

Cardiac Anatomical and Electrical Axes: Proposed Definitions and Interplay

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Introduction: ECG morphology is linked to cardiac anatomical features, including size, position and orientation within the thorax. Yet, there remains a gap in quantifying and accounting for the impact of this relationship on ECG biomarkers extracted. Anatomical and electrical axes offer potential in tailoring clinical ranges to improve diagnosis, but lack standardised definitions.

Aims: To propose a standardised definition of the electrical and anatomical axes, and to describe their relationship in an undiseased adult population.

Methods: An undiseased cohort of 3,080 subjects with paired cardiac-MRI scans and 12-lead ECGs was studied. Biventricular anatomy was automatically segmented, and surface meshes were constructed. Principal Component Analysis and spatial centres of valves were used to derive five anatomical axes. For electrical axes, the vectorcardiogram (VCG) was constructed from ECGs using Kors transformation, and five axes were computed. The anatomical-electrical relationship was evaluated using two metrics: (i) least squares approach to assess anatomical-electrical linear correlation, (ii) spatial consistency, defined by the standard deviation (SD) of the anatomical-electrical angular differences (lower SD corresponds to larger spatial consistency). Using the proposed definition pair, angle distributions were analysed in 3D and all anatomical planes.

Results: The mean error (geodesic distance between predicted & computed electrical vectors) ranged from 1.95 to 0.81 across method pairs, with 0.81 for VPA (valvular plane centre to the apex) and eig1QRS (QRS loop primary eigenvector) followed by 0.92 for VPA and maxQRS (maximum QRS dipole magnitude). The VPA-maxQRS pair showed the highest spatial consistency (SD = 0.19). In contrast, the VPA-eig1QRS pair exhibited the second-lowest (SD = 0.21), from a range of SDs spanning up to 0.65. The proposed standard for defining the anatomical axis is the VPA, while for the electrical axis, it is suggested to use the maxQRS. Electrical angle spread was wider than the anatomical, with ranging variability across planes.