Reliable MEG/MSI source localization in patients with implanted vagus nerve stimulator (VNS) devices: a single-centered, large clinical observation study

Mahmoud Jiha[1], Velmurugan Jayabal[1], Dylan Davis[1], Gavin Belok[1], Joshua Chon[1], Srivatsan Tennathur[1], Chang Cai, Mary Mantle[1], Anne Findlay[1], Heidi E. Kirsch[1], and Srikantan S. Nagarajan[1]

Background: A subset of medically refractory epilepsy patients undergo VNS implantation to minimize their seizure burden. Some of these patients do not respond to VNS stimulation or have persistent seizures; hence they are subsequently evaluated with MEG to identify the potential epileptogenic zone (EZ) for possible surgery. However, VNS devices induces persistent artifact in the raw MEG data; large-amplitude fluctuations which hinder and mask the ongoing background brain activity. Here we present our clinical experience on the utility of the dual-signal subspace projection (DSSP) algorithm in decontaminating such artifacts and identifying and localizing the interictal epileptiform discharges (IED).

Method: We included 117 patients (66 males, 51 females) with implanted VNS who underwent simultaneous MEG/EEG between November 2004 and July 2023 at the University of California, San Francisco Biomagnetic Imaging Laboratory. Patient ages ranged from 4.3 to 69.3 years (M = 32.4, SD = 14.5). Of these 117 patients with VNS, only 66 patient's (56.4%) MEG data was pre-processed with DSSP to remove VNS induced artifacts. To compare the effectiveness of our approach, we randomly included another cohort of 117 epilepsy patients (72 males, 45 females) without VNS implant who had undergone MEG/EEG between November 2004 and July 2023. In this cohort, patient ages ranged from 1.5 to 74.6 years (M = 24.6, SD = 14.7). The raw MEG data was visually reviewed for both cohorts and the following information were qualitatively interpreted as follows; 1) Presence or absence of any IED detection in the pre and post DSSP (if any) processed MEG data; 2) Successful or unsuccessful equivalent current dipole (ECD) source modeling of at least one IED. Between group (with and without VNS) and within VNS group (with and without DSSP) statistical analyses were performed using chi-squared test at the 0.05 significance level.

Results: In patients with implanted VNS, utilization of DSSP to decontaminate the raw data did not increase the likelihood of IED detection (p=0.47) when compared with patients where DSSP was not used. However, DSSP significantly improved ECD source localization of detected IEDs (76% vs 56%; X^2 = 4.68; p=0.03), in comparison to source localization of events on the non-DSSP data. It is interesting to note that both the ability to detect IED (p=0.73) and ECD source localization (p=0.39) in VNS patients was comparable with the general MEG population without VNS.

Significance: The current study attempts to provide deep insight into the clinical utility of MEG/MSI source localization in the large cohort of VNS patients amidst persistent artifacts. We demonstrated that DSSP artifact rejection improved the detection and localization accuracy of these epileptifom events.

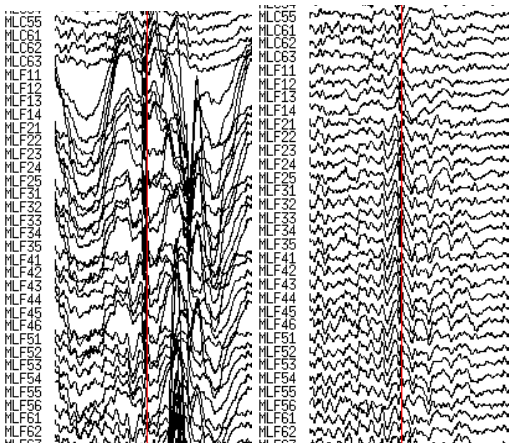

Figure-1: The figure demonstrates the raw MEG data with large amplitude VNS artifacts (left) and after being processed with DSSP, showing events without any artifacts (right)