Electroencephalography and Clinical Neurophysiology, 1974, 36: 303–307
© Elsevier Scientific Publishing Company, Amsterdam – Printed in The Netherlands



## LABORATORY NOTE

# ANATOMIC CORRELATES OF THE TEN–TWENTY ELECTRODE PLACEMENT SYSTEM IN INFANTS

WARREN T. BLUME, ROBERT C. BUZA AND HARUO OKAZAKI

*Mayo Clinic and Mayo Foundation, Rochester, Minn. 55901 (U.S.A.)*

(Accepted for publication: October 11, 1973)

When the Committee on Methods of Clinical Examination in Electroencephalography (Jasper 1958) recommended the ten–twenty system of electrode placement, its report included results of a study by Penfield *et al.* (1958) relating electrode positions to the underlying adult brain. Subsequently, Hellström *et al.* (1963) estimated the anatomic correlates of a modified ten-twenty system in the infant brain by using the relationships of each to certain features of skull roentgenograms.

To delineate these correlates more directly, we studied the relationships of the standard ten–twenty system to the infant cerebral cortex. Few laboratories use the complete ten-twenty system to record the electroencephalogram (EEG) of infants (Kohler and Blume, unpublished data). In the absence of an internationally accepted system of electrode placement for infants, however, modifications and abbreviations of the ten-twenty system are frequently used. We therefore chose this system for study. We are unaware of any other similar anatomic investigation.

## METHOD AND MATERIAL

Initially, a pilot study on four cadavers was conducted with the following objectives: (1) to perfect our techniques of measurement with the scalp reflected; (2) to discover the most satisfactory marker technique; (3) to decide whether the brain would be better photographed fresh or after formalin fixation; and (4) to determine which photographic angles most accurately illustrated marker positions. This pilot study revealed the following: (1) The most satisfactory markers were pins with short shafts and beaded colored heads (long pins were easily dislodged and india ink tended to run); (2) formalin fixation made for better photographic interpretation; and (3) the lateral view was the most informative photographic angle. With this in mind, we studied seven cadavers at the time of autopsy.

The clinical findings had given no hint of central nervous system disease or malformation. No gross skull deformities were present. Except for one 2-year-old child, all patients had been less than 4 months of age at the time of death. The brain of the 2-year-old weighed 1,165 g; the weights of the others ranged from 375 to 575 g.

We reflected the scalp to prevent disfigurement, and placed the cadaver in the sitting position. The skull was carefully measured as for the ten–twenty system of electrode placement, according to the methods suggested by International Federation of Societies for Electroencephalography and Clinical Neurophysiology (1961) and by Sannit (1963). We verified equality of interelectrode distances and interhemispheric symmetry. We then drilled 8-mm holes in the skull at the marked positions. With a scalpel, small incisions were made in the underlying dura. We confirmed that the position of the brain relative to the skull did not alter by changing the position of the head. Pins 1–1.5 cm long with colored heads were inserted into the brain at these positions and the brain was removed carefully, in an attempt to avoid dislodging the pins. The brain was then placed in formalin for 10 days. After this, the fixed brain was observed and photographed (Fig. 1); though in some cases, the brain was photographed while fresh. No gross structural abnormalities were present in any brain but, during removal of the brains, some of the pins in one hemisphere of each of three brains did become dislodged, and brain tissue was damaged.

Because of the damage by the pins to three brains, the following results apply to six right and five left hemispheres of the seven cadavers. The results are summarized in Table I.

*Frontopolar electrode (Fp 1, 2).* In every instance this position overlay the superior frontal gyrus, about 1.5–2 cm superior and lateral to its rostral limit.

*Frontal electrode (F 3, 4).* This position corresponded to the middle frontal gyrus in the nine hemispheres in which the gyral pattern was clearly divided into three frontal gyri. In the remaining two hemispheres with relatively random frontal gyral patterns, the electrode position corresponded to the same region.

In eight of the nine hemispheres with well-defined inferior frontal gyral patterns, the electrode position overlay that part of the middle frontal gyrus in apposition with the pars triangularis of the inferior frontal gyrus. In one instance the middle frontal gyrus position corresponded to the junction of the pars triangularis and the pars opercularis of the inferior frontal gyrus. In the remaining two hemispheres with ill-defined patterns of the inferior frontal gyri, the electrode position rested on the middle frontal gyrus,

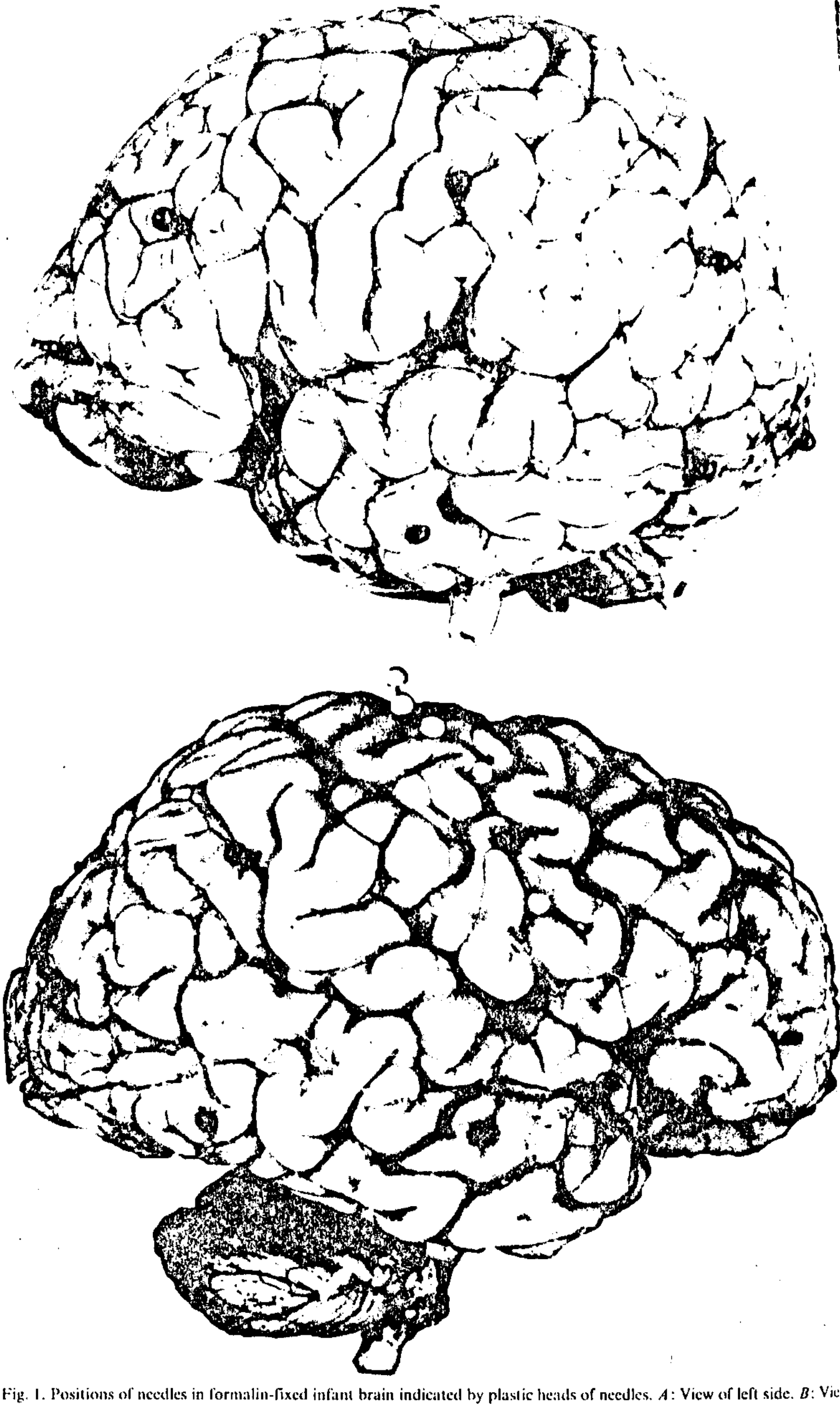

Fig. 1. Positions of needles in formalin-fixed infant brain indicated by plastic heads of needles. *A*: View of left side. *B*: View of right side. Light-colored beads identify central sulcus.

TABLE I

ihesis of findings relating electrode positions to anatomic correlates.

| Electrode position | Anatomic correlate |
|---|---|
| Frontopolar (Fp 1, 2)* | Superior frontal gyrus near rostral limit |
| Frontal (F 3, 4)* | Middle frontal gyrus, part corresponding to pars triangularis of inferior frontal gyrus, nearer inferior frontal sulcus than superior frontal sulcus |
| Central (C 3, 4)† | Postcentral gyrus, posterior to middle frontal gyrus, nearer to inferior frontal sulcus than superior frontal sulcus |
| Parietal (P 3, 4)* | Inferior parietal lobule, junction of supramarginal and angular gyri |
| Occipital (O 1, 2)† | Occipital lobe, 16 mm superior and 14.5 mm lateral to occipital pole |
| Inferior frontal (F 7, 8)* | One-half centimeter inferior to inferior frontal gyrus, pars triangularis |
| Midtemporal (T 3, 4)† | Middle temporal gyrus, inferior to postcentral gyrus |
| Posterior temporal (T 5, 6)* | Interior temporal gyrus at level of occipital notch |

* The norm at this position.
† The average at this position, as norm equaled less than one-half of total.

three-fourths of the distance from the rostral end of the hemisphere to the precentral sulcus.

In six of nine instances the electrode position rested nearer the inferior frontal sulcus than the superior frontal sulcus. In three hemispheres, the points were equidistant from these sulci. This aspect could not be determined in two instances.

*Central electrode (C 3, 4)*. The central electrode position overlay the central sulcus (of Rolando) in four hemispheres of four different brains, the postcentral gyrus in four hemispheres of four brains, and the postcentral sulcus in three hemispheres of two brains. With respect to its vertical orientation, this position corresponded to the posterior limit of the middle frontal gyrus in all nine instances in which this could be determined. In five hemispheres it was nearer the inferior frontal sulcus than the superior frontal sulcus, and in four hemispheres the position lay equidistant from these sulci. In two hemispheres with random frontal gyral patterns, the respective positions lay two-thirds and three-quarters of the distance along the postcentral gyrus from the longitudinal fissure to the lateral sulcus (of Sylvius).

Thus, the position of the central electrode appears to correspond approximately to the representation of lips, face, or thumb sensation or movement (Penfield and Jasper 1954).

*Parietal electrode (P 3, 4)*. The gyral pattern of the parietal lobe varied from brain to brain and even between hemispheres of the same brain.

In all eleven hemispheres the electrode position corresponded to the inferior parietal lobule. In five hemispheres of four brains in which individual gyri could be designated, the position corresponded to the angular gyrus in one hemisphere and to its junction with the supramarginal gyrus in four. In the six hemispheres with more random gyral patterns, the position corresponded to that normally occupied by the posterior part of the supramarginal gyrus in two hemispheres, the anterior part of the angular gyrus in one, and to their junction in three.

In summary, the parietal electrode position corresponded generally to an area occupied by the junction of the supramarginal and angular gyri of the inferior parietal lobule.

*Occipital electrode (O 1, 2)*. In every instance, the occipital electrode overlay the occipital lobe, superior and lateral to the occipital pole. The median vertical distance from the pole was 14 mm, the average being 16 mm (range, 10–25 mm). The median horizontal distance from the pole was 15 mm, the average being 14.5 mm (range, 9–21 mm).

*Inferior frontal electrode (F7, 8)*. The inferior frontal electrode position lay inferior to the inferior frontal gyrus in nine of the eleven hemispheres—within 0.5 cm of the frontal lobe in eight instances and within 1.0 cm of it in the ninth. In seven of the nine hemispheres the inferior frontal gyral pattern was distinct. In two instances the electrode position lay inferior to the pars triangularis, in three instances it was inferior to its junction with the pars opercularis, in one instance it was inferior to its junction with the pars orbitalis and, in the remaining hemisphere, the position rested inferior to the pars opercularis.

In both hemispheres of one brain the electrode position overlay the inferior frontal gyrus itself, that is, the pars triangularis.

In every instance the part of the temporal lobe nearest this electrode placement was the junction of its anterior, superior, and lateral surfaces. The position was adjacent to this junction in one instance, 1 cm distant in four, 1.5–2.0 cm distant in another four, and 2.5 cm distant in both hemispheres of one brain.

*Midtemporal electrode (T 3, 4)*. In every hemisphere this electrode position overlay the temporal lobe, directly below the inferior limit of the postcentral gyrus. This corresponded to a position one-third to one-half of the distance along the middle temporal gyrus from the abbreviated temporal tip to the level of the occipital notch. The midtemporal electrode was situated in relationship to the middle temporal gyrus in five hemispheres, the middle temporal sulcus in three, and the inferior temporal gyrus in two hemispheres of one brain. The larger the brain and its temporal lobe, the more inferiorly placed was this electrode in relationship to the temporal lobe. In one hemisphere the placement overlay the superior temporal gyrus. This temporal lobe was smaller and somewhat more vertically orientated than the others.

*Posterior temporal electrode (T 5, 6).* This placement overlay the inferior temporal gyrus in seven hemispheres -- at the level of the occipital notch in six hemispheres and 1.5 cm anterior to the notch in one. In three instances placement corresponded to the middle temporal gyrus: at the level of the occipital notch in two and 1.0 cm anterior to it in one. In one hemisphere the electrode position was in relationship to the anterior inferior portion of the lateral occipital gyrus.

With respect to the brain of the 2-year-old, the findings were similar to those of the other six brains. The findings were as follows: Fp 2, rostral part of the superior frontal gyrus; F 4, middle frontal gyrus, three-fourths of the distance from the rostral end of the hemisphere to the precentral sulcus; C 4, postcentral gyrus, two-thirds of the distance from the longitudinal fissure to the lateral sulcus; P4, supramarginal gyrus, O 2, 16 mm vertically and 9 mm horizontally from the occipital pole; F 8, adjacent to the inferior border of the pars triangularis of the inferior frontal gyrus, 1.75 cm from the temporal lobe; T 4, middle temporal sulcus; T 6, inferior temporal gyrus at the level of the occipital notch.

## DISCUSSION

Hellström *et al.* (1963), assuming a fixed relationship between cranial bones and underlying gyri, found virtually constant electrode-gyral correlations for every electrode position except their central placement. In comparison, our results show a discrete but definite variability between brains and between hemispheres of the same brain for most of the electrode positions. We believe that the latter situation is most often obtained in practice, despite meticulous measurement of electrode placements. Given the variability of skull configurations and that of lobular and gyral patterns, this finding cannot be unexpected.

The anatomic studies both of Penfield *et al.* (1958) and Hellström *et al.* (1963) place the central electrode over the precentral gyrus or the central sulcus, whereas in our investigation its average location is over the postcentral gyrus. There is a plausible explanation for the findings in each of these studies. First, the size of the parietal lobe relative to the frontal lobe is greater in infants than in adults. Therefore, the postcentral gyrus occupies a more anterior position along the sagittal axis of the skull and brain. Second, the C 3, 4 position of the standard ten-twenty system is more lateral than is the C 5, 6 position of Hellström *et al.* (1963). As the central sulcus courses anteriorly in passing laterally and inferiorly from the longitudinal fissure to the lateral sulcus (of Sylvius), the more lateral placement will be relatively posterior to the central fissure.

Our central electrode appears to overlie the sensorimotor area representing the lips face, or thumb (Penfield and Jasper 1954). This finding differs slightly from that of Penfield *et al.* (1958) in adults that the electrode corresponded to the area serving the hand.

That the inferior frontal electrode position should actually lie inferior to the frontal lobe in nine of eleven hemispheres was initially an unexpected finding. Inspection of an infant's brain, however (Fig. 1), reveals that the midpoint of an imaginary line connecting Fp 1, 2 and T 3, 4 will usually lie inferior to or at the inferior limit of the frontal lobe. In contrast, the diagram of Penfield *et al.* (1958) indicates that the inferior frontal electrode overlies the inferior frontal gyrus. Indeed, in the study of Penfield *et al.* (1958), all the temporal line electrodes lie superior to ours relative to the brain.

The incomplete opercularization of the temporal lobe in infants probably contributes to the surface distance (1.0-2.5 cm) that separated it from the inferior frontal electrode in most of the cadavers we studied.

The situation of the inferior frontal electrode relative to the frontal and temporal lobes allows it relatively little cerebral surface from which to record potentials. This must limit its clinical usefulness in infants.


## SUMMARY

The relationships of the standard ten-twenty electrode placement system to the infant cerebral cortex were studied in seven cadavers at the time of autopsy. In contradistinction to previous studies, the average location of our central electrode (C 3, 4) was over the postcentral gyrus. In addition, our entire temporal line of electrodes (F 7, 8; T 3, 4; T 5, 6) was more inferiorly placed than that of a previous study. The inferior frontal electrode actually lay inferior to the frontal lobe in most instances. Despite meticulous measurement of electrode positions, a discrete but definite variability of anatomic correlation between brains and between hemispheres of the same brain was found for most electrode positions.



## RESUME

### CORRELATIONS ANATOMIQUES DE LA POSITION DES ELECTRODES PLACEES SUIVANT LE SYSTEME 10-20 CHEZ LES ENFANTS

Les relations entre la position des électrodes placées suivant le système standard 10–20 et le cortex cérébral de l'enfant ont été étudiées sur 7 cadavres au moment de l'autopsie. En contradiction avec des études antérieures, notre électrode centrale (C 3, 4) se situait en moyenne au-dessus du gyrus post-central. En outre, notre ligne totale d'électrodes temporales (F 7, 8; T 3, 4; T 5, 6) se situait plus bas que celle de l'étude précédente. L'électrode frontale inférieure se situait réellement au-dessous du lobe frontal dans bien des cas. Malgré des mesures méticuleuses des positions d'électrodes, une variabilité discrète mais nette des corrélations anatomiques entre les cerveaux et entre les hémisphères du même cerveau a été observée pour la plupart des positions d'électrodes.

We thank Dr. Donald W. Klass for his encouragement and for his critical review of the manuscript and Mrs. A. Ness for her technical advice.

## REFERENCES

HELLSTRÖM, B., KARLSSON, B. and MÜSSBICHLER, H. Electrode placement in EEG of infants and its anatomical relationship studied radiographically. *Electroenceph. clin. Neurophysiol.*, **1963**, *15*: 115–117.

International Federation of Societies for Electroencephalography and Clinical Neurophysiology. The ten–twenty electrode system. *Amer. J. EEG Technol.*, **1961**, *1*: 13–19.

JASPER, H. H. Report of Committee on Methods of Clinical Examination in Electroencephalography. *Electroenceph. clin. Neurophysiol.*, **1958**, *10*: 370–375.

PENFIELD, W. and JASPER, H. *Epilepsy and the functional anatomy of the human brain.* Little, Brown and Co., Boston, **1954**, 896 p.

PENFIELD, MCRAE and CAVENESS, Cited in JASPER, H. H., **1958**, p. 373.

SANNIT, T. The ten–twenty system: footnotes to measuring technique. *Amer. J. EEG Technol.*, **1963**, *3*: 23–30.