High density EEG—What do we have to lose?

Citation

Chu, Catherine J. 2015. "High Density EEG—What Do We Have to Lose?" *Clinical Neurophysiology* 126 (3) (March): 433–434. doi:10.1016/j.clinph.2014.07.003.

Published Version

doi:10.1016/j.clinph.2014.07.003

Permanent link

<http://nrs.harvard.edu/urn-3:HUL.InstRepos:29666952>

Terms of Use

This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Open Access Policy Articles, as set forth at <http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#OAP>

Share Your Story

The Harvard community has made this article openly available.
Please share how this access benefits you. [Submit a story](#).

[Accessibility](#)

Published in final edited form as:

Clin Neurophysiol. 2015 March ; 126(3): 433–434. doi:10.1016/j.clinph.2014.07.003.

High density EEG—What do we have to lose?

Catherine J. Chu*

Massachusetts General Hospital/Harvard Medical School, 175 Cambridge Street, Suite 340,
Boston, MA 02144, USA

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

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

The author would like to thank Kristy Nordstrom, R.EEG and Kara Houghton, R.EEG for providing time estimates for this article. CJC is funded by NIH-5K12NS066225-02.

References

- Brodbeck V, Lascano AM, Spinelli L, Seeck M, Michel CM. Accuracy of EEC source imaging of epileptic spikes in patients with large brain lesions. *Clin Neurophysiol.* 2009; 120(4):679–85. [PubMed: 19264547]

- Brodbeck V, Spinelli L, Lascano AM, Pollo C, Schaller K, Vargas MI, et al. Electrical source imaging for presurgical focus localization in epilepsy patients with normal MRI. *Epilepsia*. 2010; 51:583–91. [PubMed: 20196796]
- Brodbeck V, Spinelli L, Lascano AM, Wissmeier M, Vargas MI, Vulliemoz S, et al. Electroencephalographic source imaging: a prospective study of 152 operated epileptic patients. *Brain*. 2011; 134:2887–97. [PubMed: 21975586]
- Englot DJ, Breshears JD, Sun PP, Chang EF, Auguste KI. Seizure outcomes after resective surgery for extra-temporal lobe epilepsy in pediatric patients. *J Neurosurg Pediatr*. 2013; 12:126–33. [PubMed: 23768201]
- Holmes MD, Tucker DM, Quiring JM, Hakimian S, Miller JW, Ojemann JG. Comparing noninvasive dense array and intracranial electroencephalography for localization of seizures. *Neurosurgery*. 2010; 66:354–62. [PubMed: 20087136]
- Holmes MD, Brown M, Tucker DM, Saneto RP, Miller KJ, Wig GS, et al. Localization of extra temporal seizure with non-invasive dense-array EEC. *Pediatr Neurosurg*. 2008; 44:474–9. [PubMed: 19066438]
- Lantz G, Grave de Peralta Menendez R, Gonzalez Andino S, Michel CM. Noninvasive localization of electromagnetic epileptic activity. II. Demonstration of sublobar accuracy in patients with simultaneous surface and depth recordings. *Brain Topogr*. 2001; 14(2):139–47. [PubMed: 11797812]
- Lantz G, Grade de Peralta R, Spinelli L, Seeck M, Michel CM. Epileptic source localization with high density EEG: how many electrodes are needed? *Clin Neurophysiol*. 2003; 114(1):63–9. [PubMed: 12495765]
- Mégevand P, Spinelli L, Genetti M, Brodbeck V, Momkian S, Schaller K, et al. Electrical source imaging of interictal activity accurately localizes the seizure onset zone. *J Neurol Neurosurg Psychiatry*. 2014; 85:38–43. [PubMed: 23899624]
- Michel CM, Murray MM, Lantz G, Gonzalez S, Spinelli L, Peralta R. EEG source imaging. *Clin Neurophysiol*. 2004a; 115:2195–222. [PubMed: 15351361]
- Michel CM, Lantz G, Spinelli L, De Peralta RG, Landis T, Seeck M. 128-channel EEG source imaging in epilepsy: clinical yield and localization precision. *J Clin Neurophysiol*. 2004b; 21:71–83. [PubMed: 15284597]
- Plummer C, Harvey AS, Cook M. EEG source localization in focal epilepsy: where are we now? *Epilepsia*. 2008; 49:201–18. [PubMed: 17941844]
- Sohrabpour A, Lu Y, Kankirawatana P, Blount J, Kim H, He B. Effect of EEG electrode number on epileptic source localization in pediatric patients. *Clin Neurophysiol*. 2014 in this issue.
- Storti FS, Galazzo IB, Del Felice A, Pizzini FB, Arcaro C, Farmaggio E, et al. Combining ESI, ASL, and PET for quantitative assessment of drug-resistant focal epilepsy. *Neuroimage*. 2013 Epub ahead of print.
- Wyllie E, Comair YG, Kotagal P, Bulacio J, Bingaman W, Ruggieri P. Seizure outcome after epilepsy surgery in children and adolescents. *Ann Neurol*. 2004; 44:740–8. [PubMed: 9818929]
- Yamazaki M, Tucker DM, Terrill M, Fujimoto A, Yamamoto T. Dense array EEG source estimation in neocortical epilepsy. *Front Neurol*. 2013; 4:42. <http://dx.doi.org/10.3389/fneur.2013.00042>. eCollection 2013 Erratum in: *Front Neurol* 2013, 4, 132. [PubMed: 23717298]
- Zumsteg D, Friedman A, Wennberg RA, Wieser HG. Source localization of mesial temporal interictal epileptiform discharges: correlation with intracranial foramen ovale electrode recordings. *Clin Neurophysiol*. 2005; 116(12):2810–8. [PubMed: 16253551]