Thoracic Vibration-Based Screening of Pediatric Congenital Heart Disease: A Prospective Feasibility Study

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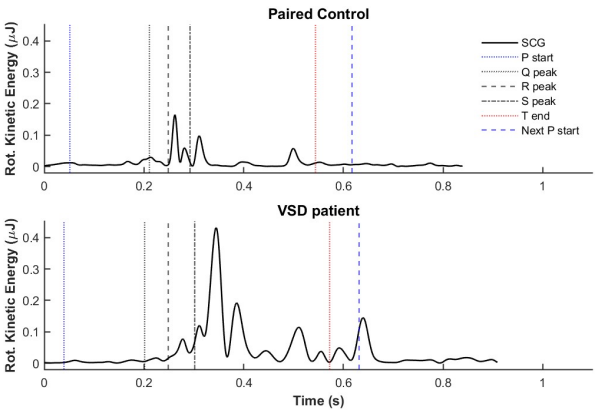
Congenital heart diseases (CHD) remain the most frequent congenital malformations, and early detection is essential to reduce their morbidity and mortality. Yet access to early, objective screening tools is limited in many clinical settings. This prospective study investigates the feasibility and diagnostic relevance of seismocardiography (SCG) for pediatric CHD screening. SCG captures chest-wall microvibrations induced by myocardial motion and blood flow, enabling noninvasive characterization of cardiac mechanics.

SCG recordings were obtained at the sternal surface and segmented using synchronized electrocardiogram (ECG) timing. Ensemble-averaged linear and rotational kinetic energy features were computed across ECG-defined cardiac phases. Ninety-two children were enrolled. The median age was 43 months [5.2–102.7], and the median body surface area was 0.75 m² [0.33–1.01]. The cohort included 36 patients with CHD-related murmurs, 18 subjects with innocent murmurs, and 38 controls. Signal quality was sufficient for analysis in 84.8% of acquisitions. Patients with CHD were younger and had lower weight and BSA (all $p < 0.05$). SCG-derived energy features were compared across diagnostic groups using rank-based ANCOVA adjusted for age and body surface area, yielding standardized effect sizes (β).
After adjustment for age and BSA, children with CHD exhibited significantly increased SCG linear kinetic energy during the atrioventricular conduction (PQ) phase ($\beta = 0.80$, $p < 0.001$), as well as elevated rotational kinetic energy over the full cardiac cycle ($\beta = 0.56$, $p = 0.02$). No statistically significant differences were observed between controls and subjects with innocent murmurs. When CHD subgroups were compared with age- and body-surface-area–matched control subjects, elevated rotational SCG energy was observed in ventricular septal defect and pulmonary stenosis, but not in atrial septal defect.

SCG captures disease-related alterations in cardiac mechanics and may enable automated murmur stratification. Further studies are required to validate its performance as a low-cost, portable screening modality.



Ensemble-averaged seismocardiography (SCG)-derived rotational kinetic energy signals are shown for a representative patient with a ventricular septal defect (VSD) (bottom panel) and a matched control subject (top panel) (age: 17 vs. 19 months, BSA 0.56 vs. 0.45 m²).