POSTER
Presentation

Comparing Optimal Tripolar Concentric Ring Electrode to Bipolar and Tripolar Commercial Configurations Using Finite Element Method Modeling

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Abstract:

Concentric ring electrodes (CREs) are showing promise in noninvasive electrophysiological measurement but electrode design criteria are rarely detailed and justified for existing commercial products. Because of that, direct comparisons of proposed electrode designs to commercially available configurations are needed. This abstract reports on the recent progress made in comparing the optimal tripolar CRE maximizing the accuracy of the surface Laplacian (second spatial derivative of surface potential) estimation at each electrode to commercial products including bipolar CoDe® electrodes manufactured by Spes Medica and tripolar t-Lead electrodes manufactured by CREmedical. The comparison was drawn using realistic finite dimensions models of the electrodes via finite element method modeling. Obtained results included relative and normalized maximum errors of Laplacian estimation.

For bipolar CoDe® electrodes, novel optimal bipolar CRE configuration was proposed and included in comparison along with the previously proposed tripolar one. They were compared to bipolar configuration of the same size with dimensions corresponding to CoDe® electrodes as well as to its scaled version of a different size. Specifically, optimal tripolar configuration was compared to a bipolar configuration consisting out of its central disc and middle ring only. Compared to the optimal tripolar CRE configuration, commercially available CoDe® electrode of the same size corresponded to a median increase in Laplacian estimation errors of 120-146 times while its counterpart one third of its size corresponds to an increase of 15-18 times. Compared to the optimal bipolar configuration, commercially available CoDe® electrode of the same size corresponded to a median increase in Laplacian estimation errors of 1.2 times.

For tripolar t-Lead electrodes, the use of finite dimensions model of CRE was two-fold. First, it was used to optimize the surface Laplacian estimate coefficients for tripolar electrode configuration with dimensions approximating t-Lead electrodes. Two differential signals representing differences between potentials on the middle ring and on the central disc as well as on the outer ring and on the central disc are combined linearly into the Laplacian estimate with aforementioned coefficients representing the weights of differential signals. Second, it was used to directly compare said tripolar configuration to the optimal tripolar CRE configuration of the same size. Obtained results suggested that optimal coefficients for Laplacian estimate based on the approximation of the t-Lead dimensions to be (6, -1) as opposed to (16, -1) widely used with this electrode in the past. Moreover, compared to the optimal tripolar CRE configuration, approximation of the commercially available t-Lead electrode of the same size corresponded to a median increase in Laplacian estimation errors of over 4 times.

These results are consistent with prior results based on both the simplistic negligible and the realistic finite dimensions model of the CRE but further investigation on real life phantom and human data via physical CRE prototypes is needed for conclusive proof. The clinical relevance of these results is that quantifying the advantage of optimal over commercially available CRE configurations could provide an insight to inform future electrode designs for real-life applications not limited to the ones that already rely on commercially available CREs.