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Editorial

Localization with high-density EEG: Complexity of analysis versus accuracy

Accurate localization of the epileptic focus is critical when surgical resection is planned for patients with pharmacoresistant focal epilepsy. A variety of factors need to be considered for localization using scalp EEG, including dipole number and orientation, the amount of cortex involved in the discharge, distance of the generator from the surface, and inhomogeneities in the structures between the generator within the brain and the scalp electrode (Burgess et al., 2006; Kaiboriboon et al., 2012; Acharya and Acharya, 2019). In addition, the number and location of scalp electrodes is important, with a greater number and wider distribution of electrodes generally providing more precise localization. Multiple studies indicate that at least 64 electrodes or more are necessary to reduce localization errors (Brodbeck et al., 2011; Lascano et al., 2016; Lantz et al., 2003; Sohrabpour et al., 2015).

The increasing use of high-density EEG (HD-EEG) systems has led to significantly improved spatial resolution, but it has also raised concerns related to practical use (Acharya et al., 2016). Placement of several additional electrodes requires increased time and effort on the part of technologists. Additional electrodes and special systems may have to be purchased. Physicians reviewing the studies also need to have greater expertise, and should be prepared to invest more time in performing complex analysis.

Due to concerns that simple visual analysis of EEG may not provide sufficient precision for localization of the focus in surgical candidates, computational techniques, such as electrical or EEG source imaging (ESI) have been developed in an attempt to better identify the presumed source of electrical activity. ESI is typically performed with interictal epileptiform discharges (IED) using specialized software, and the data are co-registered to the patient's MRI. Most of the software packages are complex programs that require sophisticated computer knowledge and skills to understand and use them. Therefore, ESI has not become part of routine clinical practice. Further, it remains unclear whether or not ESI adds any information to visual EEG analysis that has a significant influence on decisions regarding surgery.

In this issue of *Clinical Neurophysiology Practice*, Toscano and colleagues (Toscano et al., 2020) address this question in a study of 20 patients with unifocal pharmacoresistant epilepsy in whom they performed both visual analysis and ESI using HD-EEG. In summary, they found that ESI was superior to visual analysis in terms of sensitivity (75% versus 58%), specificity (87% versus 75%) and accuracy (80% versus 65%) of localization, and also provided 3D information helpful in surgical planning. Nevertheless, it is interesting to note that visual analysis was also quite helpful in providing a general estimate of localization.

The authors selected their patients carefully, performed appropriate analysis and arrived at reasonable conclusions based on their findings. They also acknowledge some obvious limitations of their study, including the retrospective design and small sample size. It would have been helpful to also compare the accuracy of localization with visual analysis of traditional EEG using the 10–20 or 10–10 system (low-density EEG) and that of HD-EEG, to see if there was any difference or incremental benefit with HD-EEG in their patients.

Most centers investing in HD-EEG systems are likely to perform ESI rather than relying entirely on visual analysis, particularly for major decisions such as surgical resection. The findings of this paper do support greater accuracy with ESI, but visual analysis of HD-EEG alone can also be clinically helpful. Even without using sophisticated techniques, visual analysis of HD-EEG provides an initial broad map of the brain. From a practical perspective, neurophysiology laboratories performing HD-EEG at epilepsy centers that provide a lower level of care for complex epilepsy could use the findings to select patients for surgical referral to centers providing higher levels of care. Moreover, in one of their cases, ESI provided incorrect results while visual analysis of HD-EEG correctly localized the focus, suggesting that, in occasional situations, visual analysis may actually be superior. It may therefore be helpful to perform and compare findings from both the techniques.

Although it is not the primary focus of this article, the authors also address the possible significance of concordance or discordance of localization when ESI was obtained from the rising phase and the peak of the IED. Previous studies have suggested that the initial component of an IED is more likely to represent the source, while the peak may reflect propagated activity (Rose and Ebersole, 2009; Plummer et al., 2008). Interestingly, in this paper, discordance was associated with a worse surgical outcome, presumably reflecting greater propagation. Additional studies are necessary to see if this has clinical relevance in terms of a need for broader surgical resection or intracranial monitoring when discordance is identified.

With further advances in computer technology and the availability of more user-friendly software for ESI, this technique is likely to become more widely used in clinical practice. Until then, visual analysis may provide a reasonable compromise between complexity of analysis and accuracy for localization of the epileptic focus.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Acharya, J.N., Acharya, V.J., 2019. Overview of EEG montages and principles of localization. J. Clin. Neurophysiol. 36, 325–329.
Acharya, J.N., Hani, A.J., Cheek, J., Thirumala, P.D., Tsuchida, T.N., 2016. American Clinical Neurophysiology Society Guideline 2: Guidelines for standard electrode position nomenclature. J. Clin. Neurophysiol. 33, 308–311.
Brodbeck, V., Spinelli, L., Lascano, A.M., Wissmeier, M., Vargas, M.I., Vulliemoz, S., et al, 2011. Electroencephalographic source imaging: a prospective study of 152 operated epileptic patients. Brain 134, 2887–2897.
Burgess, R.C., Iwasaki, M., Nair, D., 2006. Localization and field determination in electroencephalography and magnetoencephalography. In: Wyllie, E. (Ed.), The Treatment of Epilepsy: Principles and Practice. fourth ed. Lippincott Williams & Wilkins, Philadelphia, pp. 141–165.
Kaiboriboon, K., Luders, H.O., Hemaneh, M., Turnbull, J., Lhatoo, S., 2012. EEG source imaging in epilepsy-practicalities and pitfalls. Nat. Rev. Neurol. 8, 498–507.
Lantz, G., Grave de Peralta, R., Spinelli, L., Seeck, M., Michel, C.M., 2003. Epileptic source localization with high density EEG: how many electrodes are needed? Clin. Neurophysiol. 114, 63–69.
Lascano, A.M., Perneger, T., Vulliemoz, S., Spinelli, L., Garibotto, V., Korff, C.M., Vargas, M.I., et al, 2016. Yield of MRI high-density electric source imaging (HD-ESI), SPECT and PET in epilepsy surgery candidates. Clin. Neurophysiol. 127, 150–155.
Plummer, C., Harvey, A.S., Cook, M., 2008. EEG source localization in focal epilepsy: where are we now? Epilepsia 49, 201–218.
Rose, S., Ebersole, J.S., 2009. Advances in spike localization with EEG dipole modeling. Clin. EEG Neurosci. 40, 281–287.
Sohrabpour, A., Lu, Y., Kankirawatana, P., Blount, J., Kim, H., He, B., 2015. Effect of EEG electrode number on epileptic source localization in pediatric patients. Clin. Neurophysiol. 126, 472–480.
Toscano, G., Carboni, M., Rubega, M., Spinelli, L., Pittau, F., Bartoli, A., et al, 2020. Visual analysis of high-density EEG: as good as electrical source imaging? Clin. Neurophysiol. Pract. This Issue.

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