Brain Stimulation 15 (2022) 1011–1012

Contents lists available at ScienceDirect

Brain Stimulation

journal homepage: http://www.journals.elsevier.com/brain-stimulation

Evaluation of the Beam-F3 method for locating the F3 position from the 10–20 international system

1. Introduction

Electromagnetic brain transcranial stimulation techniques have emerged to treat certain pathologies that require precise anatomical localization in the scalp to access the underlying cortical targets. For example, repetitive transcranial magnetic stimulation (rTMS) is an effective treatment for major depressive disorder when targeted at the dorsolateral prefrontal cortex (DLPFC) [1,2]. The 10–20 international system of electrode placement has been increasingly applied to locate the DLPFC, allowing the placement of a stimulation device above the F3 position. The Beam-F3 method [3] is commonly used by clinicians for targeting this area of the brain [4]. Advantages of this method include its cost-effectiveness and its ease of implementation, as it does not require neuronavigational systems for target localization.

2. Beam-F3 method assumptions

The Beam-F3 method imposes two assumptions: (i) the location of F3 at the intersection between the Fz-F7 and C3-Fp1 lines, and (ii) the angle of the polar coordinates of Fz, F7, C3 and Fp1 is fixed (i.e., does not change with head shape). However, both assumptions do not hold up well to real-world applications.

To evaluate the possibility of working in a plane using these coordinates and estimating the F3 position from the intersecting point between Fz-F7 and C3-Fp1, we have utilized the Lambert azimuthal equal-area (LAEA) projection. The 2nd order exponential transformation equation (R-square: 0.9897) used in the LAEA projection (Eq. (1)) as a system to apply the coordinates from the Beam-F3 method and to evaluate the different positions between the Beam-F3 method and the 10–20 system is given as:

$$TCi = 0.9418 \cdot \exp(0.001334m) + \left(2.721 \cdot 10^{-10}\right) \cdot \exp(0.1136m) \qquad \text{Eq. 1}$$

where TCi is the transformed coordinate of each point and m is the magnitude of the position vector before transformation.

Fig. 1a shows the 10–20 international system positions from a spherical model with indication of the Beam-F3 assumptions (intersection of Fz-F7 and C3-Fp1 lines). The result from the "Beam F3 Locator" webpage [5] differs from that obtained from the previously proposed equations [3]. This difference is due to the angle coordinate of Fp1: the angle is 288° according to the published equations [3] but is 298° according to the webpage results [5]. Studies that have analyzed the Beam-F3 method [6,7] have used the result obtained in the webpage (see Fp1web in Fig. 1a). Neither the intersection obtained using the coordinates of the published equations of Fp1 nor those of the Fp1web (red crosses in Fig. 1a) establish the correct F3 position.

A further remark is that the second length needed for the Beam-F3 method to locate the F3 position should be directly the length between Cz and the intersection (red cross) in this projection. However, Beam et al. [3] use a 0.9 coefficient as an arc to cord ratio. After applying the 0.9 coefficient (red dots) the webpage result for a spherical model is closer than that obtained using the published method, but neither one establishes the F3 position.

3. Results

The numerical calculations of the position error between the Beam-F3 and the F3 position from the 10–20 system should not be performed in a projection, as shown in Fig. 1a, as there is distortion in all projections from a sphere. Other authors have attempted to evaluate the Beam-F3 method exclusively *via* neuronavigational systems [6]; however, this correction does not consider head size and differences between head morphologies.

Using one spherical and two spheroid models, we have calculated the error (Euclidean distance (e)) between the F3 position according to the 10–20 system and according to the results from the Beam-F3 webpage (with adjusted length) [5]. Results revealed an error in the location of F3 for all head models that is dependent on the head shape. For example, in a spherical model with a 58 cm head perimeter (case A) $e_{BeamF3} = 4.9$ mm, and $e_{BeamF3web} = 9.2$ mm. Considering a spheroid head model in which the LPA-RPA distance is greater (38.25 cm) than the Ns-In distance (36.25 cm) (case B) the errors are $e_{BeamF3} = 6.1$ mm and $e_{BeamF3web} = 9.3$ mm. In cases where the Ns-In distance is greater (38.25 cm) than the LPA-RPA distance (36.25 cm) (case C) the errors are $e_{BeamF3} = 3.9$ mm, and $e_{BeamF3web} = 10.5$ mm. Fig. 1b shows the position of the F3 according to the 10–20 system (star markers), and the positions according to the Beam-F3 method using the published Fp1 coordinates [3] (cross markers) and using the results from the Beam-F3 webpage [5] (dot markers).

Because of the inconsistencies in the assumptions of the Beam-F3 method revealed in the present report, we consider that the obtained result is not sufficiently accurate to locate the exact F3 position from the 10–20 international system. Although this information is important for identifying a true F3 scalp landmark, there is no direct evidence to suggest that one DLPFC target is therapeutically superior to any other for rTMS. Nevertheless, this error added to the inherent errors of the application of the rTMS technique——such as the focusing capacity of different coils, errors in coil tilt positioning, drift and head movement——contribute to the variability of rTMS

https://doi.org/10.1016/j.brs.2022.07.002

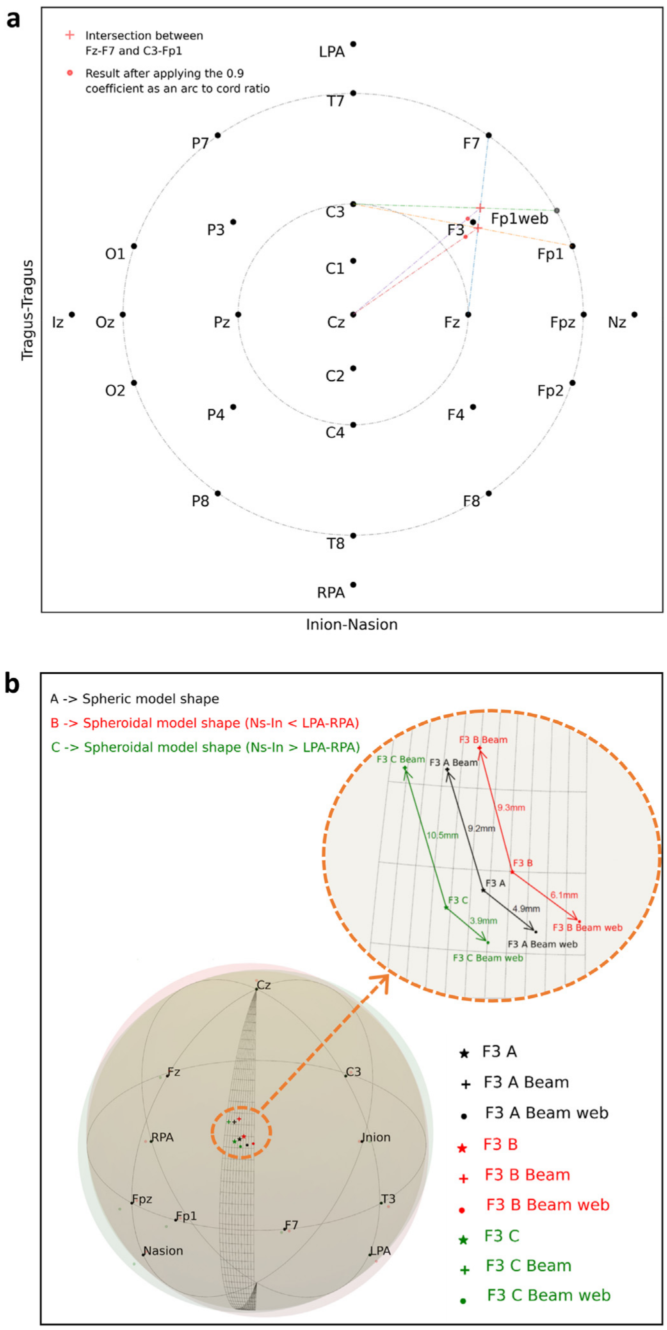

Fig. 1. 1a) The 10–20 system positions from a spherical model in a Lambert azimuthal equal-area projection. **1b)** Comparison of the three different head models of F3 from the 10–20 system, with the Beam-F3 based on the published report, and with the Beam-F3 webpage results.

efficiency. Moreover, because a recent study [8] proposes new locations to apply rTMS based on whole-brain maps of circuits associated with depression [9], the effectiveness of applying rTMS at a precise F3 position is relevant for comparative analyses.

4. Conclusions

Despite the extensive usage of the Beam-F3 method to locate the F3 position for rTMS without MRI-based neuronavigation, its limitations must be considered. The Beam-F3 method does not locate the exact position of F3, and introduces an error that is dependent on the head shape. Calculating the F3 position using the Beam-F3 might hinder the assessment of the effectiveness of the therapies applied at this location that seek to generate changes in the underlying cortex.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

Acknowledgments and Funding

This project was supported by the call Research to Business (R2B2021-02), financed by the URV and the Operating Program FEDER of Catalonia 2014–2020, in the framework of the order EMC/348/2016 of 27 of December from the European Regional Development Fund (ERDF) for the realization of projects of the units of valorization and transfer of knowledge of the universities of Catalonia.

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16 May 2022
Available online 19 July 2022