HANDBOOK OF ELECTROENCEPHALOGRAPHY AND CLINICAL NEUROPHYSIOLOGY

EDITOR-IN-CHIEF A. REMOND

VOLUME 14A

Clinical EEG, IV

EDITOR: O. MAGNUS
St. Ursula Kliniek, Wassenaar (The Netherlands)

PART A

Cardiac and Vascular Diseases

EDITOR: J.H.A. VAN DER DRIFT
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Centre National de la Recherche Scientifique, Paris (France)

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International Federation of Societies for EEG and Clinical Neurophysiology

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International Federation of Societies for EEG and Clinical Neurophysiology

A great need has long been felt for a Handbook giving a complete picture of the present-day knowledge on the electrical activity of the nervous system.

The International Federation of Societies for EEG and Clinical Neurophysiology is happy to be able to present such a Handbook, of which this is a small part.

The decision to prepare this work was made formally by the Federation at its VIIth International Congress. Since then nearly two hundred specialists from all over the world have collaborated in writing the Handbook, each part being prepared jointly by a team of writers.

The Handbook begins with an appraisal of 40 years of achievements by pioneers in these fields and an evaluation of the current use and future perspectives of EEG and EMG. The work subsequently progresses through a wide variety of topics—for example, an analysis of the basic principles of the electrogenesis of the nervous system; a critical review of techniques and methods, including data processing; a description of the normal EEG from birth to death, with special consideration of the effect of physiological and metabolic variables and of the changes relative to brain function and the individual's behaviour in his environment. Finally, a large clinical section covering the electrical abnormalities in various diseases is introduced by a study of electrographic semeiology and of the rules of diagnostic interpretation.

The Handbook will be published in 16 volumes comprising 40 parts (about 2500 pages altogether). For speed of publication most of the 40 parts will be published separately and in random order.

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PART A

CARDIAC AND VASCULAR DISEASES

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Preface

The main cause of death in many countries is constituted by disorders of the circulatory system to which the cerebro-vascular diseases contribute significantly. For example, in the Netherlands about 1/8 of all causes of death are of cerebro-vascular origin. Hence both a careful study of the pathophysiology and an accurate diagnosis of disturbances of the blood supply to the brain are of major importance to the health of the general population.

Electroencephalography which is a harmless procedure and which detects insufficient cerebral oxygen supply even in very early phases has proven to be of considerable value for diagnosis. The EEG reflects in its own particular way the variable condition of the brain. However there are restrictions to its specificity since electrical phenomena accompanying rather different noxious conditions may be very similar.

The recently developed diagnostic methods including serial angiography, brain scanning and measurements of cerebral blood flow and cerebral metabolism add new knowledge regarding the origin of the EEG phenomena. Instead of diminishing the diagnostic value of the EEG, the information derived from other procedures combined with the EEG data result in a more accurate and better understanding of the condition of the diseased brain.

Wassenaar, November 1971 J. H. A. VAN DER DRIFT

Section I. The Pathogenesis of EEG Changes During Cerebral Anoxia

A. INTRODUCTION

Prawdicz-Neminski, in 1925, reported that during anoxia 11–16 c/sec waves first appeared in the motor and visual cortex of the dog which increased in amplitude during the convulsive stage, then disappeared after about 5 minutes. Since then, many investigations have firmly established the sequence of changes in the EEG caused by anoxia (Bartley and Bishop 1933; Simpson and Derbyshire 1934; Sugar and Gerard 1938; Dell and Bonvallet 1954; Meyer *et al.* 1954, 1955, 1965, 1967; Creutzfeldt *et al.* 1957; Hugelin *et al.* 1959; Bokonjic 1963). The EEG changes are principally the same regardless of the method used to induce anoxia; however, there are some important differences between changes observed in animals and those in man.

In animals, following a latent period in which there is no change (stage A), progressive reduction occurs in EEG amplitude accompanied by an increase in rate which is best termed the "stage of desynchronization" (stage B). During stage B, EEG changes are similar, if not identical, to those observed during the cortical arousal reaction in drowsy animals without anoxia, and numerous investigators have shown this to be caused by sustained reinforcement of cortical neurons from the activating reticular system (Dell and Bonvallet 1954; Creutzfeldt *et al.* 1957; Hugelin *et al.* 1959; Naquet and Fernandez-Guardiola 1961). Activation of the reticular formation is caused by afferent relays from the chemoceptors within the carotid body as well as by the direct effect of anoxia upon the brain stem. This stage of desynchronization observed in animals is not apparent in man where anoxia causes a progressive increase in amplitude and frequency, eventually followed by decreased amplitude and electrical silence. In animals, a progressive increase in amplitude and decrease in frequency occurs only after the stage of desynchronization. High amplitude, predominantly 1–3 c/sec waves are not as remarkable or as prolonged in animals as in man. Single neurons either cease discharging during this period or continue to discharge in irregular bursts, and a tendency toward abnormal synchronization of these neuronal bursts or "synchronizing" becomes apparent. Events during stage C correspond to serious functional disturbances and coincide closely with the occurrence of loss of consciousness (Kasamatsu 1952; Gastaut *et al.* 1961a, b, c; Kornmüller *et al.* 1961; Meyer and Waltz 1961d).

Electrical silence (stage D) follows stage C, with no EEG activity and little or no neuronal activity which is identical in man and animals. If anoxia persists, complete cortical neuronal paralysis characterized by complete cessation of single neuronal electrical activity becomes evident despite maximal activity recorded from the reticular

activating system. The latter is due not only to hypoxic stimulation but also to abolition of the cortical reticular inhibiting system, as Noell and Dombrowski (1947) first suggested, and Hugelin *et al.* (1959) later demonstrated. This release of brain stem activity accounts for the tonic spasms observed during the stage of cortical electrical silence often mistaken for "seizures" (Noell and Dombrowski 1947; Dell *et al.* 1961).

Evoked potentials usually persist longer than spontaneous ones and may be found even in the first second of stage D (Libet *et al.* 1941; Creutzfeldt *et al.* 1957; Naquet and Fernandez-Guardiola 1961).

The duration of stages A, B and C after breathing pure nitrogen is 10 to 20, 10 to 20, and 1 to 10 sec, respectively. These time intervals vary according to the experimental procedure used to produce anoxia and may be affected by the state of cerebral metabolism, which in turn is influenced by drugs and other variables, such as hypothermia, present at the time of anoxia (Hirsch *et al.* 1957a, b).

Sugar and Gerard (1938) defined the duration of anoxia required to bring about electrical silence as "survival time." The length of time that anoxia can persist and still permit reversal of the change when oxygen supply is restored was termed "revival time", and the interval between readmission of oxygen to the start of restoration of EEG activity was termed "recovery time". Hirsch *et al.* (1957a, b), however, designated the interval between readmission of oxygen and start of recovery as "recovery latency" and the interval between readmission of oxygen and full recovery as "recovery time".

B. RECOVERY OF THE EEG

Return of normal cerebral rhythms following anoxia is attained in a reverse manner, *i.e.*, by going through stages C, B, and A. The stage of desynchronization during the recovery phase is characterized by continual cortical neuronal discharges similar to those observed during stage B, but it is not due to cortical reinforcement by the reticular activating system which has been shown to be inhibited at that time. The cause is not known.

As first shown by Sugar and Gerard (1938) and later by Van Harreveld and Tyler (1942) and by Heymans and Bouckaert (1958), a gradient of susceptibility to anoxia exists in the tissue of the nervous system. Phylogenetically new structures such as the telencephalic gray matter and the cerebellar cortex are most susceptible to anoxia, while the midbrain, medulla oblongata, and spinal cord are more resistant. This concept is in good agreement with findings of Himwich *et al.* (1941a, b), who showed that metabolic rates are different in various parts of the brain, with oxygen consumption being highest in the cortex and lowest in the medulla oblongata. Young animals are less susceptible to anoxia than mature ones. (Libet *et al.* 1941; Heymans and Bouckaert 1958).

C. INFLUENCE OF DIFFERENT TYPES OF ANOXIA

Although EEG changes due to anoxia are principally the same whatever their cause, some differences due to variations in the metabolic accompaniments exist, depending upon the type of anoxia.

Anoxic anoxia, produced by inhalation of oxygen-poor or oxygen-free gas mixtures, has been used in man as an activation method for investigating the EEG in normal persons as well as in patients with epilepsy and cerebrovascular disease (Gibbs *et al.* 1935; Meyer and Waltz 1961 d; Gastaut *et al.* 1961 a, b, c). In animals, anoxic anoxia has been used to determine the parameters of oxygen supply necessary to maintain brain function. Several investigators have found that acute anoxic cerebral dysfunction occurs when the cerebral venous pO_2 falls below a threshold of about 19 mm Hg (Noell and Schneider 1944; Opitz and Schneider 1950; Gotoh *et al.* 1965). Other investigators have shown in anaesthetized dogs that some correlation exists between regional oxygen consumption and the frequency pattern of the EEG (Gleichmann *et al.* 1962).

Cerebral blood flow (CBF) and arteriovenous oxygen (AVO_2) differences were recorded by Meyer *et al.* (1967) using the Guyton oxygen analyzer. Within 10 sec after inhalation of 100% nitrogen, AVO_2 began to decrease reaching the lowest point within 90 sec. Since CBF remained unchanged during the first 30–60 sec, the calculated 25% decrease of cerebral metabolic rate for oxygen ($CMRO_2$) from 3.05 to 2.29 ml/100 g/min during this interval was due to progressive reduction of oxygen consumption. At this point changes in EEG activity were not recognizable. $CMRO_2$ continued to decrease steadily despite the fact that the CBF began to increase after 30–60 sec of nitrogen breathing.

The increase in CBF was due in part to the vasodilator effect of anoxia and in part to cerebral acidosis occasioned by accumulation of acid metabolites such as lactic acid. Since this caused loss of autoregulation, the increase in CBF was enhanced by the rise in blood pressure.

The EEG showed moderate slowing of activity when the $CMRO_2$ had decreased by 29% and rapidly deteriorated with slowing first in the theta range, then in the delta range, and finally decreased in amplitude and became flat. When the EEG showed delta activity the $CMRO_2$ had decreased 68% or more.

Measurements of cortical oxygen tension using the polarographic method have shown that cortical anoxia precedes EEG changes (Meyer *et al.* 1954, 1957 b, 1961 b). Concurrent recordings of cortical and cerebral venous pO_2, pCO_2, pH, and sodium and potassium ion activity have shown that cerebral anoxia can cause EEG slowing before significant changes in blood or cortical pCO_2 or pH occur. When the mean cortical pO_2 is reduced below 10 mm Hg, a flux of sodium ions begins from the extracellular space into the brain and presumably into the intracellular space, and extracellular potassium increases. This pattern of sodium and potassium movements represents damage to active sodium transport mechanisms of the brain tissue (Meyer *et al.* 1961c; Gotoh *et al.* 1962). Recently these findings were confirmed using continuous flame photometric analysis of sodium and potassium concentrations in the cerebrospinal fluid during anoxia (Meyer *et al.* 1970).

Associated with the flux of sodium and potassium ions, changes appear in the EEG consisting first of slowing and finally flattening of the record (Meyer *et al.* 1961b, 1962b; Gotoh *et al.* 1962).

The critical average pO_2 values are 10 mm Hg for mean cortical tissue[1] values and 19 mm Hg for capillary venous blood. Below these points a change in brain function takes place as indicated by a change in EEG activity. These figures represent statistical average values and might be expected to be higher than the calculated critical mitochondrial values for pO_2 reported by Jöbsis (1964), who obtained values of approximately 5 mm Hg for a 10% loss of O_2 uptake and 0.5 mm Hg for a 50% inhibition of the respiratory chain, and those of Chance (1957) who showed less than 0.5 mm Hg for total inhibition of the Krebs cycle. Recently, Lübbers (1968) drew attention to the fact that large local differences in tissue pO_2 normally do exist. Depending upon whether the tissue pO_2 electrode was closer to the arterial part of a capillary or to the tissue mitochondria, he observed tissue pO_2 values as high as about 30 mm Hg and as low as 1 mm Hg in non-anoxic normal guinea pig brain.

Asphyxic anoxia produces a combination of cerebral anoxic anoxia and acidosis caused by CO_2 retention in the blood. The EEG changes appear to depend primarily upon anoxic brain damage, the critical level for mean cortical pO_2 being 10 mm Hg as it is in anoxic anoxia. However, cerebral acidosis may be a contributing factor since studies in animals (Meyer *et al.* 1961 a, b) and in man (Meyer *et al.* 1966) have shown that EEG slowing may occur following inhalation of gas mixtures with high CO_2 tensions in the absence of anoxia when jugular venous pH falls below 7.08.

In animals, the first change following asphyxia is usually metabolic activation with temporary increase in surface sodium as a result of the direct effect of hydrogen ions on glial and nerve cells. When cortical pO_2 falls below 6–8 mm Hg, there is a rapid efflux of sodium ions from the extracellular space and an increase in the extracellular potassium ion activity. At this point, the EEG shows diffuse slow waves of increased amplitude. When mean cortical pO_2 falls below 2–4 mm Hg, the sodium and potassium ion movements increase and the EEG becomes isoelectric. At this point the sodium and potassium flux decreases or may even be reversed, indicating that some active transport was obscured by depolarization as long as electrical activity of nerve cells persisted during the stage of EEG deterioration. One minute after electrical silence the sodium pump appeared to fail completely and there was continued loss of sodium ions from the extracellular space (Meyer *et al.* 1961c).

Prompt restoration of respiration resulted in recovery of cortical oxygen tension, ionic homeostasis, and EEG activity. If restoration of respiration was delayed too long, restoration of normal cerebral metabolism, ionic homeostasis and EEG was impossible.

In *acute ischaemic anoxia*, investigators now generally agree, the primary damage to the brain is due to anoxia. Since this early assumption of Lennox *et al.* (1938) and Davis and Wallace (1942), direct evidence from studies in both animals and man has proved this theory to be correct. Thus, generally the same sequence of events occurs in ischaemic anoxia as in anoxic or asphyxic anoxia.

However, with regard to the time course of EEG change, marked differences have

[1] A tissue electrode actually gives mean values for arterioles, capillaries and veins underlying the electrode as well as the tissue.

been found by many investigators (Sugar and Gerard 1938; Van Harreveld 1947; Harvey and Rasmussen 1951; Ten Cate and Horsten 1952, 1956; Gänshirt *et al.* 1954; Meyer *et al.* 1954; Thorn and Heitmann 1954; Hirsch *et al.* 1957 a, b). In 1954, Meyer *et al.* proved in experiments on cats and monkeys that adequate collateral circulation is crucial in determining the survival time of brain function in localized ischaemic anoxia. The reduction of cortical oxygen tension and, hence, the change in EEG activity depended almost entirely upon the effectiveness of the collateral circulation. Since the collateral circulation in cerebral ischaemia is dependent upon the maintenance of a sufficient systemic blood pressure (Meyer and Denny-Brown 1957a), it is evident that differences in blood pressure during ischaemia may contribute to differences in the time course of the EEG changes. Other factors influencing the time course of EEG changes include the depth of anaesthesia, duration of surgery, respiratory support, level of arterial CO_2, and body temperature. Hirsch *et al.* (1957a) have shown that blood pressure also greatly affects revival times. From their experiments with the isolated, perfused cat brain, it was evident that a sufficient level of systemic blood pressure was necessary to revive brain function after discontinuing ischaemia.

Recently, Lee *et al.* (1966) demonstrated in monkeys that following occlusion of both common carotid and both vertebral arteries, EEG changes occurred only when the mean arterial pressure was below 160 mm Hg.

Masland and Netsky (1961) carried out an interesting study in which localized ischaemic necrosis of the brain was caused by small emboli. The resulting localized areas of electrical silence were later found histologically to be necrotic. Slow waves did not appear until later, and then occurred in areas surrounding the softening.

D. HYPERVENTILATION

Davis and Wallace (1942) were the first to suggest that EEG changes during hyperventilation might be due to cerebral vasoconstriction resulting in ischemic anoxia. Gibbs *et al.* (1935) and Lennox *et al.* (1938) had concluded earlier that EEG slowing during hyperventilation was due to the loss of some hypothetical neurogenic action of CO_2. Lubin and Price (1942) showed that CO_2 rather than pH was the causative factor in producing the effect of hyperventilation upon cortical electrical activity, an observation which Swanson *et al.* (1958) later confirmed. The use of the Fick principle by Kety and Schmidt (1946) for measuring cerebral blood flow and cerebral metabolic rates for glucose and oxygen has proved conclusively that severe vasoconstriction is caused by hyperventilation. This finding was further confirmed by the work of Darrow and Graf (1951), who showed that cortical pallor and vasoconstriction accompanied by EEG slowing occurred during hyperventilation.

From studies employing concurrent measurements of cortical blood flow, pCO_2, pO_2, and pH in combination with EEG recording, Meyer and Gotoh (1960a) concluded that EEG slowing during hyperventilation was the result of hypocapnic cerebral vasoconstriction which caused the ischaemic anoxia.

Gotoh *et al.* (1965) measured the cerebral effects of hyperventilation in man and

demonstrated that EEG slowing during hypocapnia was due mainly to cerebral ischaemic anoxia but also was due in part to the Bohr effect whereby the rise in pH releases oxygen less readily from haemoglobin to the tissues. EEG slowing was noted when the cerebral venous pO_2 fell below 21.0 ± 0.88 mm Hg regardless of change in cerebral venous pCO_2 and pH.

Reivich *et al.* (1966) confirmed these conclusions by employing hyperventilation using different gas mixtures in a hyperbaric chamber and found the effects of hyperventilation on the EEG to be clearly due to ischaemic cerebral hypoxia.

E. METABOLIC CHANGES DURING ANOXIA

Changes in cerebral metabolism resulting from anoxia and ischaemia are similar, the primary effect being a reduction in oxygen available to tissue. The brain derives its energy almost exclusively from oxidative glucose metabolism which briefly can be described as:

$$\text{glucose} + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{energy}.$$

The energy produced from this reaction is 36 high-energy phosphate bonds, the majority being derived from oxidation of nicotinamide adenine dinucleotide hydrogenase (NADH) at the respiratory chain. If tissue pO_2 is insufficient to meet the oxygen requirements of the respiratory chain, the glucose metabolism shifts progressively to the anaerobic pathways (Pasteur effect) whereby

$$\text{glucose} \rightarrow 2 \text{ lactic acid} + \text{energy}.$$

Since this reaction provides a net yield of only 2 high-energy bonds, it is far less economical (about 1/18 as efficient) and is unable to provide sufficient energy for normal functional cell activity, although the tissue may survive if total anoxia is not prolonged. During periods of brief hypoxia, anaerobic glycolysis may make possible both survival and revival of brain tissue.

Since lactic acid accumulates during anoxia, this metabolite increases measurably in the brain tissue, spinal fluid, and cerebral venous blood (Pasteur effect). Siesjö *et al.* (1968) and Granholm and Siesjö (1969) found that the lactate:pyruvate ratio in brain tissue and cerebrospinal fluid reflects the redox state of the NADH/NAD system according to the formula:

$$\frac{\text{lactate}}{\text{pyruvate}} = \frac{\text{NADH}}{\text{NAD}} \cdot \frac{H^+}{k}$$

The concomitant increase of hydrogen ion concentration during anoxia due to lactic acidosis measured as a decrease in tissue pH exerts considerable influence upon regional as well as average cerebral blood flow and metabolism.

Reactive hyperaemia, hyperoxia and luxury perfusion. As shown by Meyer *et al.* (1954), localized tissue acidosis caused by ischaemic anoxia results in regional vasodilatation and, hence, local reactive hyperaemia. The authors postulated that if ischaemic anoxia leads to decreased $CMRO_2$, then hyperoxia could be due to a

combination of reactive hyperaemia plus depressed metabolism. Lassen (1966) termed this situation the "luxury perfusion syndrome". It may occur in areas bordering ischaemic brain tissue or after restoring blood flow in the entire territory of a formerly occluded artery. Since this state is characterized by vasomotor paralysis due to cerebral acidosis (Langfitt *et al.* 1965), cerebral blood flow follows passively changes in blood pressure (loss of autoregulation) and may not be influenced by changes in arterial pCO_2 (loss of CO_2 reactivity).

Bohr effect. A second consequence of cerebral acidosis is due to the Bohr effect; namely, if blood becomes acid, haemoglobin releases oxygen more readily to the tissue. Therefore, acidosis caused by cerebral ischaemia tends to increase both cerebral tissue and cerebral venous pO_2 (Meyer *et al.* 1961b).

Influence of acidity upon tissue enzymes. In CO_2 narcosis, Meyer *et al.* (1966) showed that a close correlation exists between the appearance of EEG slowing and jugular venous pH. Thus, it appears that during severe anoxia acidosis *per se* might be of some influence on nerve cell function, although very little is known about the direct mechanism involved.

Active ion transport mechanisms during anoxia. Some speculation has been made that the effects of high hydrogen ion concentrations are based on interactions at the cell membranes, particularly with sodium or potassium ionic movements. In this survey, no attempt is made to review what is known about active and passive transport mechanisms (Boyle and Conway 1941; Hodgkin *et al.* 1952a, b, c, d, 1953; Ussing 1957; Rosenberg and Wilbrandt 1963; Haas 1967; Meyer *et al.* 1970). However, from the evidence reported, it is apparent that cell excitability is dependent upon certain ion concentration differences across cell membranes.

Excitable cells normally are polarized, *i.e.*, they maintain low intracellular sodium concentrations whereas the intracellular potassium concentrations remain high. This polarization is characterized by an electrical potential, the intracellular space being electrically negative compared with the extracellular compartment. The ionic gradient across the cell membrane is maintained by energy-consuming processes which are probably directly linked to adenosinetriphosphatase (ATPase) activities (Glynn 1959; Hoffman *et al.* 1960), although other mechanisms have been proposed.

Depolarization takes place during excitation and is characterized by a passive influx of sodium ions into the cell and an efflux of potassium ions accompanied by changes in the membrane potential.

During repolarization, energy-consuming processes restore the ion concentration gradients so that the cell again becomes excitable. Therefore, it is apparent that the cerebral electrical activity is dependent upon active, energy-consuming processes and must cease if the cerebral energy providing metabolism is insufficient (for instance, during anoxia). If the anoxia is transient, recovery will follow. Ultimately, the EEG reflects these ionic changes dependent on energy metabolism and transport mechanisms and, hence, is a sensitive indicator of disturbances of cerebral metabolism such as anoxia.

Section II. The EEG in Cerebro-Vascular Disorders in Relation to Pathology

A. INTRODUCTION

In the preceding Section intra-vitam methods to investigate ischaemic brain disease were discussed. However, frequently it is impossible to correlate the neuropathological substratum with the EEG since the condition of the brain may have changed between the recording of the EEG and death. Furthermore, it is important to realize that ischaemic lesions must exist for some time before they give rise to alterations of the brain which can be detected with routine neuropathological methods. On the other hand arrest of circulation will induce changes in the EEG within 6 seconds. Moreover it may be found at autopsy that many factors are involved together, like ischaemia, oedema and displacement of brain substance and it is difficult to evaluate their relative importance. So we must confess that our knowledge about the actual pathology causing the alterations in the EEG in ischaemic vascular disease is still very limited. When intracranial haemorrhage is involved it is even more complex to correlate the EEG with the neuropathological substratum. Particularly aspects of cerebral pathology will be discussed which may be significant to interpret the EEG features.

The EEG retains its diagnostic value in cerebro-vascular disease. Since recently developed new methods like measurement of cerebral circulation, and cerebral blood flow and metabolism have proven to be valuable tools for obtaining new knowledge regarding the origin of EEG phenomena, this Section will not be confined solely to a description of the EEG signs found in cerebral ischaemia. It will also consider the relation between EEG, clinical findings, regional circulation, regional cerebral blood flow (r.C.B.F.) and autopsy results as did Ingvar in 1966.

To prevent misunderstanding the terms circulation and r.C.B.F. as used in the present Section are defined as follows. Regional circulation (*sensu strictiori*) is meant exclusively to indicate the velocity of blood passing a certain area of the brain. It is determined by means of serial-angiography as well as by the use of intra-arterially administered non-diffusible radio-active isotopes. Since this type of gamma emitting substance does not leave the lumen of the blood vessels it produces an intravascular clearance curve with a duration of seconds (Fazio *et al.* 1962; Van den Berg and Van der Drift 1962). Regional cerebral blood flow is measured from the clearance curve of intra arterially administered diffusible radio-active inert gas Kr-85 or Xe-133 (Lassen *et al.* 1963; Ingvar *et al.* 1965; Høedt-Rasmussen *et al.* 1966), or inhaled Xe-133 (O'Brien and Veal 1966). The gamma-emitting inert gas rapidly passes from the vascular lumen into the brain tissue. The uptake and the subsequent extravasal clearance of such a diffusible isotope occurs largely within a period of circa

10 minutes. It allows fairly local measurements over different regions of the hemisphere. In contrast to the results of intravasal clearance the extravasal ones are influenced by the condition of the brain tissue itself.

For an extensive description of the *recording techniques* of the EEG, see Magnus (1961). Only a few remarks regarding the time constant are made here. Certain types of cerebral lesions accompanied by cortical activity of very low frequencies (1 cycle per 1–3 sec) induce the necessity to record with a time constant which does not substantially reduce the sensitivity of the amplifiers for these frequencies, *i.e.* a time constant of at least 0.6 sec, preferably 1 sec.

However, in the presence of a considerable amount of slow activity it is often difficult to study the faster background activities since the latter usually have a much lower voltage than the delta patterns. In many cases it is very useful to record for some time with a time constant of approximately 0.03 sec, thus cutting off the lower frequencies and allowing an increase of gain. This facilitates study of the background activities of theta, alpha and beta frequencies, and detection of its local depression.

Unilateral phenomena encountered in the EEG of patients suffering from organic brain disease include attenuation of background activities of the theta, alpha and beta range. The presence of a silent area and the occurrence of polymorphic delta activity and sharp activity are usually the most important localizing signs. In this connection it should be mentioned that depression of the alpha activity may be due to various factors, such as damage to the cortex itself, lesion of the antero-ventral thalamic nucleus (Jasper and Van Buren, 1953) and desynchronization. In case of polymorphic delta activity the slowest and the most irregular delta activity is generally nearest to the lesion. Intermittent and/or rhythmic delta activity has far less value for the localization of pathologic processes. The same is true for theta activity.

Sharp activity (local spikes, spike and wave variants and sharp waves) is commonly of little value to localize cerebro-vascular lesions.

Bilateral signs include, among others, intermittent rhythmic delta activity. Frontal intermittent rhythmic delta activity (FIRDA) may be produced by an irritative lesion of the anterior part of the brain stem, *i.e.* of the dorso-medial thalamic nuclei (Van der Drift 1957; Cordeau 1959) or by an irritative lesion of the anterior part of the hypothalamus (Passouant *et al.* 1955). It is also found in medio-frontal processes. Intermittent rhythmic delta activity may also occur in other locations; if temporally as seen in deep temporal lesions it may be asynchronous in contrast to FIRDA. Generally speaking diffuse delta and slow theta activities may be recorded in the presence of a disorder in both cerebral hemispheres or in the brain stem, low voltage fast activity (not specifically) in patients with vertebro-basilar ischaemia, whilst variations in background activities indicate a disturbance in consciousness or attention.

To provoke EEG abnormalities in patients with latent carotid or vertebro-basilar insufficiency various methods may be applied in order to induce hypoxia, fall in blood pressure or impairment of carotid or vertebral flow.

Hypoxia (Gastaut *et al.* 1961a) can be induced by means of hyperventilation—a routine procedure in electro-encephalography—or by inhalation of a gas mixture with a low oxygen content. Either method may bring out latent ischaemic abnormali-