High density EEG—What do we have to lose?

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Multiple studies have demonstrated the utility of electrical source imaging (ESI) of high density EEG recordings for improved localization of epileptic foci in surgical candidates compared to visual interpretation of the conventional scalp EEG (Lantz et al., 2003; Holmes et al., 2008, 2010; Yamazaki et al., 2013; Storti et al., 2013; Mégevand et al., 2014; Michel et al., 2004a,b; Brodbeck et al., 2010; Zumsteg et al., 2005; Lantz et al., 2001; Brodbeck et al., 2009). A large prospective study in 151 pediatric and adult epilepsy surgery patients found that ESI using 126–256 channels and individual brain MRIs as the head model yielded a sensitivity of 84% and a specificity of 88% in identifying the seizure onset zone, which was significantly better than that obtained using low-density EEG recordings, structural MRI, PET exam, or ictal SPECT exams (Brodbeck et al., 2011). Some have argued that high density EEG should be a routine part of the evaluation of patients with localization related epilepsy (Plummer et al., 2008). Yet, most epilepsy monitoring units have not yet adopted these tools and a sparse electrode montage remains the clinical standard. A major consideration of how widely to use this technology is the technician and physician costs associated with increasing electrode number in EEG recordings. In our experience, even with very experienced technicians, high density EEG recordings with 128-channel caps take approximately 90–100 min to prepare and apply per patient and often require daily maintenance to ensure good recording quality. In contrast, a conventional EEG recording, including 21 electrodes takes ~45–60 min to set up for a single patient and only requires electrode maintenance every 5–6 days. In addition, increasing the electrode number adds to the physician time to visually review the data. Given these costs, determining the potential benefits of increasing electrode number in pre-surgical evaluations becomes a matter of significant practical importance.

In this issue of Clinical Neurophysiology, Sohrabpour et al. evaluate source localization accuracy of 4 electrode configurations in a case series of 5 pediatric patients with high density EEG and individual MRIs using electrocorticography recordings and surgical resections with good outcome to measure accuracy (Sohrabpour et al., 2014). These authors conclude that increasing electrode number decreases localization error, though this improvement plateaus. Using computational models, they demonstrate that localization accuracy for sparse and dense electrode sampling is not impacted by the location of the

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lesion relative to the overlying electrodes. However, consistent with intuition, small lesions stand to benefit from denser arrays more than larger lesions.

The study may underestimate the potential gain present in localization accuracy with increasing electrode number. Given the variability of lesion size and patient age (and presumed head circumference, which will impact electrode density), the small sample size ($n = 5$) limits the ability to find clinically significant differences in electrode configurations. In addition, the lack of true electrode position for the ESI model used a priori limits the resolution feasible with increasing electrode number. However, many epilepsy centers do not collect electrode position from each patient, and in these cases, the study represents an accurate scenario. Finally, most patients in this case series had lesions of moderate to large size, ranging up to 45.8 cm^3, and a greater gain in localization accuracy was noted for smaller lesions.

This study joins a wealth of others to demonstrate the utility of using high density electrode configurations and ESI techniques to localize the seizure onset zone in refractory epilepsy patients. Here, a plateauing effect was observed in the localization improvement as the number of EEG recording channels increased, allowing the clinicians to consider the cost-benefit ratio for additional electrode coverage. Using the ESI techniques outlined in this study, the greatest gain will come with increasing the electrode number to at least 64. Notably, the localization error continued to decrease with every increase in electrode number.

Current non-invasive modalities used by clinicians to improve localization of epileptic foci in preparation for epilepsy surgery, including PET, SPECT, fMRI and MEG studies, each add substantially to technician and physician time for data acquisition, analysis, and interpretation. In spite of all of these efforts, we still fail to accurately identify the seizure onset zone in over a third of our patients (Wyllie et al., 2004). When the seizure onset zone is extratemporal, this number rises to nearly half (Wyllie et al., 2004; Englot et al., 2013). These disheartening statistics may motivate the clinician to leverage all available technologies to better localize the seizure onset zone. If patients stand to benefit from ESI with high density configurations, these time-intensive recording techniques should be routinely employed. Although increasing electrode number may yield diminishing returns, there is justification for even incremental improvement in the accurate localization of the seizure onset zone for any of our pre-surgical patients.

Acknowledgments

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