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Guidelines

The standardized EEG electrode array of the IFCN

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HIGHLIGHTS

- An array of 25 electrodes is recommended for standard EEGs with inferior temporal electrodes.
- Due to thinner skulls (spatial aliasing), pediatric EEG requires as many scalp electrodes as in adults.
- Arrays with higher electrode numbers (64–256 electrodes) allow source imaging at sublobar level.

ABSTRACT

Standardized EEG electrode positions are essential for both clinical applications and research. The aim of this guideline is to update and expand the unifying nomenclature and standardized positioning for EEG scalp electrodes. Electrode positions were based on 20% and 10% of standardized measurements from anatomical landmarks on the skull. However, standard recordings do not cover the anterior and basal temporal lobes, which is the most frequent source of epileptogenic activity. Here, we propose a basic array of 25 electrodes including the inferior temporal chain, which should be used for all standard clinical recordings. The nomenclature in the basic array is consistent with the 10–10-system. High-density scalp EEG arrays (64–256 electrodes) allow source imaging with even sub-lobar precision. This supplementary exam should be requested whenever necessary, e.g. search for epileptogenic activity in negative standard EEG or for presurgical evaluation. In the near future, nomenclature for high density electrodes arrays beyond the 10–10 system needs to be defined, to allow comparison and standardized recordings across centers. Contrary to the established belief that smaller heads needs less electrodes, in young children at least as many electrodes as in adults should be applied due to smaller skull thickness and the risk of spatial aliasing.
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1. History

Standardising the position and nomenclature of scalp electrode arrays was an important step in the development of electroencephalography. First, the 10–20 system of the International Federation was developed by Herbert H. Jasper and his co-workers (Jasper, 1958), resulting in the first published guidelines in 1999 (Klem et al., 1999). Early on the lack of proper coverage of the temporal lobe was criticized, resulting in the proposition of the 'Maudsley electrodes' to sample the temporal pole (Binnie et al., 1982). Later, the 10–20 system was extended with the 10% electrode positions of the modified combinatorial nomenclature. With the advent of source imaging, high density EEG electrode arrays including 5% electrode positions, were developed, resulting in electrode arrays of up to 345 positions (Oostenveld and Praamstra, 2001). Due to engineering advances in EEG amplifiers, a much higher number of electrodes can be simultaneously recorded, and currently available systems allow EEG recording from up to 256 locations on the scalp. However, such a large array is reserved for specific applications, such as electric source imaging for presurgical evaluation.

In this guideline we define the minimum number, position and nomenclature of scalp electrodes for standard recordings and discuss the yield of higher electrode numbers for special clinical questions. This paper presents a unified approach for the use of electrode arrays, ranging from the basic array (25 electrodes, including six electrodes in the inferior temporal chain), through an extended version of the modified combinatorial array to the high-density array (currently commercial systems accommodate up to 256 electrodes).

2. Basic electrode array and nomenclature of the 10–20 system

Electrode positions are based on percentages of the circumferential measurements from cephalometric landmarks of the skull (Klem et al., 1999). The electrode names consist of letters and numbers. The letters (F, T, P, O) indicate the underlying lobe (exception: P7/8, overlying the posterior temporal lobe). C indicates the central region. Anatomical studies showed that using the measurements described here, C electrodes are located 1 cm within the central sulcus (Klem et al., 1999). Fronto-polar electrodes are annotated Fp. Odd numbers are on the left side, and even numbers on the right side. Electrodes in the midline are annotated with z (for zero). Landmarks on the skull are: the left and right preauricular points (depressions at the root of the zygoma, just anterior to the tragus), nasion (depression between the eyes, just superior to the bridge of the nose, at the intersection of the frontal bone and the nasal bones) and inion (the highest point of the protuberance of the occipital bone, in the midline; Fig. 1).

Based on the anatomical landmarks detailed above, the following measurements have to be obtained.

The first (longitudinal) circumferential measurement is in the sagittal plane, in the midline of the skull, from the nasion, through the vertex (the uppermost point of the head) to the inion (Fig. 1-A). Considering this distance as 100%, five points are marked between the nasion and inion, in the anterior-posterior direction, giving the level (longitude) of the following points: Fpz (10% from the nasion), Fz (20% from Fp), Cz (20% from F), Pz (20% from C) and Oz (20% from P and 10% anterior to the inion).

The second (transversal) circumferential measurement is in the coronal plane, from the left to the right preauricular point, through the vertex (Fig. 1-B). Considering this distance as 100%, seven points (latitudes) are marked in this direction: T9 (at the left preauricular point), T7 (10% from the preauricular point), C3 (20% from T7), Cz (20% from C3, at the intersection of the first and second circumferential measurement), C4 (20% from Cz), T8 (20% from C4) and T10 (10% from T8, at the right preauricular point).

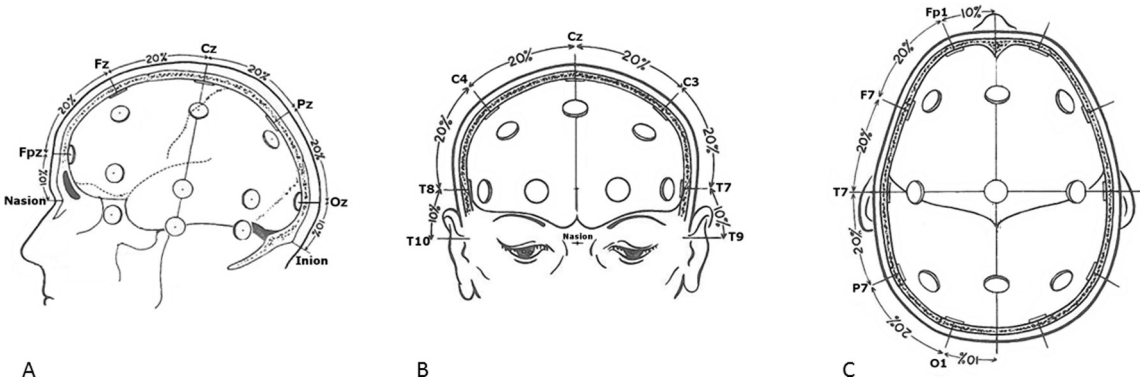

Fig. 1. A-C: Placement of the standard electrodes of the 10–20-system (modified from Klem et al., 1999, with permission). A: lateral view, B: frontal view, C: from the top.

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