished by Succinylcholine. Low and high amplitude muscle artifact is seen in many recordings, even in patients with severe damage of the brain stem. It occurs in patients who already have dilated fixed pupils and no spontaneous respiration. If these patients are continued on respiratory support, eventually all muscle activity ceases. The muscle activity may be the only remaining artifact that makes it impossible to be sure the record is that of electrocerebral silence. Also, the muscle artifact may appear actually as beta activity. Since beta activity is often seen in patients with overdose who will survive, it is extremely important that this differential be made. This can be done by a single injection of 30–60 mg of succinylcholine intravenously or, better yet, by a slow constant drip of succinylcholine (29–31). This is done, of course, only on patients with respiratory support (Fig. 4*B*).

Electrocerebral Silence Except for Myoclonic Jerks. We have observed, particularly early in the course of deep coma and especially in coma due to cerebral anoxia, that the patient may present with repeated myoclonic jerks, but the recording, except for these jerks, shows no cerebral activity (Fig. 6). Succinylcholine given in this situation has to be given in very large amounts to block the myoclonic jerks. Drugs such as diazepam may block the myoclonic jerks but then raise the question as to whether the drug might also suppress

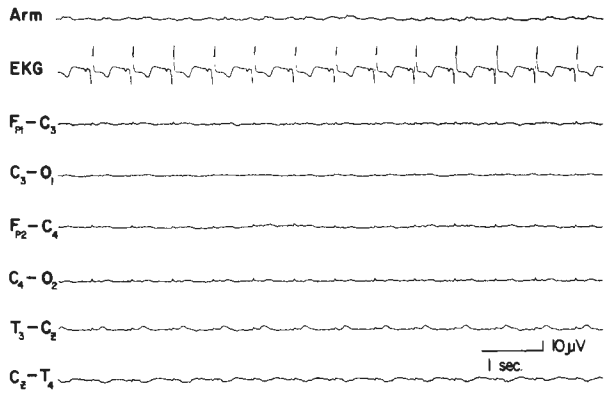

Fig. 4*B*—After succinylcholine the low amplitude fast activity seen in Channel 6 disappeared and therefore was due to muscle artifact. The recording is now that of electrocerebral silence.

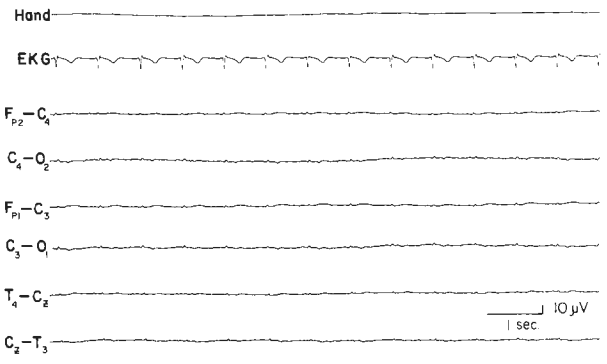

Fig. 5—At a recording amplitude of 2 μV/mm, no discernible cerebral activity appears and this is a typical record of electrocerebral silence. Very slight EKG artifact is seen.

other cerebral activity. In general, this type of record is usually, but not always, a very poor prognostic sign. The fact that myoclonic jerks exist, particularly as they are bilateral and symmetrical, indicates that some brain function remains.

Burst Suppression Pattern. In many records of deep coma, particularly due to cerebral anoxia and often following a few hours of records which show only myoclonic jerks, there may occur a burst suppression pattern. In this situation, fairly high amplitude complexes, either singly or in paroxysmal episodes, occur with intervening periods of electrocerebral silence. The intervening period may vary from one or two seconds up to a minute or more. Such a burst suppression pattern, in general, is a bad prognostic sign (Fig. 7).

PLED's and "Bilateral" PLED's. In a great number of patients with cerebral emboli or other lesions, particularly associated with some metabolic disturbance, bilateral, semirhythmic, periodic discharges are seen but these discharges are definitely greater on one side. Often associated with these discharges, there are brief but continuous myoclonic jerks. In our laboratory at the Medical College of Virginia, these were observed in the early 1960's and designated "acute spikes" (13). They also have been described and usually called "PLED's" (periodic lateralized epileptiform discharges) in the literature (32). Most patients with this pattern are stuporous but may be conscious; depending upon the lesion involved, they may proceed with it and die or they may recover completely. It is thought that the cerebral ischemia, resulting from embolization which has produced a temporary anoxia, causes the unilateral discharges. In any case, a similar pattern, bilaterally symmetrical, is seen following severe cerebral anoxia of a diffused nature such as that due to cardiac standstill. In this situation, the bilateral PLED's have a much more serious prognosis (Fig. 8*A, B*).

Continuous Spike or Spike Waves. Certain patients who are stuporous or in coma present with continuous diffuse spike or spike wave discharges. Some of these patients have a chronic form of convulsive disorder and are in a type of convulsive state. Such patients are not usually confused with deep coma, since reflexes remain and pupils react, and the patient breathes spontaneously. Following a reasonably severe anoxic insult, however, certain patients also go into a period of one, two, or three days of continuous diffuse spike and spike wave

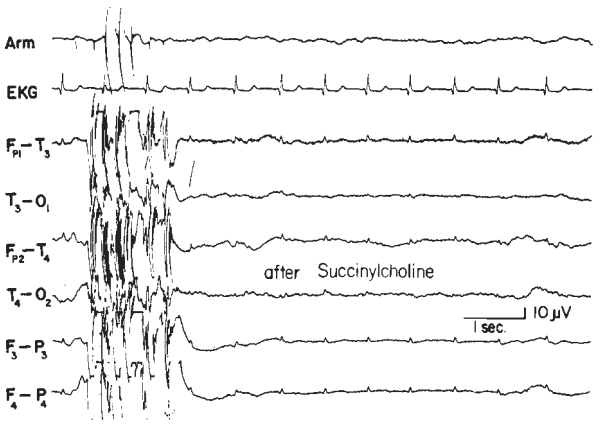

Fig. 6—In this record myoclonic seizures such as seen in the beginning of the recording occur every 10–30 seconds. Succinylcholine suppressed other muscle artifact revealing no evidence of cerebral activity between these attacks.

activity (Fig. 9). This may precede a more severe continuous burst suppression record, or it may precede a longer period when the patient simply has a theta coma. A few of these patients recover, usually with some degree of neurological damage. Control of such activity with anticonvulsant drugs usually does not produce an electrocerebral silence record but tends to produce a record with either delta or theta activity, so that there is no problem concerning decision as to electrocerebral silence.

Severe Asymmetry. A record with severe asymmetry, particularly showing essentially electrocere-

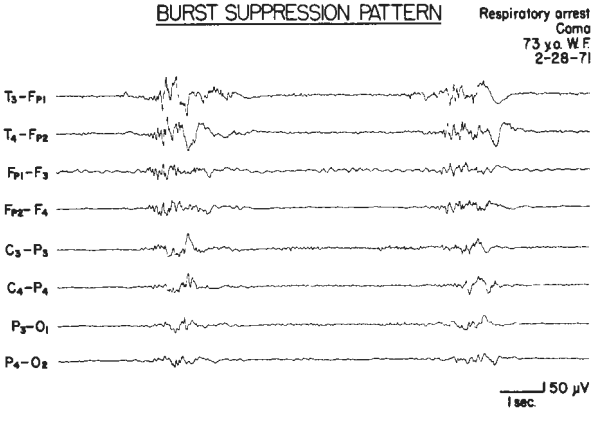

Fig. 7—This record shows relatively high amplitude discharges occurring in a rhythmic fashion with only low amplitude activity between. Such discharges appearing over a period of time in general have a bad prognostic significance.

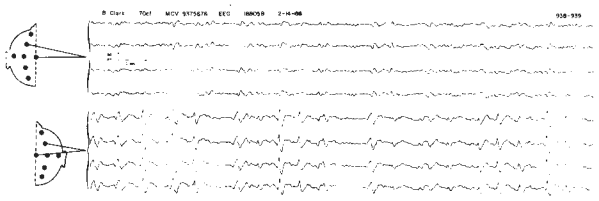

Fig. 8*A*—This is a record showing typical periodic lateralized epileptiform discharges (PLED's) secondary to cerebral embolus to the right hemisphere in a patient with some metabolic derangements.

bral silence on one side and large delta activity on the other, is seen primarily in cerebral trauma but occasionally in intracerebral hemorrhage. Such a record indicates a poor prognosis for complete recovery, though dependent upon the treatment carried out and the nature of the illness, the patient may survive (Fig. 10). Lesser degrees of asymmetry seen in ordinary subdural hematoma, of course, may be followed by complete recovery of the patient and normality of the EEG.

Diffuse Delta. Classically, diffuse delta activity has been associated with coma or diffuse brain damage or disease. Actually, this is not a very frequent pattern in the patient in deep coma. The presence of diffuse delta may indicate any of a great number of relatively acute cerebral disturbances which may be transitory. Thus, many patients who show diffuse delta and periods of coma or confusion recover completely. This is particularly true following metabolic happenings and following closed head trauma (Fig. 11).

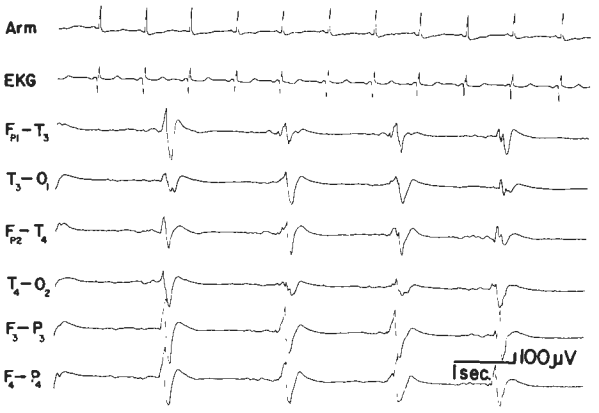

Fig. 8*B*—This is a recording showing periodic generalized discharges or so-called bilateral PLED's in a patient with diffuse cerebral anoxia secondary to cardiorespiratory arrest.

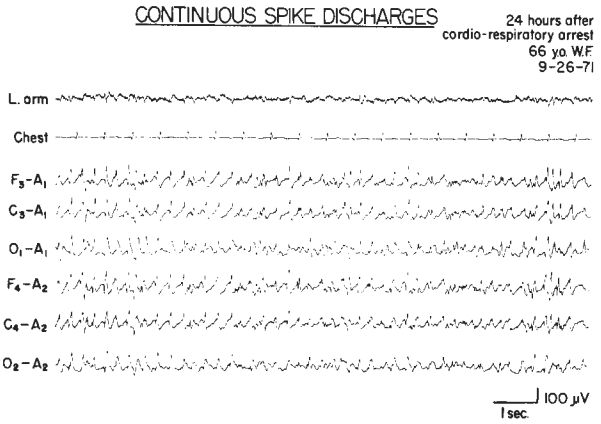

Fig. 9—This record shows continuous spikes and spike waves in a diffuse fashion due to an acute cerebral anoxia.

Diffuse Theta (Theta Coma). We have observed a number of patients with a fairly regular diffuse theta activity in the electroencephalogram (25). This activity is often seen during a recovery stage following cerebral anoxia of a severe degree. At this point the patient may deteriorate and revert to burst suppression and eventually to electrocerebral silence but more often shows a tendency toward recovery. This finding of theta coma is of importance directly in proportion to how long it occurs. As a transient happening, it has a good prognosis in general; if theta coma pattern persists for days or weeks, however, it is usually in association with a patient who has received rather severe diffused cerebral damage as well as some brain stem damage. Such patients usually breathe spontaneously, have some pupillary reflexes, but do not respond in purposeful fashion

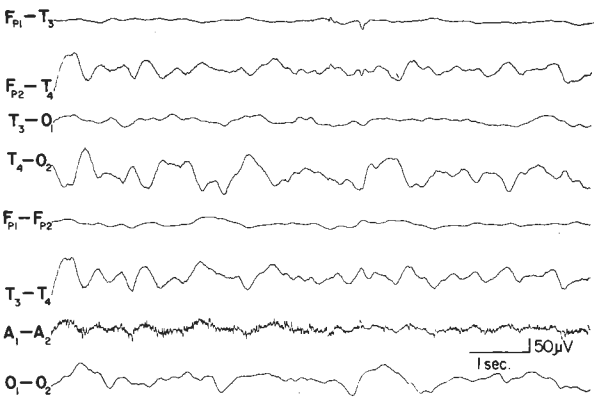

Fig. 10—This record shows marked asymmetry with severe depression over the left hemisphere secondary to a large subdural following trauma in the so-called "battered child."

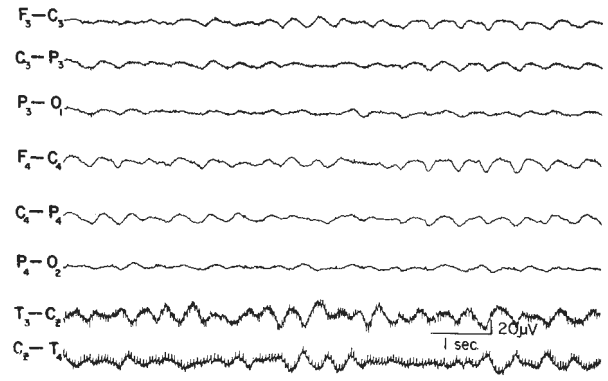

Fig. 11—This record shows diffuse delta in a patient comatose following a hypoglycemic episode.

to stimuli. They may stay in this state for long periods of time (Fig. 12).

Diffused "Sleep Spindle" Activity. Reports have appeared concerning sleep spindle activity in coma associated with brain stem lesions (24), particularly in pontine lesions. We have seen one particularly impressive case with a cerebellar hemorrhage and brain stem compression. This type of record may be confused with records in drug overdose which may also show sleep spindles. The presence of such a record in a deeply comatose patient, however, should always raise the possibility of a brain stem lesion and compression by a cerebellar lesion, particularly since this may be a treatable situation (Fig. 13).

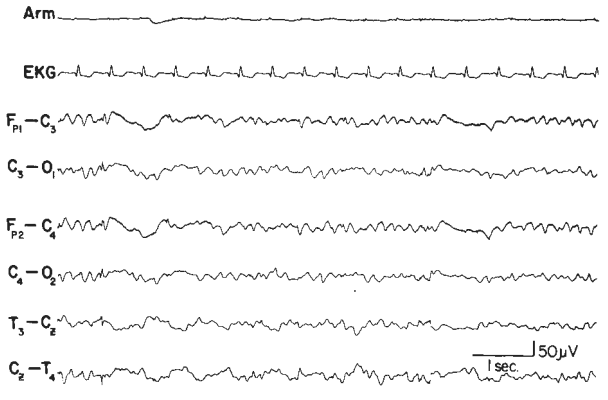

Fig. 12—This record shows so-called theta coma with predominant discharges in the 4–8 c/sec range in a diffuse fashion. This patient had severe diffuse cerebral damage following cerebral anoxia but, though comatose, was still breathing spontaneously and making nonpurposeful movements to stimuli two months following the injury.

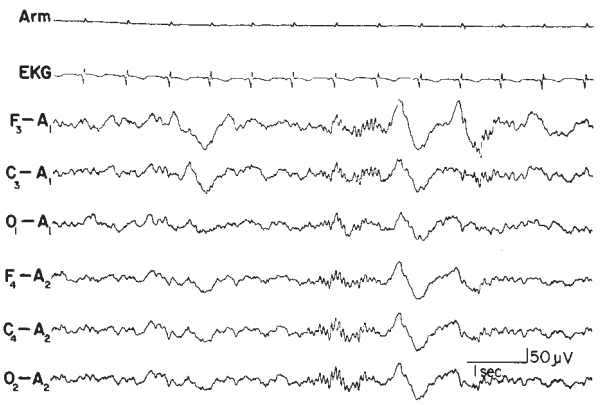

FIG. 13—This record shows diffuse spindle activity resembling sleep in a patient with a cerebellar hematoma and compression of the brain stem. Removal of the hematoma resulted in nearly complete recovery of the patient.

Diffuse Alpha Frequency (Alpha Coma). Reports of normal electroencephalograms in patients in coma have appeared (26, 27). What is usually meant by this is that the patient has an alpha frequency discharge which occurs in a diffuse fashion. Actually, such a diffuse alpha frequency discharge is quite abnormal and is indeed usually associated with coma secondary to pontine or brain stem lesions or damage. Most such patients have died; however, we have recently recorded such alpha frequency coma in several patients who survived (33). Two of these had coma following severe accidental electroshock and one had coma following cerebral vascular insufficiency attack. It would appear that recovery is not unusual in patients with alpha frequency coma, particularly when the alpha frequency coma is of brief duration (Fig. 14).

Diffuse Beta (Beta Coma). The occurrence of diffuse beta activity is usually a sign of drug overdose and is seen in patients who are not in really deep coma; occasionally, however, it is seen in patients with brain stem lesions. The literature is somewhat confused on this subject, since some of the recordings thought to be beta activity probably actually represent low amplitude muscle activity which could have been abolished by succinylcholine. Usually, the recording of a diffuse beta activity record is a good prognostic sign, because it is usually related to drug overdose (Fig. 15).

These are some of the characteristic patterns with which we have become familiar in the study of coma. As time goes on, and larger numbers of

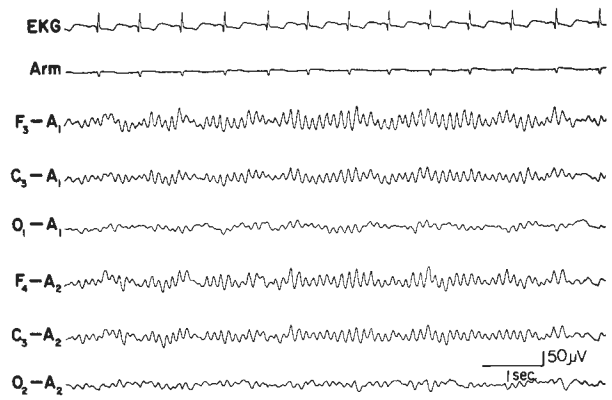

Fig. 14—This record shows so-called alpha frequency coma in a patient comatose following cardiorespiratory arrest from a severe electric shock. The patient remained comatose for nearly three weeks but then slowly regained consciousness and is still living with a large degree of recovery but with some slight memory and learning defect.

cases are collected, more definite prognostic attributes can be given to each type of finding.

Determination of Cerebral Blood Flow. Although our experience indicates that a careful clinical examination and excellent electroencephalographic recording give enough information, even within 30–90 minutes, to make a decision as to the presence of brain death (dilated fixed pupils, no spontaneous respiration, and electrocerebral silence EEG for thirty minutes equal brain death), the addition of information about cerebral blood flow might increase ones sense of confidence in cases where drugs or metabolic abnormalities might be active. For this reason, studies of the possibility for developing facilities for the easy evaluation of cerebral blood flow should be continued. In this regard, the Bolus technique shows prominence (10). In this test, radioactive material is injected into the veins and the resulting radiation is picked up within a few seconds from the cranium and from the chest or the femoral artery. This is a qualitative not a quantitative test, but in patients with brain death, essentially no blood flow is recorded over the cranium and the normal flow is recorded in the chest or femoral artery probe. This test has not yet been firmly authenticated with contrast cerebral arteriography, but so far its correspondence with other studies is excellent. Because it represents a relatively simple bedside test, could be available in a large number of hospitals, and offers confirmation of brain death from a different parameter, it may indeed have widespread application.

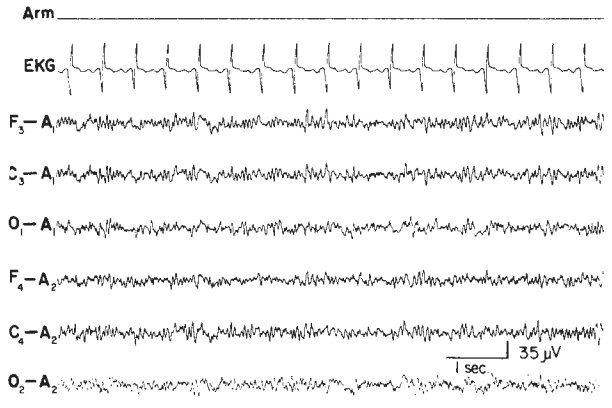

Fig. 15—This is so-called beta coma seen in a patient with a drug overdose who was comatose but who recovered rapidly and completely.

It is assumed that in a case of severe drug overdose without cerebral anoxic damage or cerebral infarction, the cerebral blood flow would be present and, if not normal, at least not severely depressed. For this reason this test would become an ideal test on a patient with drug overdose who had remained comatose with electrocerebral silence for a period of 12–24 hours. In similar cases, where ordinary contrast cerebral arteriography has been performed, it has shown no cerebral blood flow in patients even with overdose after 24 hours. This is almost certainly due to the fact that these patients have also suffered anoxic damage. Even now, when doubt exists, ordinary contrast cerebral angiography can give essentially the same type of information and should be used more often here in the United States as it is now being used in Europe.

Other Tests. At this point, it does not appear that tests and examinations other than those listed above will become critical in the examination of brain death; nevertheless, a variety of other laboratory procdures will, as time goes on, help us to understand particular types and particular degrees of brain damage. There have been a large number of reports concerning values in the cerebral spinal fluid of pH, lactic acid, and a variety of enzymes related to the stage and degree of brain damage (34, 35). In general, we have not carried out lumbar puncture or cerebral spinal fluid examination routinely in patients with deep coma, since in some cases this might be contraindicated because

of increased intracranial pressure or other intracranial lesions.

The more widespread use of monitoring intracranial pressure assures our better understanding of what role increased intracranial pressure has in the development of deep coma and at what points it might be reversed by various forms of treatment (36). From a few observations, it might appear that when the intracranial pressure passes a critical point in relation to systemic blood pressure, severe brain damage follows rather rapidly. So far, the monitoring of intracranial pressure has been largely in patients with trauma or hemorrhage, but it would appear to be a reasonable procedure in most patients in deep coma.

What of the Future? As the assessment of the patient in deep coma becomes more exact and routine, it is reasonable to expect continued progress in both diagnosis and treatment, particularly in the following areas: 1) The routine collection and correlation of data concerning the clinical examination, drug and metabolic levels, electroencephalogram, and cerebral blood flow will allow dependable decisions concerning cerebral brain death to be made at any point in the patient's course in a matter of one or two hours. As outlined previously, some combinations of these findings will supplant the Harvard criteria (4) as a dependable basis for determining cerebral or brain death. 2) Complete assessment of the patient in coma will occur earlier and nearer the time of the original insult to the brain, thus allowing a better understanding of the patterns of evolving brain damage or recovery. 3) An understanding of the usual course of coma in particular situations, such as cerebral trauma, cerebral anoxia from cardiac standstill, cerebral hemorrhage, drug overdose, and so forth, will allow better management and better judgment of prognosis in each particular situation. 4) A number of distinctive EEG patterns seen in deep coma will be more widely recognized and their significance will be validated by large series of cases. 5) Criteria concerning evaluation of deep coma which, at present, apply mainly to adults will be expanded to include an understanding of the situation in infants and children. 6) As clinical information and information from laboratory work accumulate, useful means of altering the course of severe brain damage by the application of a variety of medical and surgical treatments will be found.

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