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Original article

Myocardial strain of the left ventricle in normal children

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ABSTRACT

Background: There have been few reports regarding cardiac strain in children. The present study was performed to determine the reference values for circumferential and radial strains of the left ventricle in normal children and discern the relative influence of aging and cardiac growth on these left ventricular functional indices.

Methods: The study population consisted of 180 children (aged 2 months to 21 years) who had normal cardiac function and normal cardiac load. None of the patients had symptoms, and none was receiving medical therapy. 2D cine-loop recordings of short-axis views at the papillary muscle level were stored for off-line analysis. Custom acoustic-tracking software was used to measure left ventricular strain. Continuous variables are reported as mean values ± standard deviation. The correlation coefficients were calculated to identify the relative influences of aging on the strains. Tukey's test was used to assess differences in strain among the six-myocardial segments. In all analyses, $p < 0.01$ was taken to indicate statistical significance.

Results and conclusions: The strains of all segments could be analyzed in 136 of 180 children. There were no significant age-related changes in circumferential or radial strain in children, but regional heterogeneity in left ventricular strain. The circumferential and radial strains showed inverse distributions; the circumferential strain in the region with low radial strain was high, and that in the region with high radial strain was low. These observations indicated there are differences among the three-dimensional movements of the regions.

Introduction

Two-dimensional (2D) strain imaging by speckle tracking echocardiography, in contrast to tissue Doppler strain imaging, is angle-independent, and thus permits determination of all three (longitudinal, radial, and circumferential) strain components. These strains were measured in normal adults and data are available for adult patients with several cardiac diseases [1–3]. However, there have been few reports regarding cardiac strain in children [4].

The present study was performed to determine the reference values for circumferential and radial strains of the left ventricle in normal children, and to identify the relative influences of aging and cardiac growth on these left ventricular functional indices.

Methods

The study population consisted of 180 children (102 males and 78 females, aged 2 months to 21 years), including 62 cases of innocent heart murmur, 32 cases of benign chest pain, 31 cases of infrequent premature atrial contractions, 28 cases of natural closure of atrial septal defect, and 27 cases of infrequent premature ventricular contraction. All of them were judged to have normal cardiac function and normal cardiac load on echocardiac routine examination (the parameters of conventional echocardiography including end-diastolic and end-systolic dimensions, fractional shortening, and left ventricular ejection fraction were normal). None of the patients had symptoms, and none was receiving medical therapy. Their heart rates ranged from 51 to 150/min (84 ± 20/min).

All the patients were imaged in the supine position using a commercial ultrasound system (Vivid 7; GE Healthcare, Milwaukee, WI, USA). 2D cine-loop recordings of short-axis views at the papillary muscle level were stored for off-line analysis.

Custom acoustic-tracking software that allowed semiautomated strain analysis was used (EchoPac Advanced Analysis Technologies; GE Healthcare). This software utilizes B-mode grayscale images and tracks movement of stable acoustic patterns/markers, called speckles, in myocardial tissue. This tracking takes place frame by frame throughout the cardiac cycle [5]. The software is interactive, in that the endocardial-cavity interface is traced manually, while automated generation of a second epicardial tracing is created by the software.

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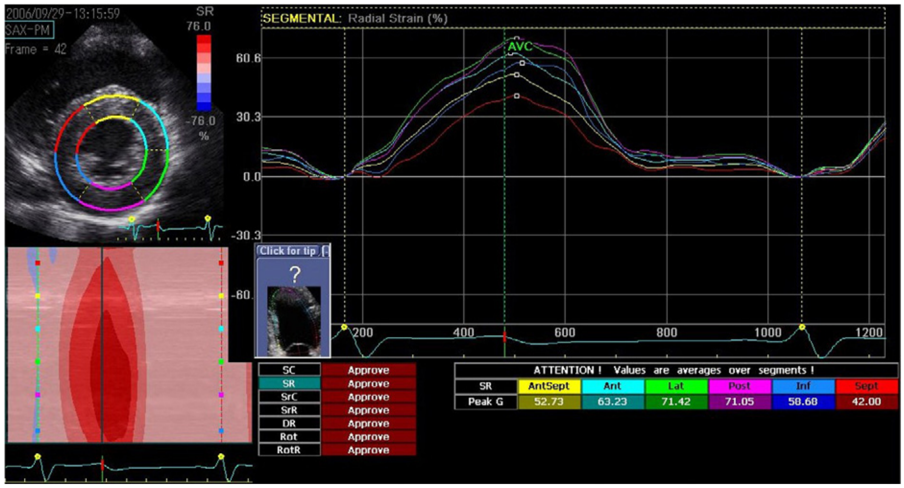

Fig. 1. Regions of interest (left) and graphic depiction of individual values of the mean transmural radial strain in a representative subject. AntSep, anteroseptal; Ant, anterior; Lat, lateral; Post, posterior; Inf, inferior; Sep, septal.

The software automatically divides the image into six segments (anteroseptal, anterior, lateral, posterior, inferior, and septal), provides automated tracking confirmation, and generates the strain values for each segment based on the spatial and temporal shift of the corresponding acoustic markers (Fig. 1).

Segments with poor image quality were rejected by the software and excluded from the analysis. The strains of all segments could be analyzed in 136 of 180 children, and data from these 136 children were included in this study.

Continuous variables are reported as mean values ± standard deviation (SD). The correlation coefficients were calculated to identify the relative influences of aging on the strains. Tukey's test was used to assess differences in strain among the six myocardial segments. In all analyses, $p < 0.01$ was taken to indicate statistical significance.

Interobserver variability was determined as the mean of differences between 10 paired strain measurements for each of the 6 segments in circumferential and radial modalities. Intraobserver variability was defined as the mean of differences between 1 measure and 10 repeated measures in all 6 segments.

Results

Peak strains were constant during childhood (Fig. 2). They were not correlated with age or heart rate. Circumferential peak strains of anteroseptal, anterior, lateral, posterior, inferior, and septal segments were −30.2 ± 5.9, −23.7 ± 5.3, −17.3 ± 4.4, −15.3 ± 4.3, −20.9 ± 5.7, and −27.6 ± 5.6, respectively (Fig. 3, upper panel). The peak strain of the anteroseptal segment was the highest, and those of septal, anterior, inferior, lateral, and posterior segments followed in descending order. Significant differences were found in the peak strains of all segments from each other ($p < 0.01$). Radial peak strains of the anteroseptal, anterior, lateral, posterior, inferior, and septal segments were 44.5 ± 10.6, 47.6 ± 11.6, 53.6 ± 15.5, 58.2 ± 16.0, 55.5 ± 16.3, and 51.6 ± 14.1, respectively (Fig. 3, lower panel). The peak strains of the anteroseptal and anterior segments were smaller than those of the lateral, posterior, inferior, and septal segments. The peak strain of the lateral segment was larger than those of the anterior and anteroseptal segments, and smaller than that of the posterior segment. The peak strain of the posterior segment was larger than those of the anteroseptal, anterior, lateral, and septal segments. The peak strain of the inferior segment was larger than those of the anteroseptal, anterior, and septal segments. The peak strain of the septal segment was larger than those of anteroseptal and anterior segments, and smaller than those of posterior and inferior segments.

The inter and intraobserver variabilities are shown on Bland–Altan plots (Fig. 4).

Discussion

There have been few reports regarding cardiac strain in children. Lorch et al. reported left ventricular longitudinal strain and

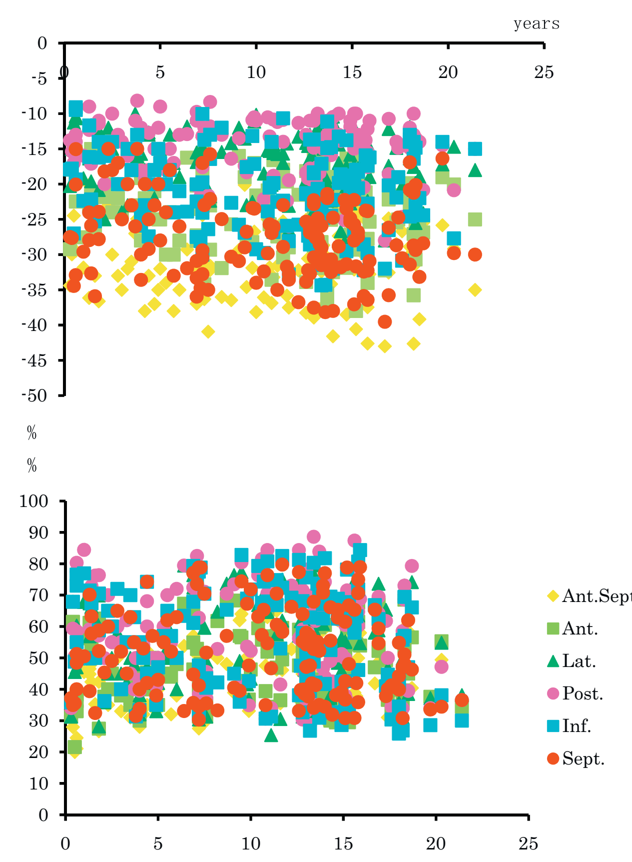

Fig. 2. Relation between circumferential strain and age (upper panel) and relation between radial strain and age (lower panel). Ant.Sept., anteroseptal; Ant., anterior; Lat., lateral; Post., posterior; Inf., inferior; Sept., septal.