MEASUREMENT OF DEPTH OF ANAESTHESIA

BY

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It is a fitting place to begin an essay on “Measurement of depth of anaesthesia” with reference to the work of John Snow. He was the first qualified physician to devote his full time to anaesthesia and published his monograph On the Inhalation of the Vapour of Ether in 1847.

He described the progression from conscious normality to respiratory paralysis with ether and quoted five recognizable stages. He deduced that the patient was completely ready for operation when all excitomotor activity had ceased, when muscular relaxation was present and when the breathing became automatic and regular, his fourth stage of etherization. In patients who did not show much muscular rigidity in the third stage, he allowed operation to begin and anticipated signs such as moaning, flinching and movement which, although they were signs of pain, did not interfere with operation or reach consciousness. He was fully aware that the only reason for carrying anaesthesia deeper than the third stage was to control muscle rigidity and involuntary movement which might interfere with operation, and he often maintained anaesthesia in the amnesic stage where full analgesia was present.

In the years following, the signs of anaesthesia were further categorized and were finally presented in fairly complete form by Guedel (1937). The stages and planes of inhalational anaesthesia which he designated still form the standard reference.

In the first few years following the clinical use of tubocurarine in 1942, little change occurred in the method of measurement of anaesthetic depth. Full anaesthesia to stage III(i) (Guedel) was commonly obtained and tubocurarine in relatively small doses was given to produce good muscular relaxation. Respiration was assisted if it was judged clinically to have become inadequate. Since assistance to respiration was difficult and rather a matter of chance that it would produce adequate ventilation, it became common to control respiration. Thus two valuable signs of the depth of anaesthesia were eliminated, the character of respiration and the presence of muscular relaxation.

CLINICAL SIGNS OF DEPTH OF ANAESTHESIA

It did not take long for anaesthetists to realize that it mattered little to the patient whether his flexor reflexes were abolished at the afferent or efferent sides of their arcs, and the use of large doses of relaxants combined with light anaesthesia became commonplace. Since such practice confers benefits in the form of reduced anaesthetic toxicity and since tubocurarine is virtually non-toxic, the technique is firmly established. Anaesthetists now advocate and practise the use of the lightest general anaesthesia. The anaesthetic literature contains many reports of consciousness during anaesthesia with good memory of events occurring during the operation, but fortunately such episodes are rarely accompanied by pain. Most anaesthetists on questioning will admit to having had some patients recall incidents which occurred during operation.

The measurement of depth of anaesthesia by objective means therefore assumes considerable importance in clinical practice. The factors which lead to anaesthesia becoming unduly light have been documented (Waters, 1968) when they are associated with errors in technique and apparatus. The anaesthetic mixture can become accidentally withdrawn or unduly diluted but this implies that the anaesthetist is relying on his experience as to what anaesthetic concentration is required for anaesthesia, rather than his ability to detect that insufficient is being given.

Some well-known but unsubstantiated signs are used and accepted as indicating too light anaesthesia. Eyelid movement, wrinkling of the forehead, slight limb movement, pupillary dilatation, lachrymation, sweating, are all noted, yet these are reflex phenomena which can also be abolished.
by agents without anaesthetic potency. Awareness during anaesthesia is not necessarily accompanied by any of these signs as evidenced by the report by Bahl and Wadwa (1968) which is typical of many.

**OBJECTIVE MEASUREMENTS: THE ELECTROENCEPHALOGRAM**

Objective methods of depth assessment have been centred round the electrical activity of the brain as recorded from scalp electrodes. Most modern textbooks on anaesthesia review this subject adequately but it is pertinent to comment on the findings and the method. The frequency of the normal electroencephalogram varies between 1 cycle in 2 seconds to 25 or more cycles per second, the findings being dependent upon the age of the subject, electrode placement, stage of alertness, sensory input and many other factors. The amplitude varies between 10 microvolts and 100 microvolts.

In anaesthetic practice it has become conventional to record from two leads placed on the frontal and occipital regions to obtain an average of electrical activity over a large area of brain. Potential changes are detected from the area of cerebral cortex underlying each electrode, the recording representing the difference in potential between the two points. In this circumstance, the predominant rhythm is the alpha rhythm, conventionally defined as being between 8 and 14 cycles per second with an amplitude of about 20 microvolts in the adult. Evidence has been presented that its origin lies in thalamo-cortical reverberation, inhibitory activity of long (100 m.sec) duration synchronizing the activity of cortical cells (Anderson and Eccles, 1962).

The changes seen in normal adults follow a fairly well defined sequence and represent complex but not understood alterations in total cerebral electrical activity. With the lightest of anaesthesia there is usually an initial speeding up of activity which then progressively slows as anaesthesia deepens. Simultaneously amplitude increases to 200–300 microvolts at its largest, deep anaesthesia being associated with large amplitude slow waves interspersed with periods with no detectable activity. The deepest stages are associated with a flat or isoelectric tracing. These changes have been correlated with the concentrations of anaesthetic drug present simultaneously in the blood for most inhalational anaesthetics. Although correlation is reasonably good between individuals and is fairly constant for a given circulating anaesthetic concentration in any one individual, other factors interfere markedly. Anoxia, hypercarbia and hypocarbia, hypotension, surgical stimulation and hypothermia all produce effects of their own so that the well-defined classical patterns are seen only in carefully controlled conditions usually with the administration of only the one drug that is under investigation. Galla, Rocco and Vandam (1958) determined that correlation with Guedel signs was poor.

In modern anaesthesia these findings are largely irrelevant and the subject is well reviewed by Marshall, Longley and Stanton (1965). These authors point out that the tracing from an adequately anaesthetized patient (in the modern sense) may be quite indistinguishable from that recorded in the same individual when he was awake, and that conversely, deep patterns may be seen when the individual is naturally sleeping. This review indicates that the principal value of the conventional electroencephalogram in modern anaesthesia lies in the detection of abnormal or unexpected patterns which might arise in otherwise steady state conditions, but it is quite clear that it does not afford a ready means of determining the depth of anaesthesia within the limits used today.

**SENSORY EVOKED RESPONSES**

More recently, sensory evoked responses, recorded from scalp electrodes, have been extensively investigated. In a normal individual the application of a stimulus such as a bright flash of light to the eyes results sometimes in a just perceptible wave in the electroencephalogram taken from the occipital region. Stimulation of a peripheral nerve produces a similar effect in the postcentral area. The average amplitude of these responses is about 3–5 microvolts and they are therefore swamped in the general on-going electrical activity of the brain. Dawson (1954) described a technique to demonstrate these potentials clearly. In principle, it consists of the repeated presentation of a stimulus to the individual, the ensuing responses being added together. The on-going activity of the brain is random with respect to the stimulus but
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the activity elicited as a result of its presentation tends to be related to it in the temporal sense. An average response can therefore be obtained from 50 or more stimuli, which clearly reveals the nature of the responses.

The evoked response is not simple or easy of interpretation when it is recorded from scalp electrodes, from the surface of the cerebral cortex, or even from neurones in the cortex itself (Robson, 1967). The most definite statement that one can make about the short-latency component is that it indicates that the afferent volley has reached the cortex, the latency indicating the conduction time of the afferent pathway.

Each afferent volley in a peripheral nerve results in a small negative deflection at the scalp followed by a larger positive deflection. The negative deflection is attributed to presynaptic potentials in afferent fibres to the cortex, the succeeding positive potential being due to postsynaptic potentials of cortical neurones which fire in response. There is, however, no correlation between these slow waves and the activity of neurones in the cortex so that interpretation of these scalp potentials is quite uncertain (Amassian et al., 1964).

Most commonly, visual evoked responses have been investigated since the stimulus is easy to apply, it can be controlled as to intensity and duration, and it gives rise to a well-characterized response recorded from the occipital area. Comparisons between the results from different workers are difficult to make because electrode placement and light intensity are very important factors in determining the form of the response. The visual response consists of a primary negative wave, the peak of which occurs at 33 milliseconds (I), followed by a positive wave (II) with its peak at 45 milliseconds, succeeded by a further negative peak (III) at 70 milliseconds and a positive at about 100 milliseconds (IV) (fig. 1).

Domino and his colleagues (1963) studied the alterations which anaesthetic drugs produce in the form of the visually evoked response in man. They investigated the effects of thiamylal sodium, diethyl ether, halothane, methoxyflurane, cyclopropane and nitrous oxide, but used depths of anaesthesia equivalent to Guedel III(i) at a minimum, progressing to Guedel III(ii-iii) with most drugs except nitrous oxide. At these depths of anaesthesia differences between drugs were quite marked. Thiamylal sodium, cyclopropane and ether could abolish the evoked response in planes (ii) or (iii). Halothane and methoxyflurane did not obliterate the response but enhanced some components, notably wave IV. In general, light levels of anaesthesia enhanced waves II and III but these were depressed and wave IV enhanced, when the depth increased. Increasing depth was also accompanied by increasing latency of the response. Nitrous oxide and oxygen (80:20) at a depth designated as Guedel III(i) caused a slight enhancement of the early components of the visually evoked response.

It is clear that visually evoked responses can be demonstrated to be altered by anaesthetics but not at the depths of anaesthesia in current use in clinical practice. The present lack of knowledge of the meaning and origin of these responses, the variations caused by all the factors which determine the electroencephalographic wave form upon which they depend and the multifactorial situation of an ordinary surgical operation are against this becoming a useful technique for the measurement of depth of anaesthesia in the immediate future. Moreover, to carry it out with reasonable electronic sophistication would require a minimum expenditure of £5,000.

CONCLUDING COMMENTS

The depth of anaesthesia used commonly is probably late stage I to stage II of Guedel's classification, the stage of amnesia with full analgesia. The only objective method of measurement of the amnesic state, the estimation of the individual's
appreciation of the passage of time (Robson et al., 1960), is not applicable to the surgical patient in everyday practice. Artusio (1954) has successfully used and measured the stage of amnesia, but again this is not possible with full muscular paralysis.

One must therefore conclude that there is as yet no practical means of measurement of the depth of anaesthesia within the range required today. The complexity and variability of the nervous system are such that a great deal more knowledge of its normal functions will have to be gained before it is likely that our efforts to measure small and significant impairment will be crowned with success.

One cannot, however, bring this discussion to an end on this negative note. We have a very practical problem of patients being awake during surgical operations and if we cannot yet measure the depth of anaesthesia, we can at least make some recommendations which might help to prevent it. One must never ignore the reflex signs already noted and when they do occur the action to be taken must consist of deepening the anaesthetic. This implies that the patient is continually observed during operation with the implication that proper lighting of the face is provided. It is also very important for the anaesthetist to ask himself what difference in morbidity or mortality exists between patients anaesthetized with minimal nitrous oxide, oxygen and hyperventilation and those in whom supplements of narcotics or volatile or gaseous agents are administered to prevent the accidental assumption of the waking state.

REFERENCES


