Deficits in nonlinear EEG synchronisation during open heart surgery: A pilot exploratory work.

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Background and Goal of Study:

Postoperative cognitive dysfunction has been reported in 50% of patients after cardiac surgery. Dysfunction in nonlinear interactions between brain network regions have been previously shown in patients with cognitive deficits. The aim of this study was to explore whether such changes in nonlinear interactions can be detected during cardiopulmonary bypass (CPB).

Materials and Methods:

After approval by local ethics comity & informed consent, 5 similar patients (2M-3F, age:53-81, ASAIII-IV) were included. Anesthesia was provided using propofol-remifentanil in TCI mode and standard neuroprotection technics (hypothermia & MAP>60mmHg). We have analysed frontopolar homologous EEG recordings (using 10-20 system of electrode placement). We used the NeuroSENSE monitor, recording at 256Hz with the WAVcns function to help maintain the depth of anesthesia throughout surgery at the recommended level (between 40-60). We have selected two one minute epochs of EEG data, one several minutes before cannulation and a second after beginning of CPB.

Results and Discussion:

The Morlet wavelets power spectrum and the magnitude of the wavelet cross spectra, between the homologous frontopolar recordings, show no significant differences on the results produced for the EEG epoch before and after CPB. However, 4 of 5 cases show a drop in the magnitude of the Cross-bispectrum (a technique assessing nonlinear interactions) that ranged between 54-93% ($p<0.04$) in the post CPB EEG epoch. The significant drop in the magnitude of the Cross-bispectrum revealed in the post-CPB EEG epochs, in comparison to the pre-cannulation EEG findings, suggests a selective relative attenuation in the intensity of nonlinear brain interactions. These findings were not reflected in the wavelet spectral and cross-spectral analysis, in keeping with a consistent depth of anesthesia throughout surgery.

No changes in the magnitude of the cross-bispectrum interactions were seen in one of the 5 cases, militating against the differences found in the remaining patients being a reflection of the cooling effect on brain function.

Conclusion(s):

We show evidence of dampening of nonlinear interactions between homologous frontopolar areas on EEG recordings during CPB. None of the remaining linear quantitative estimates show significant changes. This finding needs further confirmation on a larger cohort of patients while exploring if this technique correlates with negative cognitive outcomes.

EEG recordings with markers

Steady state anesthesia
32 minutes prior to cannulation

After beginning of CPB

ERR	Pre cannulation			Post CPB		
	Syn	Ave	Std	Syn	Ave	Std
Case 1	5%	0,22	0,16	3%	0,21	0,15
Case 2	7%	0,24	0,16	4%	0,15	0,11
Case 3	16%	0,25	0,13	15%	0,26	0,14
Case 4	35%	0,4	0,21	31%	0,35	0,19
Case 5	32%	0,39	0,23	18%	0,38	0,21
Wavelet	Max Power R	Cross BsP	Cross S	Max Power R	Cross BsP	Cross S
Case 1	30	5.3×10^{13}	800	30	5.5×10^{12}	1000
Case 2	30	10×10^{13}	1800	30	8.5×10^{12}	800
Case 3	15	3×10^{12}	300	15	14×10^{11}	300
Case 4	30	2.5×10^{16}	1500	50	2.5×10^{16}	1500
Case 5	40	9×10^{16}	1500	60	7×10^{15}	2500

1. Lombard FW, Mathew JP. Neurocognitive dysfunction following cardiac surgery. Semin Cardiothorac Vasc Anesth 2010; 14:102–110

2. Newman MF, Kirchner JL, Phillips-Bute B, et al. Longitudinal assessment of neurocognitive function after coronary-artery bypass surgery. N Engl J Med 2001; 344:395–402

3. He F, Wei HL, Billings SA, Sarrigiannis PG. A nonlinear generalization of spectral Granger causality. IEEE Trans Biomed Eng. 2014 Jun;61(6):1693-701