Electrodes

13. Silver-plated electrodes held by a cup are quick and easy to adjust. Electrodes fixed in waxed cloth are less flexible and are probably more resistant to patient discomfort. Electrode wires should be prefabricated, and where possible, the use of a local antigenic solution will reduce the number of patients with skin sensitivity reactions. Electrodes should be regularly checked for noise.

Recording

14. The 10-20 electrode system (see Appendix) is preferred. Nineteen 21 electrodes should be used for a first examination in all patients over the age of 10 years; such a number allows satisfactory separation of rhythms while not unduly reducing the risk of missing a local spike. Additional electrodes may be added for precise localization.

15. Both "bipolar" and "unipolar" recording are advantageous and should be used in a routine examination. Bipolar recording should always include electrodes with linked serial pairs in straight anteroposterior and transverse lines, preferably with leads as well as with unipolar electrode distances. The source of misinterpretation inherent in the use of unipolar electrodes should be constantly kept in mind.

16. On the record, traces from the right side should take precedence over those from the left and a transverse sequence should be read from left to right. In anteroposterior recordings the sequence Right, Right, Right-Left, Left, Left-Right is preferred to alternation.

17. A minimum period of 20 minutes is recommended for a first examination. A large number of channels does not permit significant reduction of this time.

18. All changes in recording parameters and the state of the patient, as well as stimulations applied, should be indicated on the record clearly and in understandable symbols (e.g., at each change of gain the resulting sensitivity should be recorded in ml/mm).

19. The convention that negative change of potential at grid I results in an upward pen deflection may be extended by speaking of the lead to this grid as "Black" and indicating it in diagrams by a solid line. Conversely, the lead to grid II, positivity of which causes an upward deflection, is spoken of as "White" and drawn as a broken line.

P. Activation

20. Each routine examination should include opening and closing and a period of hyperventilation of at least 3 minutes. Photic stimulation is a useful method which can easily be employed routinely. Electronic stroscopes are without danger to the retina, which is not true of some other sources.

21. Sleep, either spontaneous or induced, is of value, particularly in convulsive disorders in children.

22. Convulsant drugs (Morphine, Meptaline, etc.) are used particularly for localization in cases of epilepsy.

Evidently this is not an exclusive list. Several methods of activation may be used advantageously in combination. It is to be noted that considerable disagreement still exists as to the specific values of the various activating procedures. In general the safest and simplest should be used first.

APPENDIX

THE TEN TWENTY ELECTRODE SYSTEM OF THE INTERNATIONAL FEDERATION

At the First International Congress in London in 1947, it was recommended that an attempt be made to standardize the placement of electrodes on the head to facilitate comparison of results taken in different laboratories and to make it possible to have more satisfactory communication of results in the literature. Dr. Jasper was appointed to study this problem and report recommendations to the Second International Congress in Paris in 1949.

Systems of electrode placements then in current use were studied, particularly from The National Hospital, Queen Square, the system used by Drs. Schwan and Abbott at the Massachusetts General Hospital in Boston, and the system then in current use at the Montreal Neurological Institute. It was found that only minor differences existed between these several systems of electrode placement, though the designations used (numbers, letters, etc.) were entirely different. It was felt, therefore, that it would be possible to design a common system, making use of the advantages of the various systems then in use, so that common agreement could be reached and an international standard established.

Certain principles were laid down as follows:

1. Positions of electrodes should be determined by measurement from standard landmarks on the skull. Measurements should be proportional to skull size and shape, as far as possible.

2. Adequate coverage of all parts of the head should be provided with standard designated positions even though all would not be used in a given examination.

3. Designations of positions should be in terms of brain areas (Frontal, Parietal, etc.) rather than in numbers so that communication would become more meaningful to the non-specialist.

4. Anatomical studies should be carried out to determine the cortical areas most likely to be found beneath each of the standard electrode positions in the average subject.

Method of Measurement.

The anterior-posterior measurements are based upon the distance between the frontal and the union of the vertex in the mid-line. Five points are then marked along this line, designated Frontal pole (FP), Frontal (F), Central (C), Parietal (P), and Occi-
The first point (Fp) is 10 per cent of the nasion-inion distance above the nasion; the second point (F) is 20 per cent of this distance back from the point Fp, and so on in 20 per cent steps back for the Central, Parietal, and Occipital mid-line points (hence the name 10-20 system). These divisions are

be 6 cm. between the C and D lines, and 6 cm. between P and O. The occipital points are then 3 cm. above the inion.

Lateral measurements are based upon the Central coronal plane. The distance is first measured from left to right preauricular points (felt as depression at the root of the zygoma just anterior to the tragus). These points were selected because they seemed easier to determine with accuracy than the external angular points. Be sure the tape is passing through the pre-auricular point on either side. The Central points are then marked 20 per cent of the distance above the temporal points, as shown in figure 2.

Then A-P line of electrodes over the temporal lobe, frontal to occipital, is determined by measuring the distance between the Fp mid-line point (as determined above), through the T position of the Central line, and back to the mid-occipital point. The F electrode position is then marked 10 per cent of the distance from the mid-line in front, and the occipital electrode position 10 per cent of the distance from the mid-line in back. The inferior Frontal and posterior temporal positions then fall 20 per cent of the distance from the Fp and O electrodes respectively along this line, as shown in figure 3.

Superior view with cross section of skull through the 10-20 line of electrodes illustrating the 10-20 system applied in direction as described in the text.

The remaining mid-Frontal (F3 and F4) and parietal (F3 and F4) electrodes are then placed along the Frontal and Parietal coronal lines respectively, equidistant between the mid-line temporal line of electrodes on either side, as shown in figure 4.

This provides 10 additional electrodes. For the purposes of all electrodes, the electrode speed, with the exception of the central electrode, is 1 cm. per second. The electrodes are placed on the skin with a break after each point, being careful to avoid fat or oil beneath the skin.
This provides a total of 21 standard electrode locations, including midline electrodes in Frontal, Central, and Parietal regions, and the two auricular electrodes. Electrode separations are approximately the same for all pairs in the A-P direction. Coronal lines of electrodes are also approximately equally spaced, with the exception of the shorter distance between the auricular and mid-temporal points. Additional electrodes may be placed between any of these principal standard positions for especially refined localization studies (with numbers provided for these special positions as well, as indicated below).

Designations of Electrode Positions.

Traditional anatomical terms have been employed to designate electrode positions over the various lobes of the brain, with the exception of the Central region, which is, strictly speaking, partly frontal and partly parietal. It represents the cortex in the vicinity of the Central Sulcus, both pre and post-central. It is sometimes called the sensori-motor area.

In order to differentiate between homologous positions over left and right hemispheres it was decided to use even numbers as subscripts for the right hemisphere, and odd numbers for the left hemisphere. Fp1, F4, F6, T4, T6, and C2 become standard positions on the lateral aspect of the right hemisphere, while Fp1, F3, F7, C3, F9, T3, T5, and O1 become standard lateral positions over the left hemisphere. These numbers were selected to allow for intermediate positions (e.g. F2, C4, C6, etc.) for special localization studies.

Electrodes at the mid-line in Frontal, Central and Parietal regions were originally designated Fo, Co and Po but this led to some confusion since Po, for example, might be interpreted as parieto-occipital. Consequently the midline positions have been changed to Fz, Cz, and Pz (x for zero). The complete system of placements with designations is shown in figure 4, 5, and 6.

In addition to the positions described above pharyngeal electrodes are designated Pgl or Pgz2 for the left and right side respectively. Additional electrode positions over the posterior fossa are also shown, designated Ch1 and Ch3 (Cerebellar) for the left and right sides respectively.

Anatomical Studies.

After these electrode positions were agreed upon, anatomical studies were carried out with the help of Dr. Penfield, Dr. McRae and Dr. Carew to determine the cortical areas over which each position would lie in the average brain. Two methods were employed: (1) metal clips placed along the Central and Sylvian fissures at operation were then used to identify these fissures in X-ray studies of the skull after the EEG electrodes had been applied, and (2) electrode positions were carefully marked in the head of cadavers, drill holes placed through the skull and the cortex marked with India ink in each position before removing the brain for examination. Brains with gross lesions or local atrophy were excluded.

Although some variability was found, and is to be expected, the position of the two principle fissures

![Fig. 4](image-url)
Fig. 5
Frontal superior and posterior views showing all the standard electrode positions as described in the text.

Fig. 6
A single plane projection of the head, showing all standard positions and the location of the Rolando and Sylvian fissures. The outer circle was drawn at the level of the nasion and inion. The inner circle represents the temporal line of electrodes. This diagram provides a useful plan for the indication of electrode placements in routine recording.
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... be within plus or minus about 1 cm. of that location on the skull, provided the head measurement is carefully made and the brain is free of distortion due to expanding or contracting pressure. Due to the obliquity of the Central Fissure, upper central electrodes will usually lie pre-central and the lower ones will be post-central in most cases.

COMMENTS

This electrode system was adopted for trial at the request of the General Assembly of the International Congress in Paris, 1949. Since then it has been adopted by several laboratories and has been found in practice fairly satisfactory. It was not intended that the system should prevent trials of other electrode arrangements, possibly with the view of its revision at a subsequent International Congress. It should help to make more comparable the results obtained in various laboratories. It should certainly facilitate the communication between laboratories, in the literature, and with referring physicians who become familiar with the localization of EEG abnormalities in terms of these standard landmarks.

It should be pointed out that this is not the Montreal system or the Jasper system as it has sometimes been erroneously called. A different method of measurement was used in the Montreal Laboratories prior to 1949 when it was changed to conform to the International Standard recommendation.

Respectfully submitted,

HERBERT H. JASPER, M.D.