Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Evaluation of Cardiac Function Changes Before and After Exercise Treadmill Stress Test in Children with Premature Atrial Contraction Using Speckle-Tracking Echocardiography

Lijuan Peng
Wuxi Children's Hospital
Haixia Yang
Wuxi Children's Hospital
Yunxiang Cao
497575970@qq.com

Wuxi Children's Hospital

Research Article

Keywords: premature atrial contraction, speckle-tracking echocardiography, exercise treadmill test, children, myocardial strain, left atrial function

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11566446/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Evaluation of Cardiac Function Changes Before and After Exercise Treadmill Stress Test in Children with Premature Atrial Contraction Using Speckle-Tracking Echocardiography

Abstract

Background: Premature atrial contraction (PAC) is a common ectopic arrhythmia in pediatric clinical practice. While most affected children are asymptomatic, exercise may induce palpitations, chest tightness, and increased PAC burden, with potential progression to more severe arrhythmias. Conventional echocardiographic parameters such as left ventricular ejection fraction (LVEF) may fail to detect early subclinical cardiac dysfunction. Two-dimensional speckle-tracking echocardiography (2D-STE) enables quantitative analysis of myocardial deformation independent of Doppler angle, providing a reliable means to assess early left atrial and ventricular impairment.

Methods: Fifty children with isolated PAC (27 males, 23 females; mean age 9.83 ± 2.18 years, range 6–16 years) were enrolled. All subjects underwent a modified Bruce protocol exercise treadmill test. Conventional echocardiographic parameters and 2D-STE strain parameters were acquired at rest and at 20 minutes during the recovery period after exercise. Conventional parameters included left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), LVEF, mitral E wave, A wave, E/A ratio, and E/e' ratio. 2D-STE parameters included global longitudinal strain (GLS) and left atrial three-phase strain: reservoir strain (εRs/LASr), conduit strain (εCd/LAScd), and atrial contraction strain (εCt/LASct). Paired-sample t-tests were used for pre- and post-exercise comparisons, and Pearson correlation analysis was performed to assess associations between strain changes and 24-hour PAC burden.

Results: At rest, all children had normal LVEF. No significant differences were observed in conventional echocardiographic parameters (LVEDD, LVESD, LVEF, mitral E wave, A wave, E/A ratio, E/e' ratio) before and after exercise (all $P > 0.05$). Compared with baseline, GLS (−20.14 ± 1.62% vs. −18.36 ± 1.75%, $P < 0.05$) and left atrial reservoir strain εRs (48.63 ± 4.71% vs. 43.25 ± 3.22%, $P < 0.05$) significantly decreased during the recovery period after exercise. No significant changes were found in εCd or εCt (both $P > 0.05$). The magnitudes of GLS and εRs reduction were moderately positively correlated with 24-hour PAC burden ($r = 0.463$ and $r = 0.491$, respectively; both $P < 0.05$).

Conclusion: In children with isolated PAC, conventional LVEF remains within the normal range at rest, but 2D-STE can detect reductions in left ventricular GLS and left atrial reservoir strain after exercise stress, suggesting occult impairment of cardiac

reserve. Compared with conventional echocardiography, myocardial strain is more sensitive in identifying exercise-induced subclinical cardiac dysfunction. The combination of exercise treadmill testing and pre-/post-stress 2D-STE may establish a noninvasive comprehensive assessment protocol for risk stratification and individualized exercise management in children with PAC.

Keywords: premature atrial contraction; speckle-tracking echocardiography; exercise treadmill test; children; myocardial strain; left atrial function

1 Materials and Methods

1.1 Study subjects

Fifty children diagnosed with isolated PAC who visited the outpatient department of Wuxi Children's Hospital from January 2024 to July 2026 were enrolled, including 27 boys and 23 girls, aged 6-16 years, with a mean age of (9.83 ± 2.18) years.

Inclusion criteria

① Age ranging from 6 to 16 years old;
② PAC confirmed by resting 12-lead ECG or 24-hour Holter monitoring;
③ Organic cardiovascular diseases such as congenital heart disease, cardiomyopathy and valvular lesions excluded by conventional echocardiography;
④ Children were able to complete modified Bruce protocol exercise treadmill test;
⑤ Written informed consent was obtained from guardians.

Exclusion criteria

① Complicated with other arrhythmias including ventricular premature contraction, atrioventricular block, paroxysmal supraventricular tachycardia;
② Past medical history including hypertension, viral myocarditis, chronic respiratory diseases and other systemic disorders;
③ Oral administration of β-blockers or antiarrhythmic agents within one month before examination;
④ Poor echocardiographic image quality unsuitable for speckle-tracking analysis;
⑤ Inability to complete full exercise protocol due to obvious discomfort or malignant arrhythmias during exercise.

This study protocol was approved by the Institutional Medical Ethics Committee of our hospital.

1.2 Instruments and examination protocol

Philips EPIQ 7C and EPIQ CVX color Doppler ultrasound systems with S5-1 cardiac probe and built-in speckle-tracking workstation were adopted. Exercise treadmill test was performed using pediatric modified Bruce protocol.

Children were required to rest quietly for 30 minutes before examination and avoid strenuous physical activity.

Examination procedures:

① Pre-exercise resting acquisition: dynamic images of apical four-chamber, apical two-chamber and apical three-chamber views were acquired. Apical four-chamber and two-chamber views ensuring complete visualization of left atrium were collected with frame rate ≥50 frames per second. Consecutive five normal cardiac cycles were stored. Conventional echocardiographic and strain parameters were recorded.

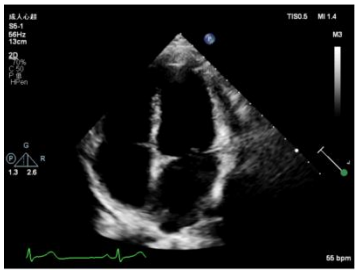


Figure 1 Apical four-chamber view

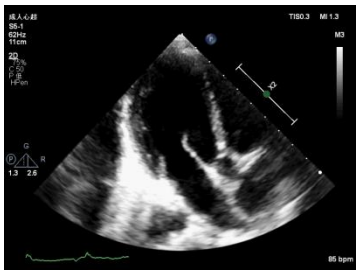


Figure 2 Apical three-chamber view

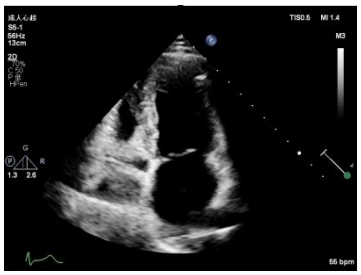


Figure 3 Apical two-chamber view

② After 30 minutes of resting recovery, exercise treadmill stress test was performed. 12-lead ECG, blood pressure and clinical symptoms were continuously monitored

throughout the test and assessed by clinicians. Peak heart rate, exercise tolerance and PAC episodes during exercise were documented.

③ Twenty minutes after exercise termination (recovery phase), echocardiographic images were acquired following identical acquisition protocols by the same operator to guarantee reproducibility. Speckle-tracking quantitative analysis was repeated.

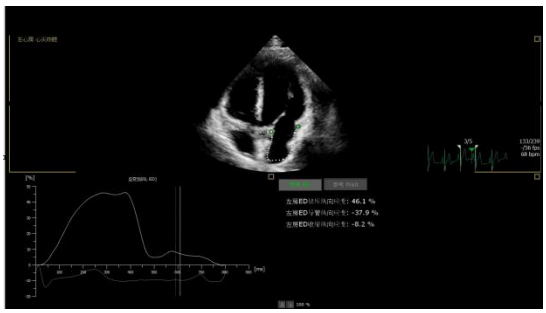


Figure 4 Left-atrial strain before treadmill exercise test

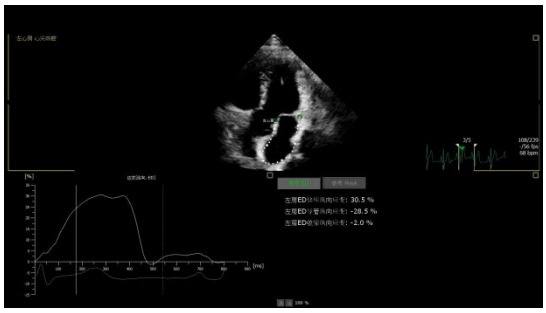


Figure 5 Left-atrial strain after treadmill exercise test

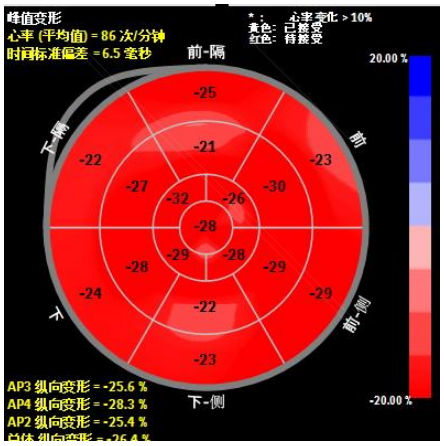


Figure 6 Left-ventricular strain before treadmill exercise test

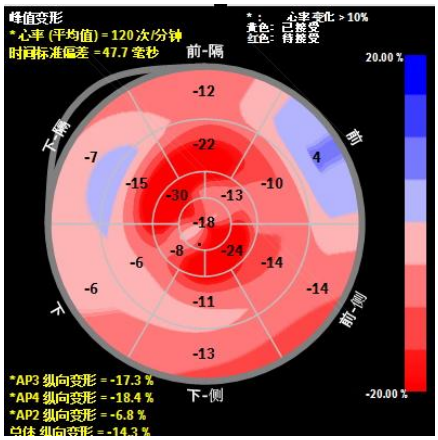


Figure 7 Left-ventricular strain after treadmill exercise test

1.3 Observed parameters

(1) Conventional echocardiographic parameters: left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), LVEF, mitral E-wave velocity, mitral A-wave velocity, E/e' ratio.

(2) 2D-STE parameters: left ventricular global longitudinal strain (GLS); three-phase left atrial strain: reservoir strain εRs, conduit strain εCd, atrial contraction strain εCt.

Note: Only consecutive sinus cardiac cycles were selected for analysis; waveforms with frequent premature beats were excluded.

1.4 Statistical analysis

SPSS 28.0 software was used for statistical analysis. Paired-samples t-test was applied for intra-subject comparison of parameters before and after exercise. Pearson correlation analysis was used for correlation assessment. P-value < 0.05 was considered statistically significant.

2 Results

2.1 Comparison of conventional echocardiographic parameters

All children exhibited normal LVEF at rest. There were no statistically significant differences in LVEF, LVEDD, LVESD, E/A ratio between pre-exercise and post-exercise recovery phase (all $P > 0.05$), as shown in Table 1.

Table 1 Comparison of conventional echocardiographic parameters in children with PAC before and after exercise ($\overline{x} \pm s$)

Parameters	Pre-exercise	Post-exercise recovery	P-value
LVEDD(mm)	40.36±3.84	40.71±3.69	> 0.05
LVESD(mm)	26.17±2.93	26.42±2.86	> 0.05
LVEF(%)	66.35±4.12	65.78±4.33	> 0.05
Mitral E-wave(cm/s)	92.46±10.35	94.13±10.82	> 0.05
Mitral A-wave(cm/s)	56.74±7.26	57.31±7.14	> 0.05
E/A ratio	1.64±0.21	1.61±0.23	> 0.05
E/e’ ratio	7.26±1.14	7.43±1.18	> 0.05

Note: Paired-samples t-test; P > 0.05 indicates no statistically significant difference.

2.2 Comparison of 2D-STE myocardial strain parameters

Left ventricular GLS and left atrial reservoir strain εRs were significantly decreased in post-exercise recovery phase compared with baseline (P < 0.05). No significant differences were observed in εCd and εCt before and after exercise (P > 0.05), shown in Table 2.

Table 2 Comparison of 2D-STE strain parameters before and after exercise

Parameters	Pre-exercise	Post-exercise recovery	P-value
GLS(%)	−20.14±1.62	−18.36±1.75	< 0.05
εRs (LASr, %)	48.63±4.71	43.25±3.22	< 0.05

εCd (LAScd, %)	−32.72±3.15	−31.86±3.22	> 0.05
εCt (LASct, %)	−11.85±1.43	−11.47±1.39	> 0.05

Note: Paired-samples t-test; $P < 0.05$ indicates statistically significant difference. GLS, εCd and εCt are negative values, εRs is positive value. Original measured values were used for statistical analysis.

2.3 Correlation analysis

Children with increased PAC burden during exercise presented larger magnitude reductions in GLS and εRs. The decreased magnitudes of GLS and εRs showed moderate positive correlation with 24-hour PAC burden ($P < 0.05$), Table 3.

Table 3 Correlation between changes of myocardial strain and 24-hour PAC burden

Parameters	r value	P-value
Difference of GLS vs 24-h PAC burden	0.463	< 0.05
Difference of εRs vs 24-h PAC burden	0.491	< 0.05

Note: Pearson correlation analysis; r, correlation coefficient; $0.3 < r < 0.5$ indicates moderate correlation.

3 Discussion

PAC originates from ectopic atrial foci. Premature activation causes asynchronous atrial contraction, shortens ventricular filling time and disturbs atrioventricular mechanical coupling[1]. Under resting conditions, low cardiac load and body compensatory mechanisms may mask myocardial dysfunction. LVEF possesses wide compensatory range and tends to yield false-negative results. During exercise, increased myocardial oxygen consumption and elevated heart rate may unmask inadequate cardiac reserve.

2D-STE enables quantitative myocardial deformation analysis independent of

ultrasound beam angle[2,6]. The left atrium is the primary organ affected by atrial arrhythmias. Atrial remodeling can occur even before atrial enlargement. εRs is currently the most sensitive parameter reflecting global left-atrial diastolic reserve. Our results demonstrated that LVEF remained unchanged after exercise, whereas GLS and left-atrial εRs declined in recovery phase. This confirms limitations of conventional echocardiography and proves that myocardial strain can detect subclinical myocardial impairment[3].

Sympathetic over-activation during exercise increases the frequency of atrial ectopic beats and PAC episodes. Persistent disturbed atrial contraction rhythm elevates myocardial oxygen demand. Long-term exposure may lead to atrial fibrosis and even atrial cardiomyopathy[4].

This study carries important clinical value. For asymptomatic children with PAC detected incidentally during physical examination, the combined protocol of exercise treadmill test plus pre-post-exercise speckle-tracking can be applied for risk stratification[5]. Children with decreased myocardial strain after exercise suggest impaired cardiac reserve; restriction of high-intensity sports and regular long-term follow-up are recommended. Patients without obvious strain changes are generally allowed to participate in regular physical activities. Holter monitoring can only quantify PAC burden but cannot evaluate myocardial reserve. Left-atrial strain is promising to serve as a new quantitative imaging marker for follow-up of children with PAC.

Limitations

Several limitations of this study should be acknowledged. First, this was a single-center study with a relatively small sample size, which may limit the generalizability of the findings. Second, echocardiographic images were acquired only during the recovery period after exercise, and real-time stress echocardiographic monitoring during exercise was not performed; thus, the peak changes in myocardial strain during exercise could not be captured. Third, long-term follow-up data are lacking, and whether the observed strain abnormalities can predict the progression to more severe arrhythmias in the future remains uncertain. Fourth, there is currently no unified domestic reference standard for normal myocardial strain values across different age groups in children, which may affect the interpretation of the results. Further multicenter studies with larger sample sizes and long-term follow-up are warranted to validate these findings.

4 Conclusion

Children with isolated PAC usually have normal resting LVEF. Nevertheless, after exercise stress stimulation, 2D-STE can detect decreased left-ventricular GLS and left-atrial reservoir strain, indicating occult impairment of cardiac reserve. Compared with conventional echocardiography, myocardial strain is more sensitive for identifying exercise-triggered subclinical cardiac dysfunction. The combination of exercise treadmill stress test and pre-post-exercise two-dimensional speckle-tracking echocardiography establishes a non-invasive comprehensive assessment protocol for children with PAC, facilitating risk stratification and individualized exercise management.

References

[1] Chinese Society of Pediatric Cardiology, Chinese Medical Association. Recommendations for diagnosis and management of pediatric arrhythmias (2023 edition)[J]. Chin J Pediatr, 2023,61(8):641-648.
[2] Chinese Society of Ultrasound in Medicine and Engineering. Chinese expert consensus on clinical application of speckle-tracking echocardiography[J]. Chin J Ultrasonogr, 2021,30(4):277-287.
[3] Chen Y, Zhu S-L. Research progress of two-dimensional speckle-tracking imaging for assessment of subclinical myocardial dysfunction in children[J]. Chin J Pediatr Emerg Med, 2024,31(2):148-152.
[4] DI SALVO G. Speckle-tracking echocardiography in pediatric arrhythmias[J]. Eur J Pediatr,2022,181(7):2611-2621.
[5] Lu G-P. Application of exercise treadmill test in diagnosis and management of pediatric arrhythmias[J]. J Clin Pediatr, 2023,41(5):321-325.
[6] Zhang Y. Clinical advances in myocardial strain echocardiography[J]. Chin J Cardiol, 2020,48(10):827-830.