# Multi-Domain Quantitative ECG Analysis Reveals Distinct Morphological Patterns in Brugada Syndrome

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Brugada syndrome is associated with an elevated risk of sudden cardiac death and is conventionally diagnosed through visually identified electrocardiographic (ECG) patterns in the right precordial leads. However, visual assessment may not fully capture the broader quantitative phenotype present within the 12-lead ECG. This study aimed to investigate whether multi-domain ECG measurements can identify a distinct morphological signature in Brugada syndrome beyond conventional visual criteria.

We analyzed the publicly available Brugada-HUCA database. Each 12-second recording (100 Hz) was cropped to 10 seconds and upsampled to 500 Hz to conform to standard 10-second 12-lead ECG analysis using the Philips DXL algorithm. Quantitative ECG features were extracted across multiple domains, including amplitude, slope, duration, and area. Group differences were assessed with emphasis on right precordial leads V1 and V2.

Compared with controls, Brugada ECGs demonstrated substantially higher STJ amplitudes and more negative ST slopes in both V1 and V2 leads (all $p < 0.0001$). QRS and T-wave areas also differed significantly between groups ($p < 0.0001$). The most prominent waveform deviations were localized to the J-point, ST segment, and T-wave regions in V1-V2, supporting a predominantly repolarization-based phenotype. Figure 1 illustrates superimposed average representative beats for the Brugada and control groups in V1 (left) and V2 (right).

Multi-domain quantitative ECG analysis reveals a reproducible morphological signature of Brugada syndrome characterized by enhanced right-precordial ST-segment elevation, altered ST-segment slope, and repolarization abnormalities. These findings complement conventional visual interpretation and provide a structured quantitative framework for automated screening, interpretable machine learning, and improved risk stratification.

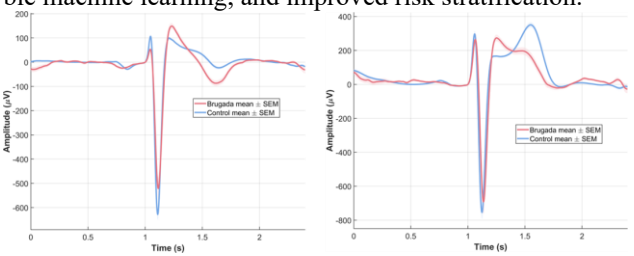


Figure 1. Average representative beats (mean ± SEM) for Brugada (red) and control (blue) in V1 (left) and V2 (right).