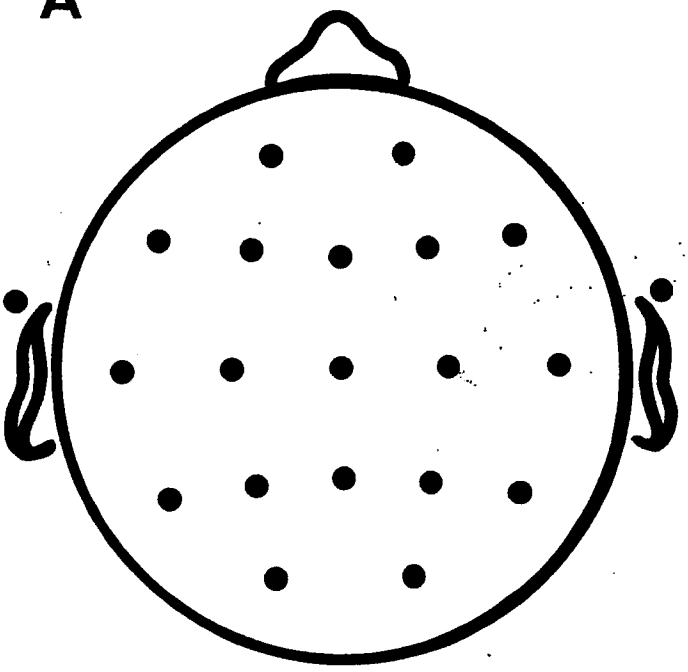
A REVIEW OF THE INTERNATIONAL TEN-TWENTY SYSTEM OF ELECTRODE PLACEMENT



Astro-Med, Inc
GRASS
INSTRUMENT DIVISION

A REVIEW OF THE INTERNATIONAL TEN - TWENTY SYSTEM OF ELECTRODE PLACEMENT

WHY AND WHEN WAS THE 10 - 20 SYSTEM DEVELOPED?

The 10 - 20 System of Electrode Placement was developed in 1958 by electroencephalographers who wanted a standard format and common terminology to describe the location of scalp electrodes, so that EEG records could be compared serially, exchanged among electroencephalographers and shared through the literature.

The initial recommendation was made at the International Congress of Electroencephalography and Clinical Neurophysiology in London in 1947. Subsequently, H. Jasper at the Montreal Neurological Institute was appointed to head up this study. In addition to his system, the electrode systems of R. Schwab and R. Abbott from the Massachusetts General Hospital, F. Gibbs in Chicago, and that of W. Cobb at the National Hospital for Neurologic Disorders, Queen's Square in London were compared (The Ten Twenty System, International Federation of Societies for EEG and Clinical Neurophysiology, 1958). Although there were differences in these systems, some of the common elements were taken from each to develop the 10 - 20 system of electrode location and nomenclature.

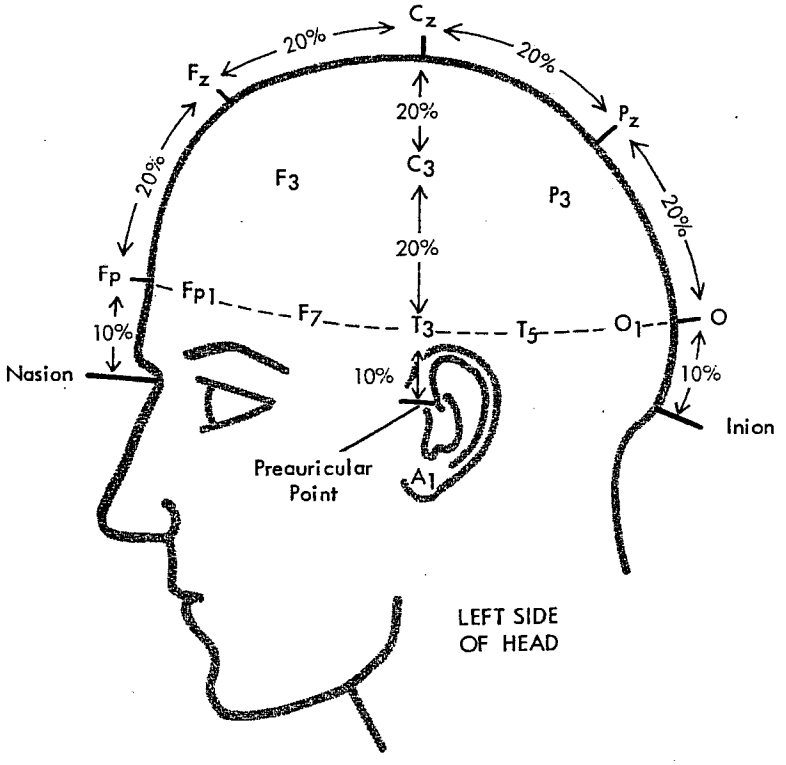
WHAT IS THE 10 - 20 SYSTEM?

The International 10 - 20 System of Electrode Placement is a procedure for the measured location of equally spaced electrode positions on the scalp, using identifiable skull landmarks as reference points. See fold-out 10-20 Diagram. This system is based on the proven relationship between a measured electrode site and underlying cortical structures and areas.

The system is termed "10 - 20" because electrodes are spaced either 10% or 20% of the total distance between a given pair of skull landmarks. See FIG. 1.

Percentages rather than absolute distances are used to allow for normal differences in head size and shape. The absolute distances between electrodes vary from one patient to another, but the distances are proportionally the same. The 10 - 20 system is designed to give adequate coverage of the head and provide flexibility for the placement of additional electrodes within the prescribed framework using the 10 - 20 nomenclature.

NOTE: If the 10 - 20 nomenclature is used for electrodes in other than the precisely specified and measured locations described by the International Congress, the International 10 - 20 System of Electrode Placement is <u>not</u> being used.



IN THE 10 - 20 SYSTEM, ELECTRODES ARE PLACED EITHER 10% OR 20% OF THE TOTAL DISTANCE BETWEEN SKULL LANDMARKS

FIGURE 1

ADVANTAGES OF THE 10 - 20 SYSTEM

The advantages established by the International 10-20 System are:

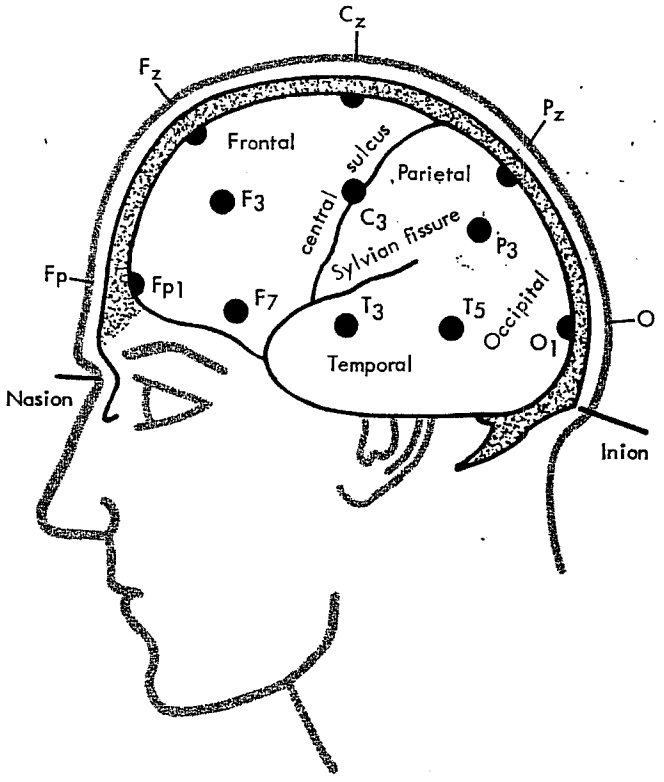
- an internationally accepted standard format for placing electrodes on the scalp
- an anatomically proven correlate for each electrode which is consistent from patient to patient
- uniform spacing of electrodes for accurate comparison of different brain areas
- a system of labeling electrode locations which is identical in all languages
- comparable data for the comparison of serial (follow-up) EEGs on the same patient in the same or in different laboratories
- a flexible system which provides adequate brain coverage and permits the addition of electrodes if more detailed coverage is required.

ANATOMICAL JUSTIFICATION OF THE 10 - 20 SYSTEM

From its inception, the group assigned to develop a standard system of electrode placement felt that it was necessary to define the anatomical relationship of each electrode position to a cortical landmark in the average subject. Once the electrode sites had been agreed upon, two studies were undertaken by H. Jasper, W. Penfield, D. McRae, and W. Caveness (Jasper, 1958).

One technique involved the operative placement of metal clips over the Sylvian fissure and central sulcus. A full complement of electrodes was then placed on the scalp. X-rays were taken to establish the relationship between the two fissures and electrode positions.

The second study involved the use of a twist drill (rather than the introduction of india ink spots previously reported)* to penetrate and remove small plugs from the cortical surface of adult cadavers. The holes were drilled in each measured electrode location. The relationship of the missing brain plugs to the Sylvian fissure and central sulcus on the surface of the cortex was measured. See FIG. 2. The results of both studies show that in subjects without lesions or deformities, the correlation between electrodes placed according to the 10 - 20 system and the location of the Sylvian fissure and the central sulcus is within ± 1 cm of that shown on FIGURE 2.



RELATIONSHIP BETWEEN CENTRAL SULCUS, SYLVIAN FISSURE, LOBES OF THE BRAIN AND ELECTRODE POSITIONS.

FIGURE 2

*Caveness, W. Personal Communication.

WHAT ARE THE SKULL LANDMARKS IN THE 10 - 20 SYSTEM?

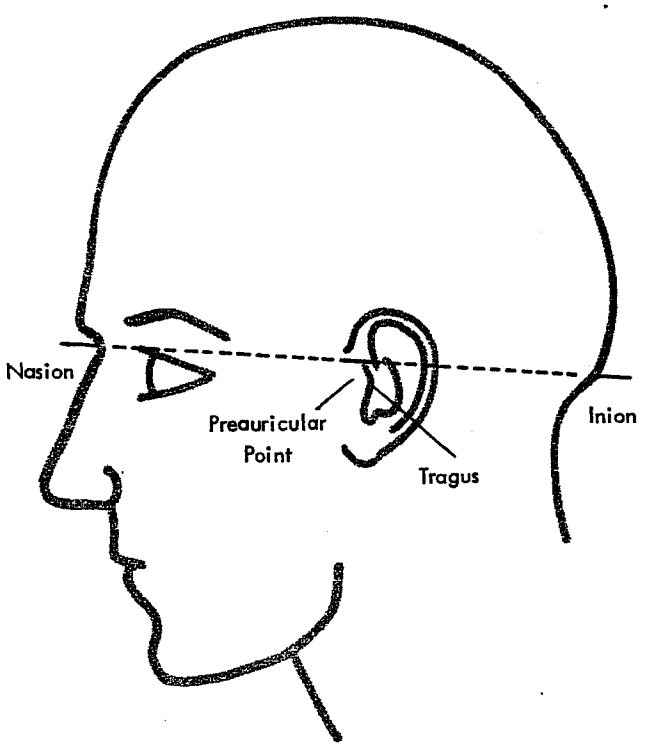
There are four skull landmarks used in the 10 - 20 system: the nasion, the inion and the right and left preauricular points. See FIG. 3A and 3B. Learning the location of the inion takes time and practice. Below are some guidelines that may be helpful in identifying these reference points.

The nasion is the indentation between the forehead and the nose.

The inion is a ridge or knob that can be felt as you run your finger up the back of the neck to the skull. You should first encounter a depression with the ridge of the protruding inion just above it. If the location of the inion is not at first obvious to you, ask the patient to tilt his head all the way back or backward and forward while you try to feel the ridge. If the location of the inion is still in doubt, mark it at the same level as the preauricular points.

The preauricular points are indentations just above the cartilage (tragus) which covers the external ear opening. Locate this point on both the right and left sides.

Locating these landmarks is the first step in the measuring procedure. Once located, each is usually marked with a nontoxic skin pencil. Remember these locations are not electrode positions, but reference points from which the basic measurements are made.



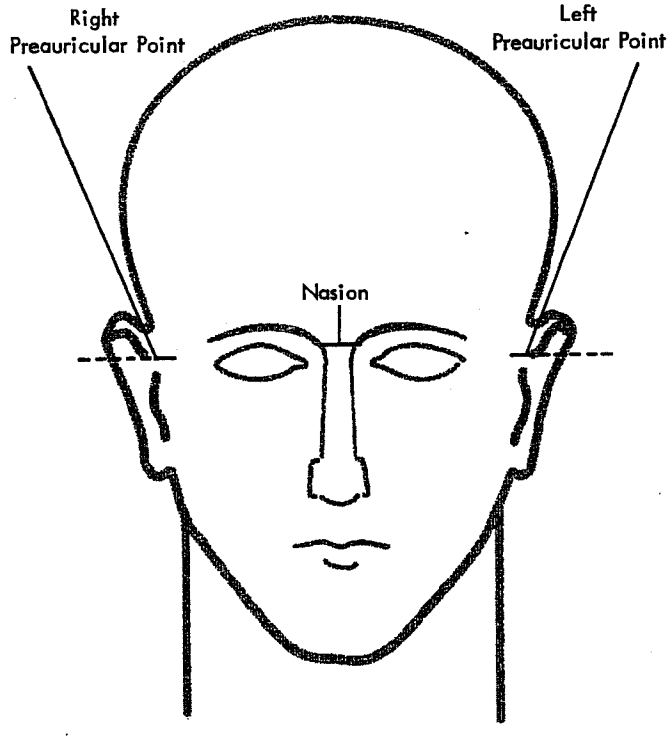
LEFT LATERAL VIEW OF SKULL LANDMARKS.

FIGURE 3A

HOW WAS THE NOMENCLATURE FOR THE INTERNATIONAL 10 - 20 SYSTEM DEVELOPED?

The nomenclature was developed to give each electrode site a logical alphabetical abbreviation that immediately identifies it with the lobe or area of the brain to which it refers. See fold out 10 - 20 diagram of standard placements. In the abbreviation F_z for example, the F stands for the Frontal lobe of the brain. All the alphabetical characters refer to the area of the brain over which they are located with the exception of "z", which is used for the numerical subscript zero or the midline zero reference. All the midline points (those on a direct line between the inion and nasion) have the subscript "z". From front to back the electrode sites on the midline are F_z = Frontal zero (mid-frontal), C_z = Central zero (vertex), and P_z = Parietal zero (mid-parietal).

The numbered subscripts however refer to the right or left hemisphere. All the even subscripted letters, i.e., F_{p2}, F_4, F_8, etc., refer to electrode positions on the right side of the head, whereas all the odd numbered subscripts, i.e., F_{p1}, F_3, F_7, etc., refer to the left hemisphere. Thus, F_3 refers to the left frontal lead. The numbered subscripts also define the electrode location in relation to the midline. For example, the smaller the subscript, the closer the electrode position is to the midline. F_3 is closer to the mid-



FRONT VIEW OF SKULL LANDMARKS.

FIGURE 3B

line than F_7. If an additional electrode is desired between F_3 and the midline, it would be midway between and labeled F_1. Between C_z and C_4 an additional electrode would be labeled C_2 and so on. This applies to all electrodes except those on the temporal lobes where the subscripts get larger towards the posterior part of the head. A complete diagram of the designated positions for extra electrodes is given on page 12.

When electrodes are properly applied according to the 10 - 20 system, the coverage of the hemispheres is symmetrical. That is to say each electrode on the left side of the scalp has a homologous electrode on the right side of the scalp. If electrodes are not symmetrically placed on each hemisphere, voltage asymmetries may occur during recording.

DESIGNATED ABBREVIATIONS FOR THE 10 - 20 SYSTEM

BRAIN AREA	LEFT HEMISPHERE	MIDLINE	RIGHT HEMISPHERE
Frontal pole	Fp_1		Fp_2
Frontal	F_3		F_4
Inferior Frontal	F_7		F_8
Mid - Frontal		F_z	
Anterior Temporal*	T_1		T_2
Mid - Temporal	T_3		T_4
Posterior Temporal	T_5		T_6
Central	C_3		C_4
Vertex or Mid - Central		C_z	
Parietal	P_3		P_4
Mid - Parietal		P_z	
Occipital	O_1		O_2
Cerebellar**	Cb_1		Cb_2
NON SCALP LEADS			
Auricular	A_1		A_2
Nasopharyngeal***	Pg_1		Pg_2

*Although not part of the original 10 - 20 system, electrodes are sometimes desired over the tip of the temporal lobe, particularly in cases of suspected psychomotor seizures. When used, they are labeled T_1 and T_2 consistent with 10 - 20 terminology (Silverman, 1965).

**Cb_1 and Cb_2 were part of the original 10 - 20 system. However, they are seldom used because they don't accurately reflect the electrical activity of the cerebellum.

***Pg_1 and Pg_2 are often seen on 10 - 20 diagrams. These are optional leads used in some laboratories to record from the medial aspect of the temporal lobe.

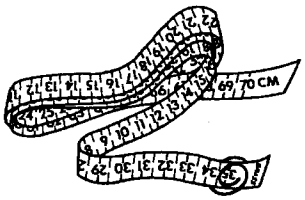
EQUIPMENT NECESSARY FOR THE EFFICIENT USE OF THE 10 - 20 SYSTEM

The equipment that is necessary for the efficient use of the 10 - 20 system is a narrow centimeter tape measure at least 70 mm long, non-toxic skin marking pencils (preferably in two colors), a pair of 4" spring tip dividers and assorted hair clips. Merthiolate (available from your pharmacist) is used in some laboratories to mark the skin.

CENTIMETER TAPE

RETRACTABLE TAPE AVAILABLE FROM A DRAFTING SUPPLY HOUSE.

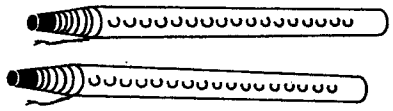
FIGURE 4



FLEXIBLE STRIP TAPE AVAILABLE FROM GRASS INSTRUMENT CO.

FIGURE 5

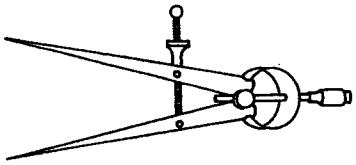
NON-TOXIC SKIN MARKING PENCILS



AVAILABLE FROM BLAISDELL PENCIL COMPANY IN ASSORTED COLORS.

FIGURE 6

DIVIDERS



AVAILABLE FROM DRAFTING SUPPLY HOUSE OR HARDWARE STORE.

FIGURE 7

HAIR CLIPS

AVAILABLE FROM LOCAL 5 & 10¢ STORE OR BEAUTY SUPPLY HOUSE.

FIGURE 8

THE SEQUENCE OF MEASUREMENT IN THE 10 - 20 SYSTEM

ı the 10 - 20 system, centimeters (cm) are the unit of measure. ıere are 10 millimeters (mm) in one centimeter and approximately .5 cm per inch. Use of a tape measure graduated in centimeters ıther than inches is preferred to prevent errors in determining 0% or 20% of distances between landmarks.

he sequence of measurement is critical. The inion - nasion dis- ınce is the first measurement and if this is not accurate, the ıcceeding electrode locations will not be accurate. It is im- ortant to remember that an electrode position is determined by ıe intersection of 2 measured points, one from an anterior- osterior measurement and one from a measurement across the ead. The resulting cross is the site of electrode placement. ılthough the inion and the nasion are the two starting reference oints, they are not electrode locations.

ıriefly, the sequence of measurement as shown on FIG. 9 is as ollows (Sannit, 1963):

1. Nasion to inion measurement followed by subdivision for Fp, F_z, C_z, P_z, and O locations.

2. Preauricular point to preauricular point through C_z - completing the C_z placement and locating one mark of T_3, C_3, C_4 and T_4.

3. Circumference measurement through O, Fp, T_3 and T_4, followed by the division of this total distance into 10 equal segments to locate the vertical mark for Fp_1, F_7, T_3, T_5, O_1 and Fp_2, F_8, F_4, T_6 and O_2, completing T_3 and T_4. Extend the O, Fp, T_3 and T_4 horizontal marks to complete the other positions.

4a. Fp_1 to O_1 measurement through C_3 on the left side of the head establishes the anterior-posterior marks of F_3, C_3, P_3 and completes the C_3 location.

4b. Repeat for the right side of the head.

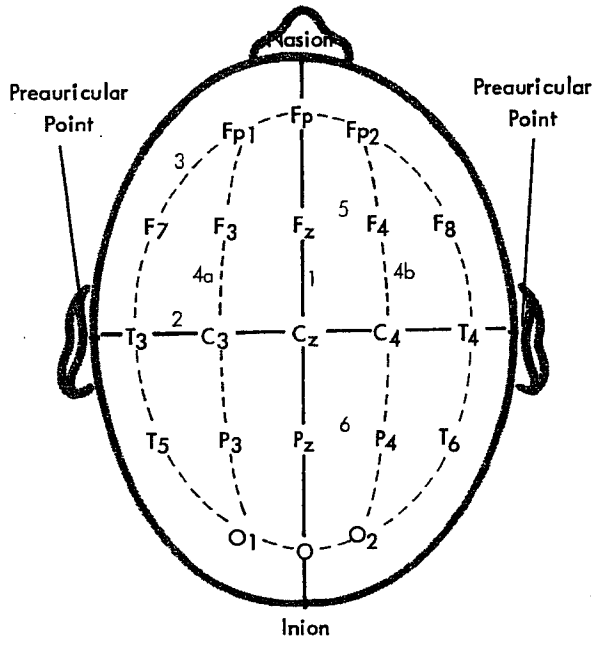
5. F_7 to F_8 measurement through F_z to complete electrode positions F_z, F_3 and F_4.

6. T_5 to T_6 measurement through P_z to complete electrode positions P_z, P_3 and P_4.

10 - 20 MEASUREMENT PROCEDURE

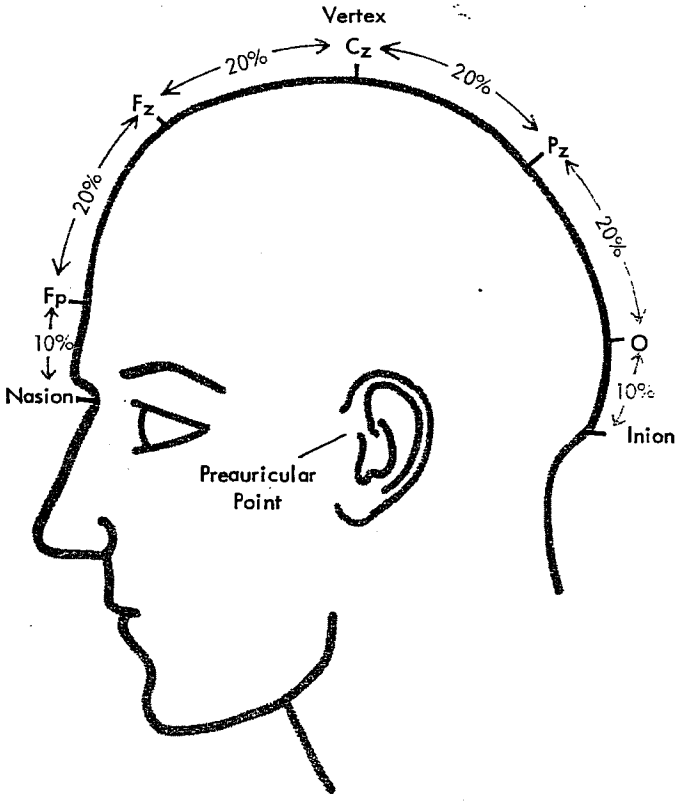
1. Locate the skull landmarks: inion, nasion and preauricular points. See FIG. 3A and 3B. It is often helpful to mark the inion in one color and all other positions in another color. Corrections can then be done in the first color.

2. Measure the distance along the midline between the nasion and the inion with the centimeter tape. Refer to FIG. 10. Remember the arbitrary value for this example is 30 cm.



SEQUENCE OF MEASUREMENTS

FIGURE 9



MEASURING INION TO NASION DISTANCE

FIGURE 10

a. Determine what half (50%) of this distance is, i.e., 15 cm. One half the distance between the nasion and the inion, place the a - p mark (perpendicular to the tape) for C_z. See FIG. 11.

b. Determine 10% of the total inion-nasion distance, i.e., 3 cm. Mark 3 cm posterior from the nasion along the midline. This is reference point F_p (F_{pz}).

c. Determine 20% of the total distance, i.e., 6 cm. From F_p reference (not the nasion) measure 6 cm back along the midline. This is the a - p location of F_z.

d. 20% of the total distance (6 cm) back from C_z, mark the anterior-posterior location for P_z.

e. Locate O which is 20% (6 cm) back along the midline from P_z.

f. Verify that O is 10% above the inion.

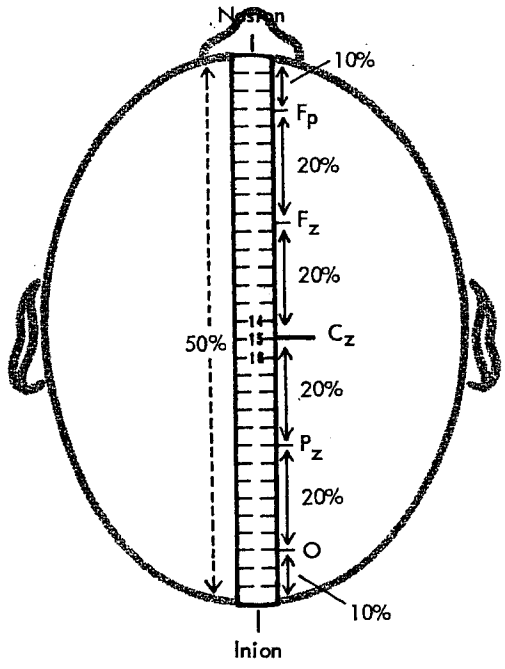
3. Measure the distance between the right and left preauricular points making sure that the tape goes through C_z, for example 35 cm. See FIG. 12.

a. Place the second mark for C_z exactly halfway between the preauricular points. This completes the two marks for the C_z position.

b. Keeping the tape in place through C_z, measure up 10% from the right preauricular point and mark. This is one mark for T_4.

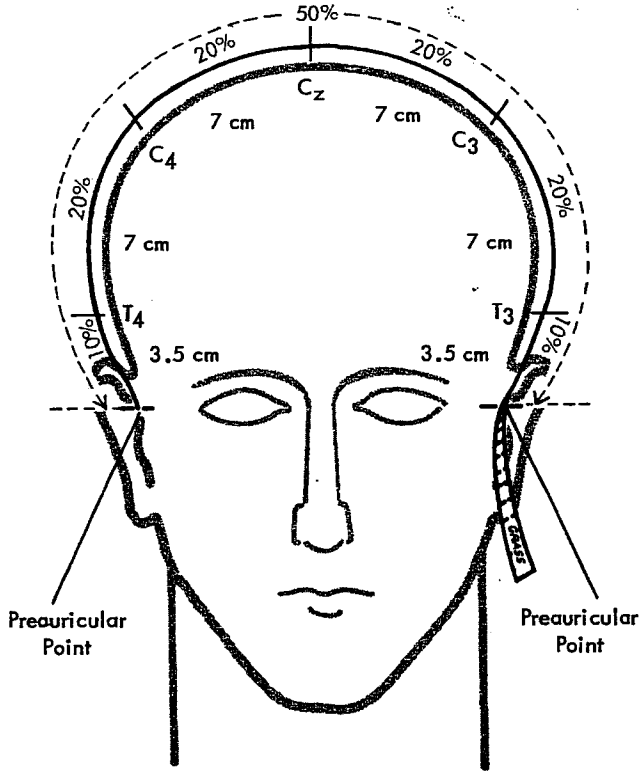
c. Place the mark for electrode position C_4 halfway between T_4 and C_z.

d. Follow the same procedure for the left side of the head.



FIRST MARK FOR C_Z PERPENDICULAR TO TAPE

FIGURE 11



MEASURING THE DISTANCE BETWEEN LEFT AND RIGHT PREAURICULAR POINTS

FIGURE 12

4. Measure the circumference of the head making sure that the tape goes through the frontal pole (F_p) and the occiput (O) reference points and T_3 and T_4 (midtemporal). See FIG. 13. Divide the circumference of the head into 10 equal parts as follows:

   a. Determine 10% of the total circumference of the head and set the dividers to that figure.

   b. Position the dividers so that they straddle the midline at the level of F_p. See FIG. 14. Make a vertical mark at each divider tip. The right mark is the first for the Fp_2 position and the left mark the first for the Fp_1 position.

   c. Put one tip at Fp_2 and the second tip posteriorly along the circumference line. The second point becomes the vertical mark for F_8.

   d. With one tip of the dividers at F_8, proceed posteriorly along the circumference line and make a vertical mark through the previous mark for T_4. NOTE: This position may not be directly above the preauricular point.

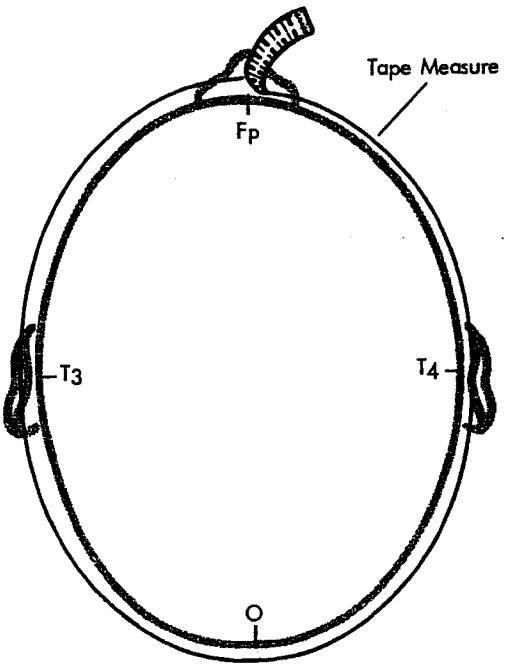
   e. Continue with the dividers posteriorly along the circumference from T_4 to make the vertical mark for T_6.

   f. Proceed posteriorly from T_6 to make the first mark for O_2.

   g. Repeat this procedure for the left side of the head, working posteriorly from the Fp_1 mark previously made. One mark for F_7, T_5 and O_1 should be established during this step and the T_3 location is completed.

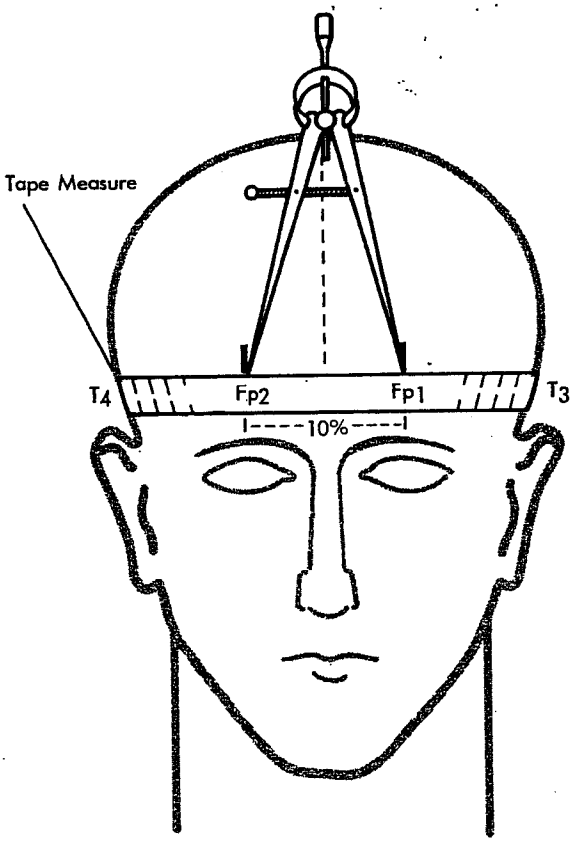
   h. With the dividers, verify that the distance between O_1 and O_2 is 10% as well.

   NOTE: Fp_1 and Fp_2 should be equidistant from the midline at the front of the head and O_1 and O_2 should be equidistant from the midline at the back of the head. T_3 and T_4 should be in the same position with respect to the ear on each side of the head.



MEASURING THE CIRCUMFERENCE OF THE HEAD

FIGURE 13



DIVIDERS SET AT 10% OF TOTAL CIRCUMFERENCE DISTANCE

FIGURE 14

5. To determine the second coordinate for each of the positions identified in the previous step (commonly referred to as the temporal or lateral chain of electrodes) extend the 4 horizontal marks for Fp, O, T3 and T4 to intersect with the vertical marks just made for Fp1, F7, T5, O1, and on the right Fp2, F8, T6, and O2. See FIG. 15. For example, this can be done by holding one end of the tape measure at Fp and the other at T3. Place a horizontal mark through Fp1 and F7 along the straight edge of the tape. Repeat this between T3 and O, O and T4, and T4 and Fp.

6. Measure the distance from Fp1 to O_1 going through C_3. See FIG. 16. At one half of this distance, make the intersecting a - p mark that completes electrode position C_3.

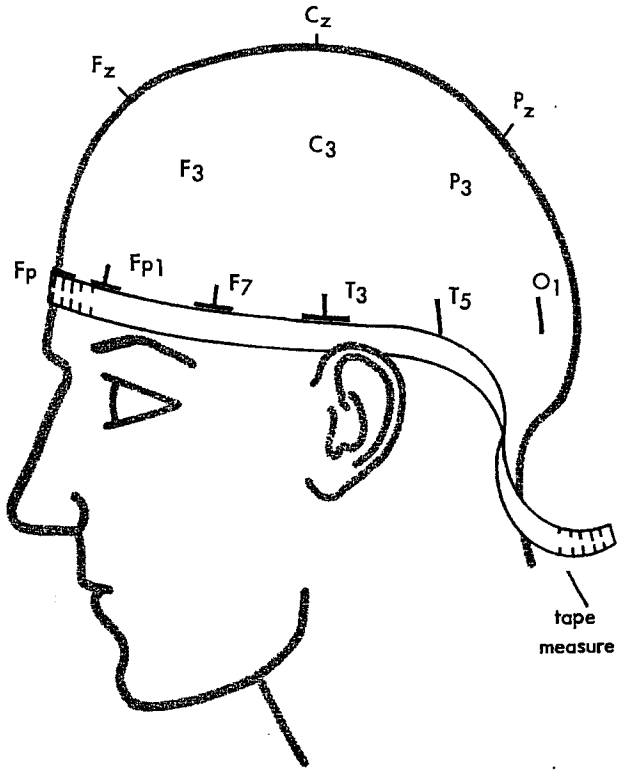
   a. Locate F3 halfway between Fp1 and C_3.

   b. P_3 is halfway between C_3 and O_1.

7. Repeat this procedure on the right hemisphere. At one half of the distance from Fp2 to O2 through C4, complete the a - p mark for the C_4 position.

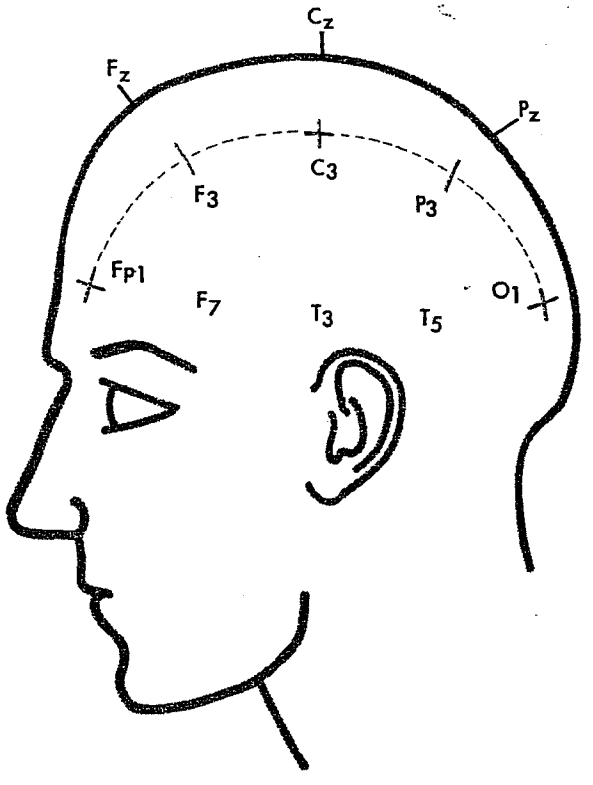
   a. Halfway between Fp2 and C_4, make one mark for the F4 location.

   b. Halfway between C4 and O_2, make one mark for the P_4 location.



COMPLETING CIRCUMFERENCE MEASUREMENTS

FIGURE 15.



MEASURING DISTANCE FROM Fp1 TO O_1

FIGURE 16

8. With the tape, measure the distance from F_7 to F_8 through F_z. See FIG. 17. Determine one half of this distance and mark. This becomes the final mark for F_z.

   a. The final mark for F3 is placed halfway between F_z and F_7.

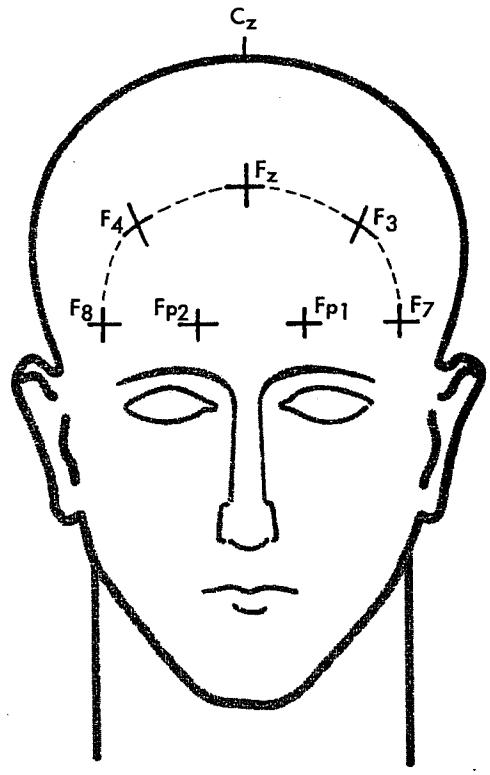
   b. Similarly, the final mark for F_4 is halfway between F_8 and F_z.

9. Measure the distance from T_5 to T_6 through P_z. See FIG. 18. Mark one half of this distance. This mark completes the P_z location:

   a. One half of the P_z to T_5 distance is the final mark for P_3.

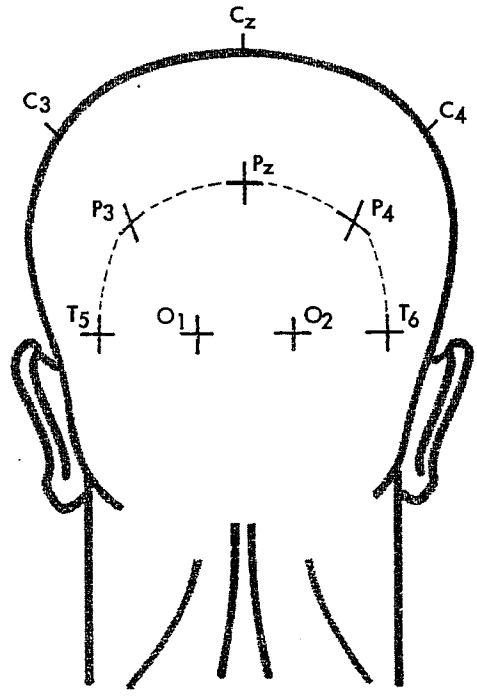
   b. One half of the distance from P_z to T_6 is the final mark for P_4.

YOU SHOULD NOW HAVE TWO COORDINATES FOR EACH OF THE 19 STANDARD ELECTRODE POSITIONS ON THE SCALP. EAR ELECTRODES, A_1 and A_2, MAKE A FULL COMPLEMENT OF 21 ELECTRODES.



MEASURING FROM F_7 TO F_8

FIGURE 17



MEASURING FROM T_5 TO T_6

FIGURE 18

HAVE YOU NOTICED THAT in some of the steps above, halfway points were taken instead of constant use of the 10% and 20% of the landmark distances. This is because all of the frontal, central and parietal electrodes are midway between adjacent electrodes in any direction. They can most easily be located by dividing specific distances in half as described from Step 3 on. Thus, one could begin by locating F_z halfway between Fp and C_z (see FIG. 19) and P_z halfway between C_z and O.

Similarly, C_3 is halfway between C_z and T_3 as well as halfway between F_3 and P_3. P_3 is halfway between P_z and T_5 and between O_1 and C_3, etc.

FRONTAL, CENTRAL AND PARIETAL ELECTRODES ARE HALFWAY BETWEEN ADJACENT ELECTRODES. SEE FIG. 19 AT RIGHT.

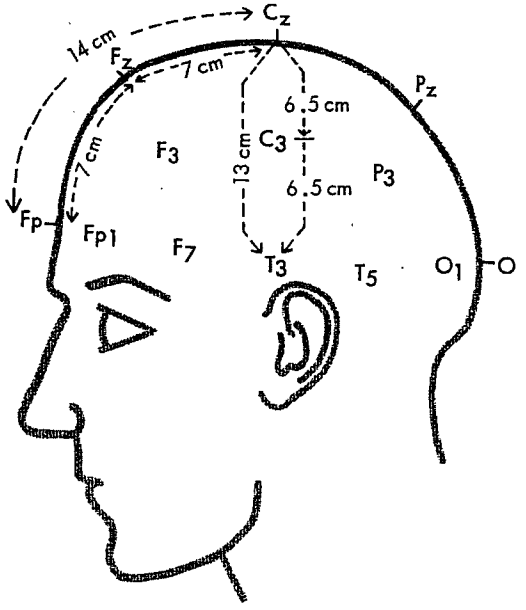


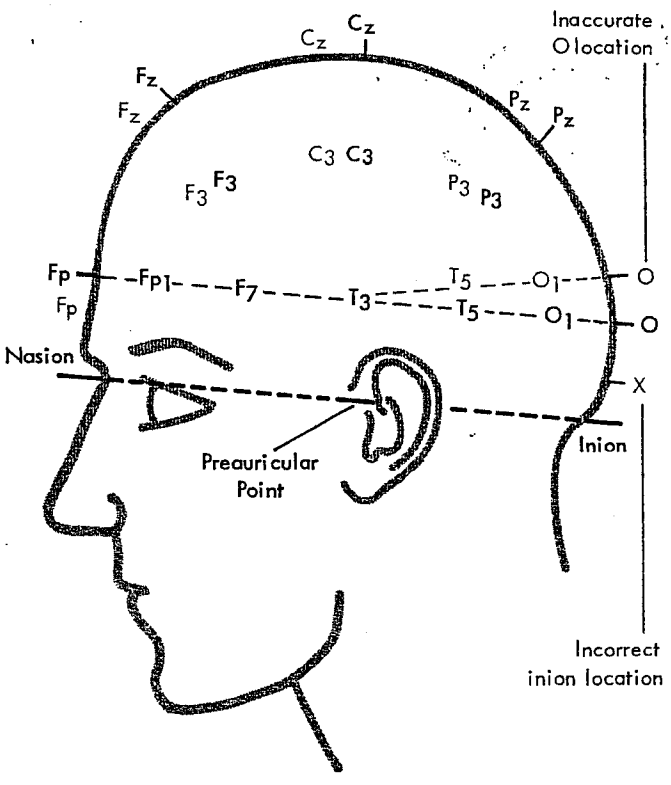
FIGURE 19

A QUICK VERIFICATION OF THE 10 - 20 SYSTEM MEASUREMENT

When you finish measuring and marking the head so that there is a cross for each electrode position, visually check the pattern formed by your markings. Each electrode should have a symmetrical counterpart on the opposite side of the head. Corresponding electrodes on each side of the head should be equidistant from the structural landmarks. With experience, a quick look at the patterns formed by your measured marks will verify the accuracy of your measurements. Differences in the placement of electrodes on one side as compared to the other may result in voltage asymmetries on the record which may confuse interpretation. Remember, the EEG is a diagnostic tool and errors in electrode placement due to inaccurate measurement may interfere with an accurate diagnosis.

COMMON SOURCES OF ERROR IN THE 10 - 20 SYSTEM OF ELECTRODE PLACEMENT

Inaccurate location of the inion is a frequent source of error. Its identification is often difficult, but is crucial for all subsequent measurements. When the inion is not accurately marked, the inion-nasion distance will be inaccurate. Thus, the midline locations as well as all those marked with the tape lying over the midline positions will be inaccurate. The most common error in marking the inion is marking it too high. This becomes obvious when the circumference measurement is attempted. Although it is not unusual for the tape to slant upward from T_3 and T_4 to Fp, if the upward tilt occurs when the tape goes from T_3 and T_4 to O, the inion and in turn O have been marked too high. See FIG. 20.



CORRECT ELECTRODE POSITIONS AND LANDMARKS ARE INDICATED IN BLACK. INACCURATE POSITION OF INION AS EVIDENCED BY UPWARD SLANT OF TAPE DURING CIRCUMFERENCE MEASUREMENT IS INDICATED IN BLUE. THE RESULTING INACCURATE ELECTRODE LOCATIONS ARE ALSO MARKED IN BLUE.

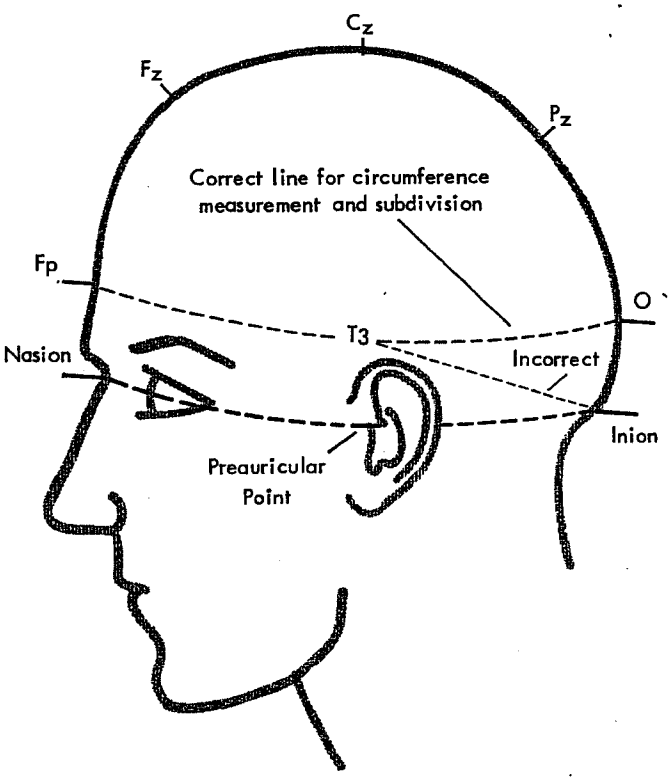
FIGURE 20

On the other hand, the inion mark is sometimes mistaken for the O reference when measuring and subdividing the circumference, particularly on people with long hair. Therefore, it may be helpful to mark these two points in different colors. When this error occurs, the occipital and posterior temporal locations will be too low. Visually check to see if the level of the tape at the back of the head reference O is slightly higher than the ears. The reference point O should be on line (in the same plane) with the midtemporals on any given patient. See FIG. 21.

A frequent source of error arises when subdividing the circumference. Always check to see that T_3 and T_4 are in corresponding positions with relation to the ears. It is very easy to mark equal 10% spacing without the electrodes being homologous. See FIG. 22. Non-homologous electrode placement may be a source of voltage asymmetries.

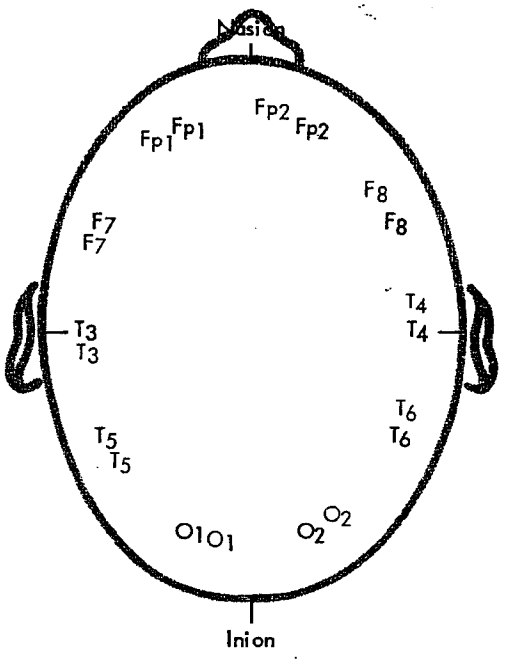
Arithmetic errors often crop up when you are rushed or are dealing with an uncooperative patient. Once the spatial patterns of a properly marked head are understood, these errors will be noticed and quickly corrected. If mismarks are made, they can be removed with alcohol or a second color pencil mark can be used for the corrected location.

In this publication, some short cuts have been mentioned and others will be obvious to you or practiced by your co-workers. Avoid short cuts until you are very familiar with the philosophy and practice of the 10-20 system and feel confident in its application.



CORRECT (BLACK) AND INCORRECT (BLUE) LEVEL FOR CIRCUMFERENCE MEASUREMENT

FIGURE 21



ACCURATELY LOCATED AND EQUALLY SPACED TEMPORAL CHAIN ELECTRODES ARE INDICATED IN BLACK. INACCURATELY LOCATED, BUT EQUALLY SPACED, ELECTRODES ARE INDICATED IN BLUE.

FIGURE 22

MODIFICATION OF THE 10 - 20 SYSTEM

In some instances, it is desirable to use additional electrodes for the exact localization of a focus. In other cases, it is impossible or impractical to apply a full complement of electrodes according to the prescribed 10 - 20 method. Such cases include newborn infants, post-neurosurgical patients or those with head injury or deformity. There is flexibility within the 10 - 20 system to allow for the addition or deletion of electrodes so that studies can be readily communicated.

A. ADDITIONAL ELECTRODE COVERAGE OF THE SCALP

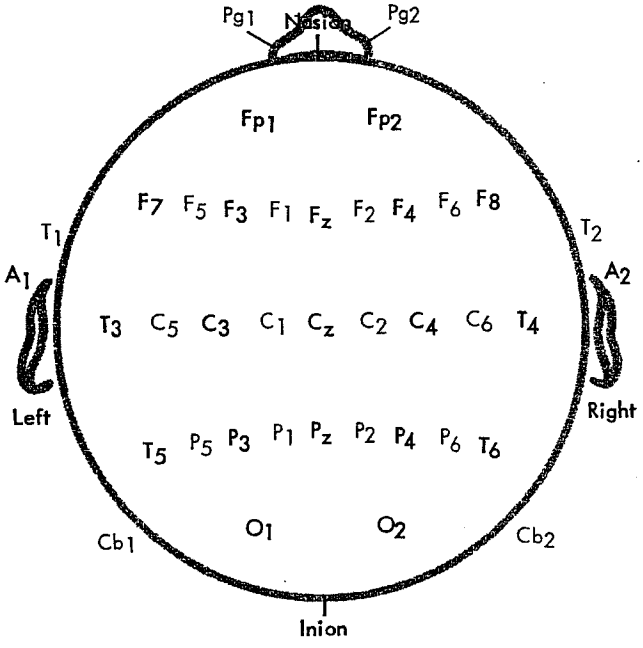
Provisions for additional electrode coverage were included in the 10 - 20 system. If an extra pair of electrodes is needed in the frontal region, their location and name can be recognized by anyone familiar with the 10 - 20 system. FIG. 23 gives the position and nomenclature for additional electrodes (in blue) in relation to the 21 standard electrode locations (in black).

B. RECORDING FROM NEWBORN INFANTS

The small size of an infant's head, particularly in the neonatal period, may not permit the application of a full set of electrodes. (Kagawa, 1962, 1973.) Furthermore, Hellstrom et al., in 1964 and recently Blume et al., (1974) showed that anatomical studies on infants show tremendous variations between the skull landmarks and the underlying cortical structures from one hemisphere to another in one patient and between patients. However, there is a need for a standard measured system of electrode placement which provides for the symmetrical placement of electrodes, albeit fewer in number.

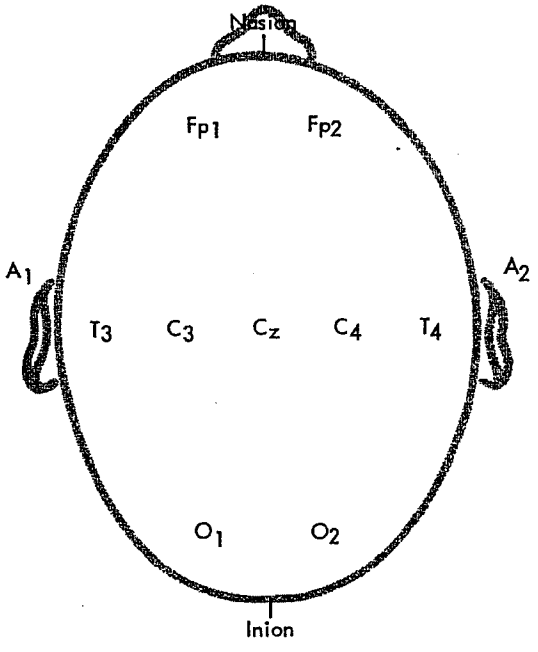
The initial development of the 10-20 system did not specify electrode placement for neonates. In 1968, Torres and Blaw described a modification of the 10 - 20 system for neonates. Essentially every other electrode in the 10 - 20 format is used for a total of 9 scalp electrodes and right and left ear references. The electrode positions are located according to the same measurement procedures described previously. See FIG. 24.

It is important to bring out two points in relation to this modification of the 10 - 20 system for infants. One, there is not as close a correlation between the measured locations in infants and the underlying brain structures as there is in adults. Secondly, the inter-electrode distances are not uniform over the head. Most importantly however is that in this abbreviated 10-20 system corresponding electrode pairs will have the same inter-electrode distances. This system can be used on infants up to 4 to 6 months after which time a full complement of electrodes is usually used.



SINGLE PLANE VIEW OF TOP OF HEAD SHOWING PLACEMENT OF ADDITIONAL ELECTRODES IN BLUE.

FIGURE 23



10 - 20 PLACEMENT FOR NEWBORNS

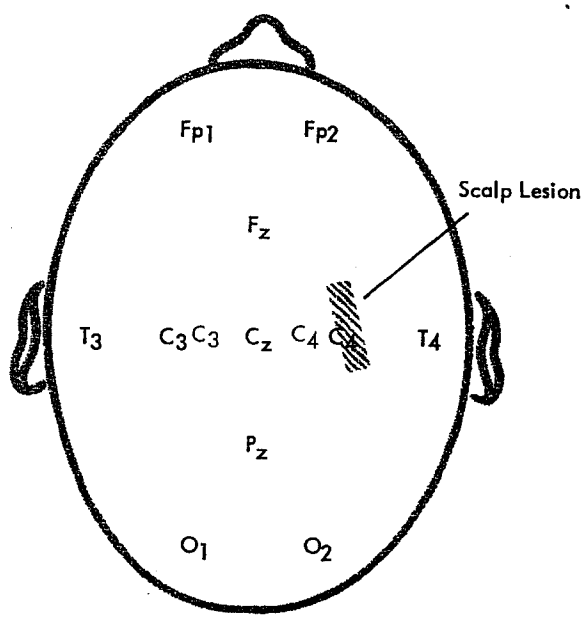
FIGURE 24

C. ELECTRODE PLACEMENT ON PATIENTS WITH SCALP LESIONS OR HEAD DEFORMITIES

A variety of abnormal conditions which affect the scalp or distort the head shape can prevent exact application of the 10 - 20 system. In some cases, scalp wounds or contusions may interfere with one or more standard 10 - 20 placements and an adjustment of homologous electrodes is all that is necessary to maintain symmetry between the two hemispheres. In others, elevated or depressed areas may affect the contour or symmetry of the head to a degree that makes it necessary to alter the basic measuring procedure. Although each case is unique, a few general rules should be observed.

Scalp Lesions

When a measured electrode position coincides with an open lesion or tender area, the electrode should be displaced by the least amount necessary to clear the lesion. If there is an homologous electrode, it too must be relocated to correspond to the location on the altered side. This is essential to maintain corresponding anatomical locations and equal spacing between electrode pairs over the right and left hemispheres. The location of the lesion and the distance and direction of electrode position change should be clearly diagrammed on the record. In FIG. 25, C_4 was relocated 2 cm further from T_4 and nearer to C_z than its normal position, and the homologous C_3 electrode site was changed accordingly.



STANDARD ELECTRODE POSITIONS ARE INDICATED IN BLACK. C_3 AND C_4 ELECTRODES (BLUE) ARE DISPLACED MEDIALLY BECAUSE OF LESION IN C_4 AREA.

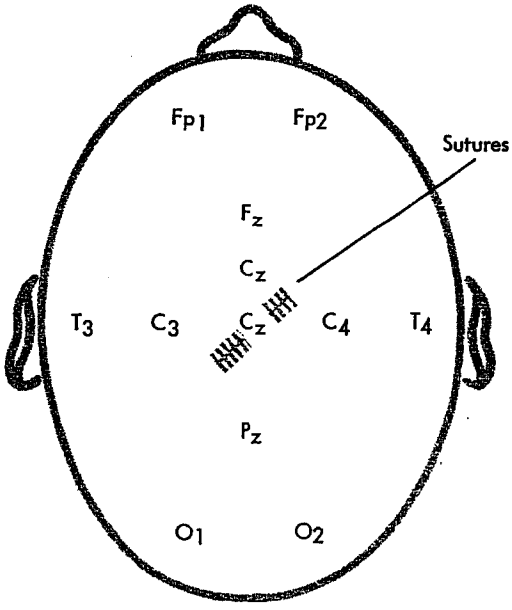
FIGURE 25

If a midline electrode must be relocated, move it anteriorly or posteriorly along the midline whenever possible. This will maintain its equal distance from the right and left parasagittal electrodes. See FIG. 26. Where the extent of the lesion makes this impractical, omit the affected midline location and substitute electrodes on both sides in the subscript 1 and 2 locations - for example, C_1 and C_2 instead of C_z. See FIG. 27. This will still permit logical and interpretable referential runs and sequential transverse montages.

When electrodes are repositioned, it is important to remember that altered distances will affect the amplitude of the recorded electrical activity. Shorter inter-electrode distances will result in lower recorded amplitude and longer inter-electrode distances will produce the reverse effect.

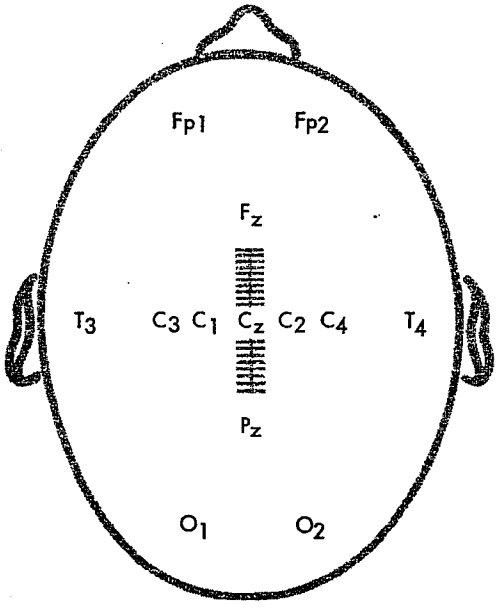
Deformity

When pathological conditions distort the shape of the head, it is sometimes impossible to achieve the goals of the 10 - 20 system because equidistant electrodes may not have reliable anatomical correlates. Compromises may have to be made between equal spacing of electrode pairs and the placement of electrodes over corresponding anatomical areas. If a choice must be made, try to achieve corresponding anatomical relationships between the right and left hemispheres. While the effects of the unequal spacing between electrodes may make it difficult to interpret sequential runs, referential montages should offer reliable comparisons between right and left hemispheres.



STANDARD ELECTRODE POSITIONS ARE INDICATED IN BLACK. C_Z IS DISPLACED (BLUE) 1.5 CM ANTERIORLY BECAUSE OF SUTURES AT C_Z.

FIGURE 26



STANDARD ELECTRODE POSITIONS ARE INDICATED IN BLACK. C_1 AND C_2 IN BLUE ARE ADDED TO REPLACE C_Z WHICH WAS OMITTED BECAUSE OF LACERATIONS IN THAT AREA.

FIGURE 27

Posterior Deformity

For example, in FIG. 28 an elevated area from post-traumatic swelling enlarges the posterior part of the head. Measuring from the nasion to the inion will not result in the accurate location of C_z which would normally be 50% of this distance.

1. Estimate and locate C_z as follows:
   C_z falls on the midline and usually just over or slightly posterior to the external ear openings. Taking care not to allow the tape to slant forward, extend it across the head between the preauricular points. Place the first mark for C_z perpendicular to the tape at the 50% point. Keep the tape in place and make a second intersecting mark parallel to and against the tape edge. This will serve as the estimated mark to complete the C_z location.
2. Make the remaining measurements between the preauricular points in the usual way (T_3, C_3, T_4, C_4).
3. Measure from the nasion to the C_z mark determined in the previous step, for example 17.5 cm.
4. Consider double 17.5cm or 35 cm to be the actual nasion to inion distance. On this basis, proceed with the usual midline measurements over the normal parts of the head, working from the front to C_z and from the inion up to P_z.
5. Proceed in the usual way with the circumference and other measurements.

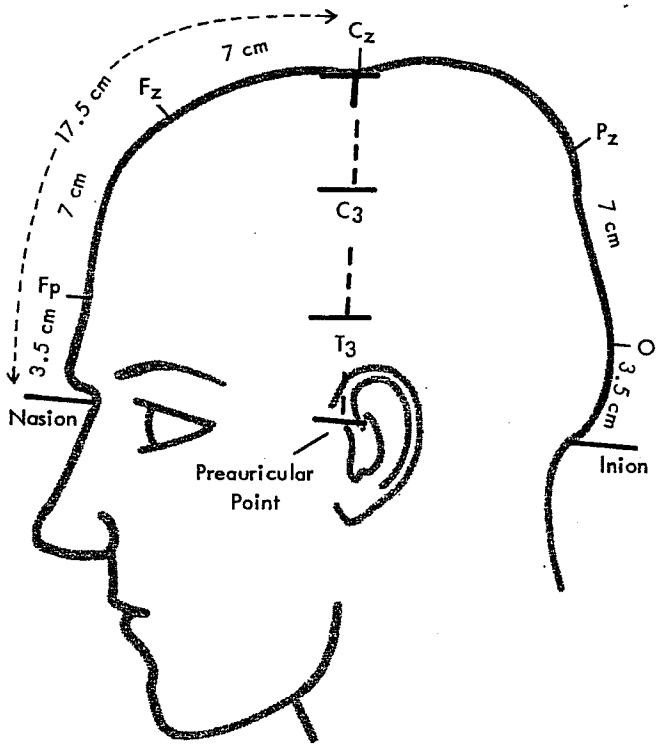
In this illustration, the protuberance does not interfere with the standard 10 - 20 locations based on distance from the closest skull landmarks, although the distance between C_z and P_z over the elevation is distorted.

If the raised area is extensive, as in FIG. 29, follow the same procedure except measure between O and C_z over the raised area and mark P_z midway between. Anatomically, this placement is only a gross approximation. If in your judgement it does not fall over the midparietal skull area, relocate it accordingly.

Always indicate the actual distances between electrodes and the site of deformity on the head diagram on the record.

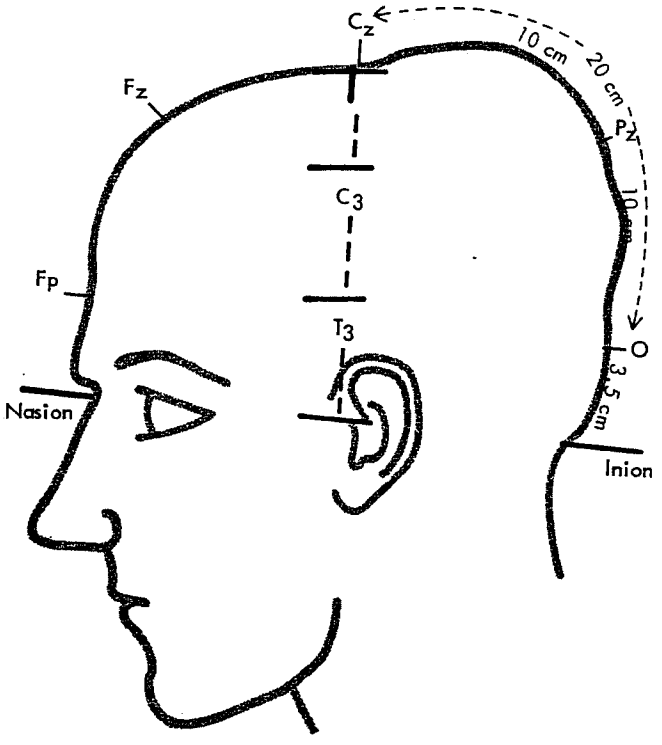
Anterior Deformity

A similar problem involving the anterior part of the head would be handled the same way except that in Step 3 referred to above, measure from the inion to C_z to get half the nasion to inion distance and then double that figure for the estimated total distance between those two landmarks.



SITING ELECTRODES IN CASES OF POSTERIOR SWELLING.

FIGURE 28



SITING ELECTRODES OVER HEAD WITH EXTENSIVE POSTERIOR SWELLING.

FIGURE 29

Deformities Confined To One Hemisphere

Extensive deformities of one side of the head, either elevations or depressions, affect electrode placement in a more complex manner. The dimensions of the abnormal side may be markedly different in both the anterior-posterior and the transverse directions (FIG. 30) from the normal side of the head. In this circumstance, electrode spacing obviously cannot be symmetrical on the right and left sides. Here are some general guidelines.

1. Identify as many locations as possible according to standard 10 - 20 measurement procedure.

2. If the midline is relatively unaffected, make the usual nasion to inion measurements. If this is not possible, locate C_z by making a mark across the midline at a point approximately in line with the external ear openings. Measure the other midline locations as previously described under Posterior Deformity.

3. Along the estimated midline make an intersecting mark to complete C_z.

4. Measure from the preauricular point on the normal side of the head to C_z (assume, e.g., 18 cm). Double that figure (36 cm) and use that total as the distance between the preauricular landmarks to calculate the temporal and central locations on the normal side. See FIG. 30.

5. On the abnormal side, whenever possible, locate the first temporal mark in the usual fashion at 10% above the preauricular point (in this illustration, T_3 at 3.6 cm from the left preauricular point).

6. Measure between T_3 and C_z and mark C_3 halfway between them. See FIG. 30.

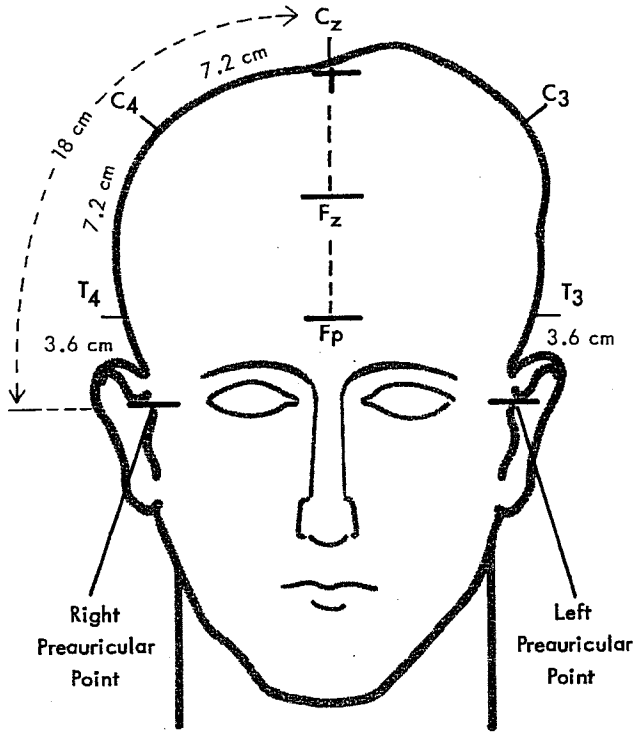
7. Proceed with the circumference measurements and extensions in the usual fashion.

8. The anterior-posterior measurements over each hemisphere from frontal pole to occiput and the final transverse measurements will also be asymmetrical. Follow the general principle of first determining the basic distances over the normal side of the head.

9. Whenever possible, transfer the spacing determined in Step 8 to homologous locations over any relatively normally shaped areas on the distorted side.

10. Over the deformed areas, locate each electrode halfway between its adjacent electrodes in both the anterior-posterior and transverse lines.

In all departures from the standard electrode sites, carefully diagram the electrode positions and the head deformity on the head diagram on the record.



SITING ELECTRODES ON HEAD WITH SINGLE HEMISPHERE DEFORMITY.

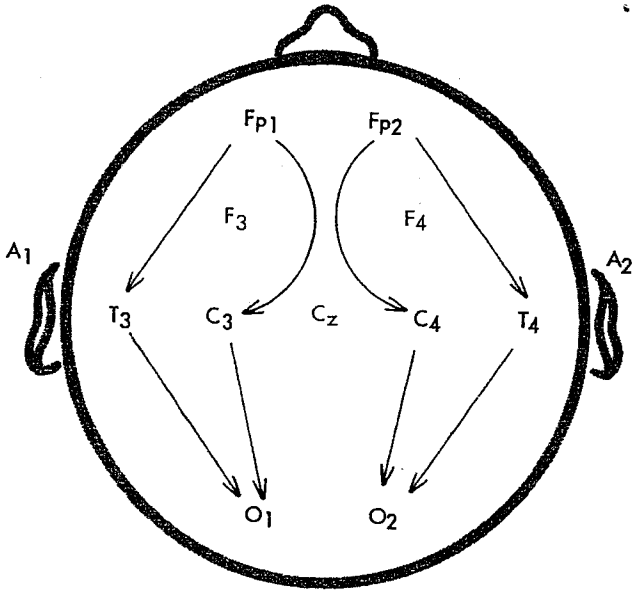
FIGURE 30

D. CEREBRAL DEATH RECORDING

The 10 - 20 system is uniquely adaptable to the principles of appropriate ECS (Electrocerebral Silence) recording. The American EEG Society has set up "Minimum technical standards for EEG recording in suspected cerebral death" based on the 10 - 20 system. In their guidelines, an inter-electrode distance of at least 10 cm is recommended. This may be achieved by skipping every other electrode placement. Longer inter-electrode distances enhance the possibilities of picking up low amplitude surface potentials and electrical activity from the deeper structures of the brain.

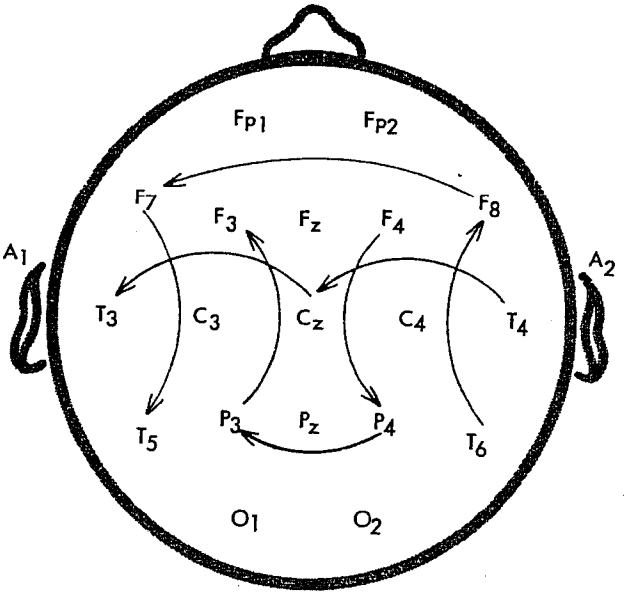
A minimum of eight electrodes (Fp_{1-2}, C_{3-4}, O_{1-2}, and T_{3-4}) is recommended in addition to the two ear references, A_{1-2} (FIG. 31). These are used in long distance combinations for anterior-posterior, transverse and reference montages. The strong suggestion is made that F_{3-4} and C_z be included as standard placements in ECS recording. However, many electroencephalographers prefer a full complement of electrodes which may be paired as shown in FIG. 32 to provide additional sequences with double interelectrode distances.

In ECS, skull landmarks are identified and the electrode sites that are used are measured as previously described.



THE MINIMUM NUMBER OF ELECTRODES FOR ECS RECORDING AS RECOMMENDED BY THE AMERICAN EEG SOCIETY STANDARDS COMMITTEE ARE INDICATED IN BLACK. THOSE IN BLUE ARE STRONGLY RECOMMENDED FOR INCLUSION DURING ECS RECORDING.

FIGURE 31



ADDITIONAL MONTAGES WITH DOUBLE INTERELECTRODE DISTANCES FOR ECS RECORDING WITH 10 - 20 SYSTEM.

FIGURE 32

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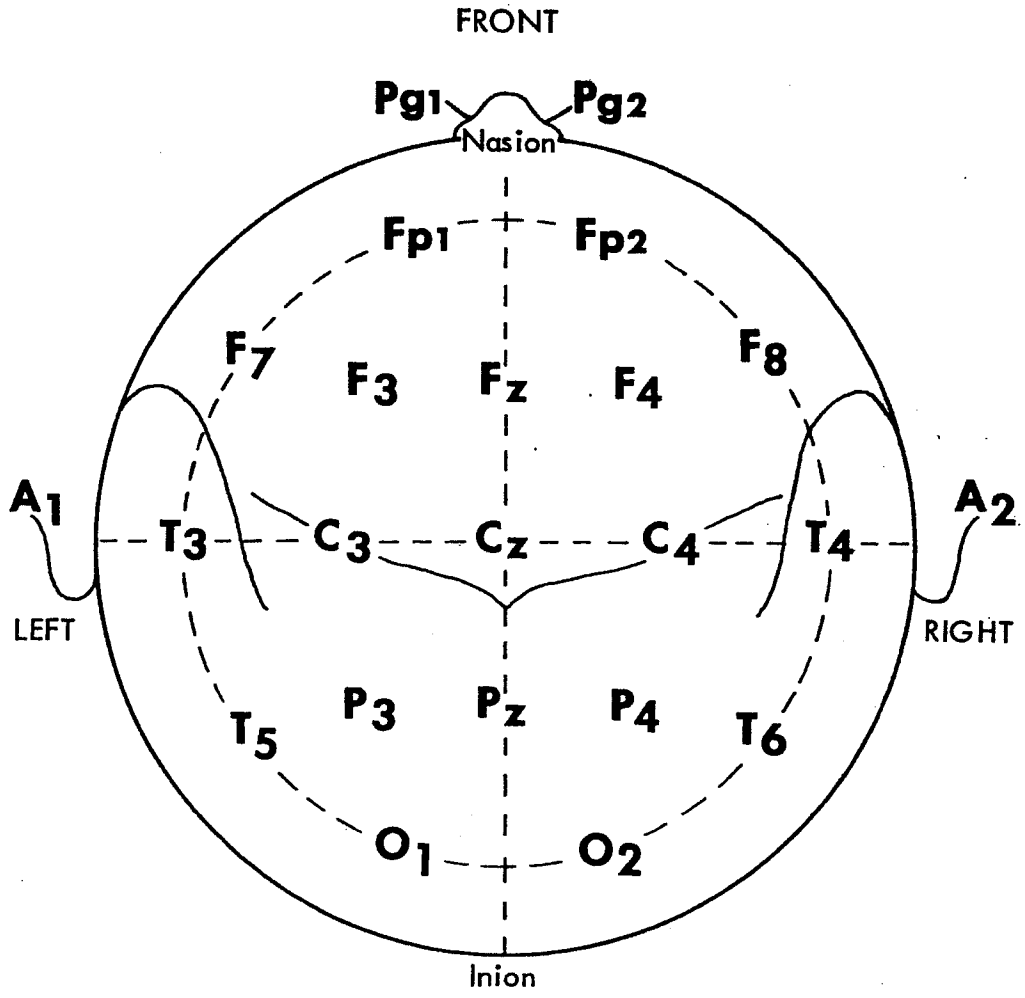
STANDARD INTERNATIONAL (10-20) ELECTRODE PLACEMENT



TOP OF HEAD