The Heart as an Acoustic Dipole: Spatiotemporal Mapping of the Cardiac Acoustic Activity on the Chest

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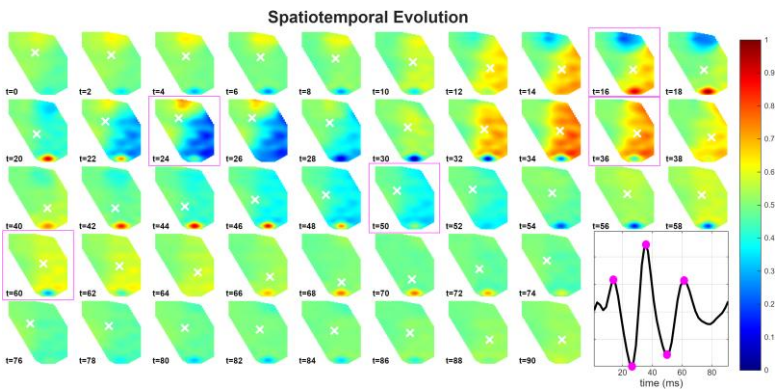
Aims: Digital auscultation is a promising tool to monitor cardiac hemodynamics, but traditional single-point recordings are highly sensitive to sensor placement. Knowledge of the morphological difference of the signals across the chest is still sparse. In this work, we propose a spatiotemporal analysis of the evolution of the two main heart sounds aimed at modelling the nature of the acoustic source and its effect on the location-specific sound morphology.

Methods: We recorded high-spatial-resolution multi-source heart sounds with a 58-channel microphone array. Topographic maps of the instantaneous intensity of the first (S1) and second (S2) heart sounds were obtained, and the coordinates of the intensity centroid estimated. The directionality of the trajectory of the instantaneous intensity centroid was quantified using Principal Component Analysis and anisotropic 2D Gaussian modelling.

Results: Mapping the acoustic field of S1 and S2 reveals the heart is not an isotropic acoustic source. Instead, topographic mapping shows distinct spatial phase inversions indicative of a directional mechanical dipole. The principal direction of the dipole lies between 40° and 90° (hexaxial reference system) in 8 healthy volunteers, compatible with the heart's longitudinal axis. The angle was repeatable over daily recordings from one subject.

Conclusion: These findings expand the knowledge on spatiotemporal evolution of heart sounds, highlight the importance of sensor placement and lay the foundations for a comprehensive mapping of the cardiac acoustic activity.



Topographic maps of the instantaneous intensity of S2 across the chest.