Measurement of Time-Resolved Septal Curvature to Assess Pediatric Pulmonary Hypertension

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Background

Pediatric pulmonary hypertension (PH) diagnosis remains challenging, often necessitating invasive catheterization for comprehensive hemodynamic assessment. Pressure-loaded right ventricles (RVs) negatively affect left ventricular (LV) geometry, which can be characterized using measurements such as septal curvature (SC) or intraventricular septal angle. SC has been shown to be promising for estimating PH severity, providing a non-invasive MR surrogate for invasive mean pulmonary arterial pressures (mPAP). A previous study with same day CMR and catheterization found a high correlation (r=0.81, p<0.001) between mPAP and SC (1). Yet, the need for manual contouring is time-consuming and observer-dependent, limiting clinical use.

Purpose

We propose an automated approach to measure SC using standard contours obtained for ventricular function and volumes, which may increase the clinical application of SC in pediatric PH MRI interpretation.

Methods

27 PH patients underwent cine balanced steady-state free precession (bSSFP) imaging in LV short-axis view and cardiac catheterization within a year of imaging and were compared to 17 normal controls.

A MATLAB tool computed SC values based on time-resolved LV and RV contours exported from Circle CVI42. LV epicardium and RV endocardium contours were annotated with 2 reference points at their intersections. These data were imported to MATLAB, in which a least-square fit was used for reference points and contours to compute approximated circles at each cardiac phase. Septal/free wall curvatures were calculated by the radius inverse of these circles (Fig. 1A). The obtained SC was normalized by free wall curvature to mitigate body size effects (Fig.1B). An area-based index called SC area was also computed (Fig. 1A). Statistical analyses were performed in Prism Graphpad.

Results

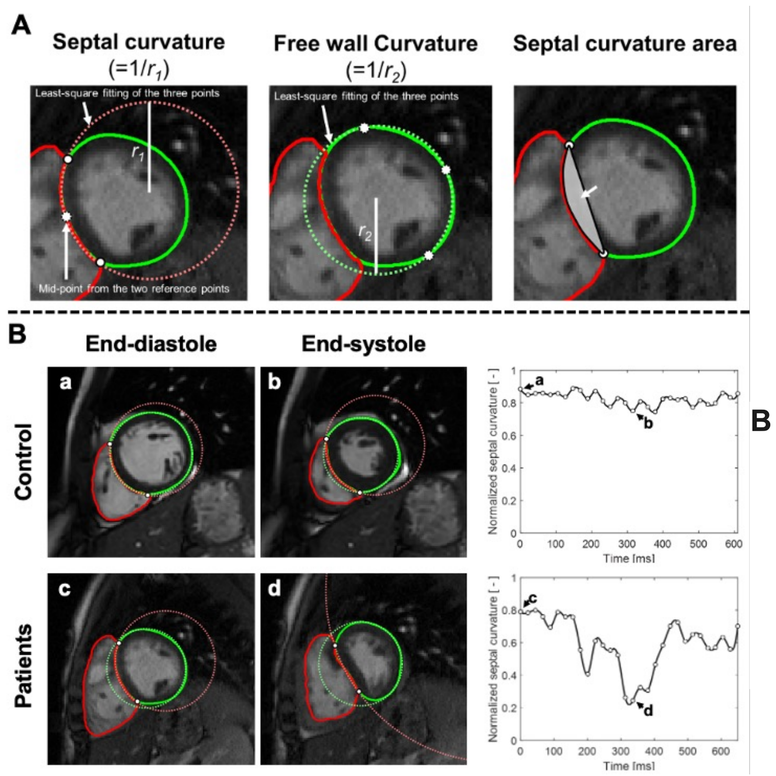

Figure 1. **A.** demonstrates calculation of septal curvature (SC), free wall curvature, and SC area. Contouring (solid red and green lines) was applied to the septum, lateral wall, and inferior wall at different points throughout the cardiac cycle. SC area is surrounded by the line connecting two reference points and the right ventricular contour.
B. shows end-systole and end-diastole, for a control and a patient, corresponding to points on the normalized SC (SC divided by free wall curvature) graphs. Diagrams, a and b, demonstrate a control's contours, while c and d demonstrate those of a PH patient. The labeled points (a, b, c, d) on the normalized SC graphs correspond to end-diastole and end-systole in the cardiac cycle for patient and control and show the large change in the patient's SC over time, compared to that of the relatively stable control's.

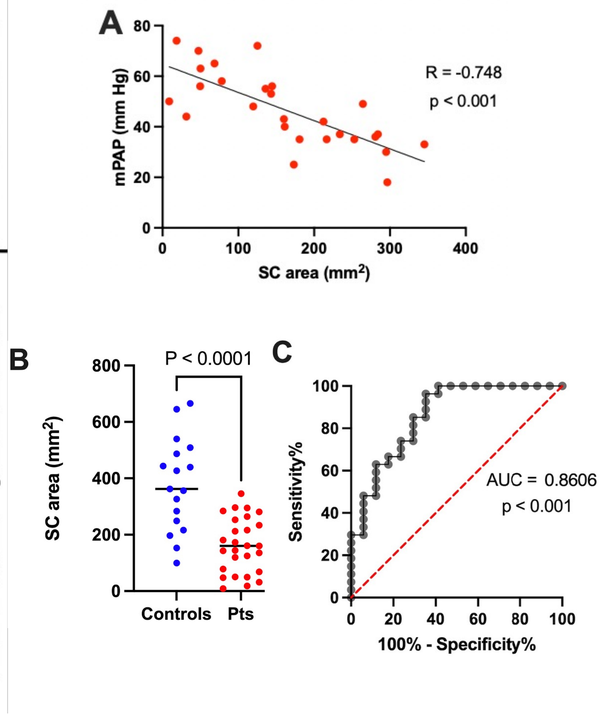

Figure 2. **A**. shows a correlation plot that displays the strong linear relationship (r=-0.75, p<0.0001) between SC area and mPAP. **B.** shows a boxplot comparing SC area of the patient and control groups, showing a significant difference (p<0.0001). **C.** The receiver operator characteristic (ROC) curve and area under curve (AUC) of SC area are shown.

Results

Patients and controls were well-matched with mean age of 14.3 ± 5.6 and 14.2 years ± 5.9 respectively (p=0.99) (Table 1). SC area was smaller in patients with a mean of 167.00 mm^2 compared to 366.33 mm^2 in controls (p<0.0001) (Fig 2A). Correlation between SC area and mPAP was strong (r = 0.75, p<0.0001) even with a median of 2 days (range 0 – 356) between CMR and catheterization (Fig 2B). SC area's AUC was 0.86, indicating SC area has strong predictive accuracy (Fig 2C).

Conclusions

We show a strong correlation of SC with mPAP, computed from contours obtained for calculating ventricular function, even for values obtained days or months after imaging. The results agree with prior reports using a custom manual segmentation approach and dedicated sequences.

This proposed algorithm could facilitate a rapid non-invasive method of estimating mPAP in-line with ventricular volume measurements, even in focused protocols.

References

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