ADVANCES IN NONCONTACT ENDOCARDIAL MAPPING

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Abstract-**We globally investigated (1) the properties of noncontact cardiac electrograms measured by multielectrode cavitary probes, (2) the features of endocardial electrograms computed from the noncontact probe electrograms, and (3) the impact of the probe size on both the noncontact and the computed electrograms. We deployed a custom catheter in the dog RA, which consisted of a cylindrical probe with 64 electrodes on its surface, for measuring noncontact cavitary electrograms, and a concentric endocardial basket carrying an additional array of 64 electrodes, for measuring contact endocardial electrograms. Both a 5-mm and a 10-mm diameter probe were sequentially tested during normal as well as during paced rhythms. Boundary element method and numeric regularization were applied to compute endocardial electrograms at the basket electrode locations. We found that noncontact electrograms were attenuated and smoothed, and this effect was exaggerated with the small probe. Computed endocardial electrograms more accurately reconstructed important amplitude distribution and morphological features. In conclusion, global RA activation may be delineated directly from noncontact cavitary electrograms alone, but may be affected by volume attenuation, smoothing, and probe size. Accurate endocardial electrograms, however, can be successfully computed from noncontact electrograms acquired with small probes.**
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I. INTRODUCTION

Our objectives were (1) to compare at multiple sites the activation, amplitude, and morphological properties of noncontact cavitary electrograms with those of contact endocardial electrograms, (2) to solve the "inverse problem" by computing endocardial electrograms based on measured noncontact electrograms and highlight the advantages gained by this approach, and (3) to investigate the impact of probe size on the features and accuracy of both noncontact cavitary electrograms and computed endocardial electrograms.

II. METHODOLOGY

We built an electrode-system that consisted of a custom cylindrical probe and a concentric basket-shaped catheter [1], [2]. The probe was used to measure noncontact cavitary electrograms. The basket, included only for experimental purposes, was used to measure electrograms at the same time directly on the endocardium. Two different size probes were tested in one dog; a 5-mm diameter probe and a 10-mm diameter probe. Both probes contained 64 electrodes on their surfaces, arranged in 8 columns and equally spaced at 4 mm along the columns. The basket carried 64 electrodes mounted on 8 flexible splines (8 electrodes per spline).

The probe-basket system was placed in the RA and deployed in the center of the cavity. Noncontact probe and contact basket unipolar electrograms were simultaneously recorded during baseline sinus rhythm and while pacing through basket electrode pairs.

Similar to previous studies [1]-[4], Laplace's equation was applied to describe the electrical potential (V) in the blood-filled cavity volume between the probe surface and the endocardial surface, subject to the boundary condition $\partial V/\partial n = 0$ on the surface of the probe, where n is the surface normal. Once the three-dimensional geometrical model was established, the boundary element method was employed to derive a function that described the relationship between the endocardial and probe potentials. The potentials were related according to $V_p = \mathbf{A}V_e$, where V_p is a set of potentials (electrograms) sampled at 64 electrodes on the probe surface, V_e is a set of potentials (electrograms) sampled at 64 nodes on the endocardial surface, and $\mathbf{A}$ is a matrix (function) of influence coefficients that depends on the probe-endocardium geometrical relationship. Matrix $\mathbf{A}$ was ill-conditioned and, therefore, Tikhonov numeric regularization of the first order was utilized to solve this endocardial "inverse problem" and compute endocardial surface electrograms based on the measured 64 noncontact probe electrograms.

III. RESULTS

Noncontact probe electrograms were initially compared with contact basket electrograms. To accomplish this, noncontact probe electrograms were assigned to the closest basket electrode locations facing the probe. Using the 5-mm probe, activation error was 9.4±7.1 ms and amplitude error was 57±6% (3.9±0.7 mV). With the 10-mm probe, activation error was 5.9±5.5 ms and amplitude error was 42±8% (2.6±0.5 mV).

Endocardial electrograms were computed based on measured noncontact probe electrograms by solving the "inverse problem". Both the 5-mm and the 10-mm probes were tested and the results were compared with contact basket electrograms. Using the 5-mm probe, activation error was 8.8±6.8 ms and amplitude error was 35±7% (2.4±0.5 mV). Spatial error in localizing the site of pacing was 5.1±6.1 mm. Whereas, with the 10-mm probe, activation error was 6.0±5.5 ms and amplitude error was 34±5% (2.1±0.4 mV). Spatial error in localizing the site of pacing was 3.2±4.4 mm.

IV. CONCLUSION

Both contact endocardial and noncontact cavitary electrograms reveal global features of activation. Noncontact

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electrograms are attenuated and smoothed, and this phenomenon is exaggerated with small cavitary probes. However, endocardial electrograms can be successfully computed based on noncontact cavitary electrograms acquired with a small probe to accurately reconstruct both electrogram amplitude and detailed morphology.

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