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Electrophysiological Risk in Pediatric Intermittent versus Persistent Ventricular Pre-excitation: A Large Single-Center Cohort

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Research Article

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Abstract

Purpose

To compare invasive electrophysiological risk characteristics between children with intermittent and persistent ventricular pre-excitation and assess whether symptom status identifies high-risk accessory pathways.

Methods

This retrospective single-center study included 917 patients aged ≤ 18 years undergoing a primary electrophysiological procedure for ventricular pre-excitation between 2010 and 2025. High-risk electrophysiological characteristics were defined as an accessory pathway effective refractory period (APERP) ≤ 250 ms, shortest pre-excited R–R interval during atrial fibrillation (SPERRI) ≤ 250 ms, and/or shortest pre-excited paced cycle length during rapid atrial pacing (SPPCL) ≤ 250 ms. Multivariable logistic regression adjusted for age, sex, symptom status, pre-excitation pattern, and Ebstein anomaly. Sixty-five pediatric redo procedures were analyzed descriptively.

Results

Intermittent pre-excitation was present in 191 patients (20.8%). Median APERP was longer in intermittent than persistent pre-excitation (320 vs. 290 ms; $p < 0.001$). High-risk characteristics were less frequent in intermittent than persistent pre-excitation (15.2% vs. 36.9%; $p < 0.001$). Intermittent pre-excitation remained independently associated with lower odds of high-risk characteristics (adjusted OR 0.30, 95% CI 0.20–0.47; $p < 0.001$). High-risk characteristics were similarly prevalent in symptomatic and asymptomatic patients (32.1% vs. 32.8%; $p = 0.872$). Right-sided pathways accounted for 60.0% of pediatric redo procedures.

Conclusion

Intermittent pre-excitation is associated with a lower probability of high-risk electrophysiological characteristics but does not exclude them. Symptom absence likewise does not identify a low-risk accessory pathway.

What is Known

- Intermittent ventricular pre-excitation is generally associated with longer accessory pathway refractory periods and is considered a favorable noninvasive marker.

- The relationship between symptoms and invasive electrophysiological risk remains uncertain in children.

What is New

- In this pediatric cohort, 15.2% of children with intermittent pre-excitation met invasive high-risk criteria.
- Intermittent pre-excitation independently predicted lower risk, while high-risk characteristics were similar in symptomatic and asymptomatic children.

INTRODUCTION

Ventricular pre-excitation due to an atrioventricular accessory pathway (AP) is observed in approximately 0.1%–0.3% of the general population. Although many individuals remain asymptomatic, accessory pathways may support supraventricular tachycardia and, rarely, permit rapid ventricular conduction during atrial fibrillation, potentially resulting in sudden cardiac death (SCD)[1, 2]. Risk stratification therefore aims to identify pathways capable of rapid antegrade conduction using invasive electrophysiological parameters such as the accessory pathway effective refractory period (APERP), the shortest pre-excited R–R interval during atrial fibrillation (SPERRI), and the shortest pre-excited paced cycle length during atrial pacing (SPPCL) [3, 4].

Intermittent loss of ventricular pre-excitation has traditionally been considered a favorable marker because it is generally associated with longer AP refractory periods [5]. However, intermittent pre-excitation does not uniformly indicate benign pathway physiology. Pediatric studies have demonstrated that intermittent or abrupt loss of pre-excitation during noninvasive evaluation may occur despite invasive electrophysiological characteristics consistent with rapid antegrade AP conduction [6, 7]. More recent data similarly suggest that noninvasive evidence of intermittent or absent pre-excitation cannot reliably exclude high-risk AP properties [5, 8].

Clinical symptoms may also be an imperfect marker of electrophysiological risk. Symptoms generally reflect the occurrence of re-entrant tachyarrhythmias, whereas APERP, SPERRI, and SPPCL characterize the capacity of an AP for rapid antegrade conduction. Accordingly, the absence of symptoms does not necessarily indicate favorable AP physiology, and life-threatening events have been reported in children without preceding symptoms attributable to ventricular pre-excitation [4]. This distinction is particularly relevant in pediatric practice, where considerable variation persists in the evaluation and management of asymptomatic ventricular pre-excitation[9].

AP anatomy represents an additional but distinct consideration. Certain locations, particularly right-sided, para-Hisian, and coronary sinus–related pathways, may increase the technical complexity of catheter ablation because of catheter instability, proximity to the atrioventricular conduction system, or deep and epicardial pathway insertion [10, 11]. These procedural challenges should be distinguished from electrophysiological characteristics associated with rapid antegrade conduction. Therefore, this

study aimed to compare invasive electrophysiological characteristics between children with intermittent and persistent ventricular pre-excitation, assess the association between symptom status and high-risk AP characteristics, evaluate the anatomical distribution of high-risk pathways, and describe AP locations encountered during redo procedures.

METHODS

Study Population

This retrospective, single-center study included consecutive patients aged ≤ 18 years who underwent an electrophysiological procedure for ventricular pre-excitation at the Department of Pediatric Cardiology, University of Health Sciences, Istanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital, between February 2010 and November 2025. Of 1,053 procedure records reviewed, 31 were excluded because of unavailable clinical or electrophysiological data or a fasciculoventricular pathway and 40 because patients were aged > 18 years. The final pediatric population comprised 982 procedure records: 917 primary procedures forming the main cohort and 65 redo procedures analyzed separately.

Patients were classified as having intermittent or persistent pre-excitation according to preprocedural findings. Intermittent pre-excitation was defined as spontaneous, abrupt, complete loss of the delta wave with QRS normalization on resting or serial electrocardiograms or ambulatory monitoring. Patients were considered symptomatic if they had documented supraventricular tachycardia, palpitations, syncope, or ventricular dysfunction clinically attributable to pre-excitation; incidentally detected cases without related manifestations were classified as asymptomatic.

The study complied with the Declaration of Helsinki and was approved by the Ethics Committee of Istanbul Saglik Bilimleri University Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital (protocol no. 106; July 6, 2026).

Electrophysiological Study and Risk Stratification

All patients underwent comprehensive EPS. Antegrade AP conduction was assessed using APERP, SPERRI, and SPPCL, according to available measurements. High-risk electrophysiological characteristics were defined as APERP ≤ 250 ms, SPERRI ≤ 250 ms, and/or SPPCL ≤ 250 ms. When both SPERRI and SPPCL were available, the shorter value was used for risk classification. In patients with multiple APs, the shortest available antegrade conduction parameter was used. AP localization was determined using three-dimensional mapping and standard electrophysiological maneuvers.

Accessory Pathway Localization

AP location was based on electroanatomical mapping and the successful or presumed ablation site documented in the procedural report. Coronary sinus ostial, middle cardiac vein ostial, and coronary venous/epicardial posteroseptal pathways were categorized as coronary sinus-related. Coronary sinus diverticulum was assigned only when documented in the procedural report or demonstrated by angiography; para-Hisian pathways were analyzed separately. In patients with multiple APs, the pathway associated with the shortest APERP, SPERRI, or SPPCL was used for location-specific analysis. Patients without identifiable AP location were excluded only from location-specific analyses.

Redo Procedure Analysis

Redo procedures were defined as repeat procedures after previous unsuccessful ablation or recurrence of AP conduction. Demographic characteristics, pre-excitation pattern, and AP location were summarized descriptively. Because several index procedures had been performed at external centers and complete baseline procedural data were unavailable, redo procedures were not interpreted as a patient-level recurrence rate and were not used to identify predictors of recurrence.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). Distribution was assessed using the Shapiro–Wilk test and visual inspection of histograms. Continuous variables were summarized as mean ± standard deviation or median (interquartile range), as appropriate, and compared using Student's *t*-test or Mann–Whitney *U* test. Categorical variables were summarized as n (%) and compared using chi-square or Fisher's exact tests, as appropriate.

The primary outcome was documented high-risk electrophysiological characteristics, defined as APERP ≤ 250 ms, SPERRI ≤ 250 ms, and/or SPPCL ≤ 250 ms. Patients with at least one measurement meeting a threshold were classified as high-risk; missing measurements were not imputed. For the categorical outcome, all patients remained in the denominator, and those without a documented high-risk measurement were not classified as high-risk.

Multivariable logistic regression evaluated the independent association between intermittent pre-excitation and high-risk characteristics, adjusting for prespecified covariates of age, sex, symptom status, pre-excitation pattern, and Ebstein anomaly. Age was entered continuously and Ebstein anomaly as a binary variable. Results are reported as adjusted odds ratios with 95% confidence intervals. Comparisons by symptom status within intermittent and persistent groups were exploratory. The redo cohort was excluded from predictive modeling. All tests were two-sided, with $p < 0.05$ considered statistically significant.

ChatGPT (OpenAI) was used during manuscript preparation to assist with language refinement and editing of author-generated text. All AI-assisted content was critically reviewed and revised by the authors, who take full responsibility for the final manuscript.

RESULTS

Study Population and Patient Characteristics

A total of 1,053 procedure records were reviewed. After exclusions, 982 pediatric procedure records remained, including 917 primary procedures constituting the study cohort and 65 redo procedures analyzed separately.

The median age of the primary cohort was 12.0 years (IQR, 9.0–14.9 years; range, 0.01–18.0 years), and 541 patients (59.0%) were male. Persistent pre-excitation was present in 726 patients (79.2%), whereas 191 (20.8%) had intermittent pre-excitation. Overall, 533 patients (58.1%) were symptomatic and 384 (41.9%) were asymptomatic.

Baseline demographic and clinical characteristics were comparable between the persistent and intermittent pre-excitation groups (Table 1).

Table 1
Clinical and Electrophysiological Characteristics According to Pre-excitation Pattern

Variable	Total (n = 917)	Persistent (n = 726)	Intermittent (n = 191)	P value
Age, years	12.0 (9.0–14.9)	11.9 (9.0–14.9)	12.2 (9.1–14.8)	0.610
Male sex, n (%)	541 (59.0)	431 (59.4)	110 (57.6)	0.718
Symptomatic, n (%)	533 (58.1)	422 (58.1)	111 (58.1)	1.000
Ebstein anomaly, n (%)	36 (3.9)	29 (4.0)	7 (3.7)	1.000
APERP, ms	290 (260–320)	290 (260–320)	320 (280–382.5)	< 0.001
APERP ≤ 250 ms, n (%)	180 (19.6)	156 (21.5)	24 (12.6)	0.008
SPERRI and/or SPPCL ≤ 250 ms, n (%)	231 (25.2)	216 (29.8)	15 (7.9)	< 0.001
High-risk electrophysiological characteristics, n (%)	297 (32.4)	268 (36.9)	29 (15.2)	< 0.001

Data are presented as median (interquartile range) or n (%), as appropriate. APERP measurements were available in 839 patients, and SPERRI and/or SPPCL measurements were available in 753 patients. High-risk electrophysiological characteristics were defined as APERP ≤ 250 ms, SPERRI ≤ 250 ms, and/or SPPCL ≤ 250 ms. When both SPERRI and SPPCL were available, the shorter value was used for risk classification. Percentages for categorical high-risk outcomes were calculated using the total number of patients in each corresponding group. APERP, accessory pathway effective refractory period; IQR, interquartile range; SPERRI, shortest pre-excited R–R interval during atrial fibrillation; SPPCL, shortest pre-excited paced cycle length during atrial pacing.

Electrophysiological Risk Parameters

APERP measurements were available in 839 patients, and at least one SPERRI or SPPCL measurement was available in 753 patients. Patients with intermittent pre-excitation had significantly longer AP refractory periods than those with persistent pre-excitation. Median APERP was 320 ms (IQR, 280–382.5 ms) in the intermittent group and 290 ms (IQR, 260–320 ms) in the persistent group ($p < 0.001$).

An APERP ≤ 250 ms was documented in 24 patients (12.6%) with intermittent pre-excitation and 156 (21.5%) with persistent pre-excitation ($p = 0.008$). A SPERRI and/or SPPCL ≤ 250 ms was documented in 15 patients (7.9%) and 216 patients (29.8%), respectively ($p < 0.001$).

Overall, documented high-risk electrophysiological characteristics, defined as APERP ≤ 250 ms, SPERRI ≤ 250 ms, and/or SPPCL ≤ 250 ms, were present in 29 of 191 patients (15.2%) with intermittent pre-excitation compared with 268 of 726 patients (36.9%) with persistent pre-excitation ($p < 0.001$) (Table 1).

Association Between Symptom Status and Electrophysiological Risk

Documented high-risk electrophysiological characteristics were similarly prevalent in symptomatic and asymptomatic patients (32.1% vs. 32.8%; $p = 0.872$). Neither APERP ≤ 250 ms nor SPERRI and/or SPPCL ≤ 250 ms differed significantly according to symptom status. This pattern was maintained within both the persistent (36.5% vs. 37.5%; $p = 0.842$) and intermittent pre-excitation subgroups (15.3% vs. 15.0%; $p = 1.000$) (Table 2).

Table 2

Clinical and Electrophysiological Characteristics According to Symptom Status

Total cohort (n = 917)			
Variable	**Symptomatic (n = 533)**	**Asymptomatic (n = 384)**	**P value**
Age, years, median (IQR)	12.1 (8.8–15.0)	11.7 (9.1–14.6)	0.720
Male sex, n (%)	311 (58.3)	230 (59.9)	0.688
Ebstein anomaly, n (%)	30 (5.6)	6 (1.6)	**0.003**
Intermittent pre-excitation, n (%)	111 (20.8)	80 (20.8)	1.000
APERP, ms, median (IQR)	290 (260–320)	290 (260–330)	0.121
APERP ≤ 250 ms, n (%)	101 (18.9)	79 (20.6)	0.599
SPERRI ≤ 250 ms and/or SPPCL ≤ 250 ms, n (%)	137 (25.7)	94 (24.5)	0.731
High-risk electrophysiological characteristics, n (%)	**171 (32.1)**	**126 (32.8)**	**0.872**
Persistent pre-excitation (n = 726)			
Variable	**Symptomatic (n = 422)**	**Asymptomatic (n = 304)**	**P value**
APERP, ms, median (IQR)	280 (260–310)	290 (260–320)	0.220
APERP ≤ 250 ms, n (%)	88 (20.9)	68 (22.4)	0.690
SPERRI ≤ 250 ms and/or SPPCL ≤ 250 ms, n (%)	127 (30.1)	89 (29.3)	0.876
High-risk electrophysiological characteristics, n (%)	**154 (36.5)**	**114 (37.5)**	**0.842**
Intermittent pre-excitation (n = 191)			
Variable	**Symptomatic (n = 111)**	**Asymptomatic (n = 80)**	**P value**

Data are presented as median (interquartile range) or n (%), as appropriate. APERP measurements were available in 476 symptomatic and 363 asymptomatic patients overall, including 394 and 301 patients with persistent pre-excitation and 82 and 62 patients with intermittent pre-excitation, respectively. SPERRI and/or SPPCL measurements were available in 427 symptomatic and 326 asymptomatic patients overall, including 363 and 279 patients with persistent pre-excitation and 64 and 47 patients with intermittent pre-excitation, respectively. High-risk electrophysiological characteristics were defined as APERP ≤ 250 ms, SPERRI ≤ 250 ms, and/or SPPCL ≤ 250 ms. When both SPERRI and SPPCL were available, the shorter value was used for risk classification. Percentages for categorical high-risk outcomes were calculated using the total number of patients in each corresponding group. APERP, accessory pathway effective refractory period; IQR, interquartile range; SPERRI, shortest pre-excited R–R interval during atrial fibrillation; SPPCL, shortest pre-excited paced cycle length during rapid atrial pacing.

Total cohort (n = 917)			
Variable	**Symptomatic (n = 533)**	**Asymptomatic (n = 384)**	**P value**
APERP, ms, median (IQR)	310 (280–380)	340 (290–420)	0.229
APERP ≤ 250 ms, n (%)	13 (11.7)	11 (13.8)	0.843
SPERRI ≤ 250 ms and/or SPPCL ≤ 250 ms, n (%)	10 (9.0)	5 (6.3)	0.670
High-risk electrophysiological characteristics, n (%)	**17 (15.3)**	**12 (15.0)**	**1.000**

Data are presented as median (interquartile range) or n (%), as appropriate. APERP measurements were available in 476 symptomatic and 363 asymptomatic patients overall, including 394 and 301 patients with persistent pre-excitation and 82 and 62 patients with intermittent pre-excitation, respectively. SPERRI and/or SPPCL measurements were available in 427 symptomatic and 326 asymptomatic patients overall, including 363 and 279 patients with persistent pre-excitation and 64 and 47 patients with intermittent pre-excitation, respectively. High-risk electrophysiological characteristics were defined as APERP ≤ 250 ms, SPERRI ≤ 250 ms, and/or SPPCL ≤ 250 ms. When both SPERRI and SPPCL were available, the shorter value was used for risk classification. Percentages for categorical high-risk outcomes were calculated using the total number of patients in each corresponding group. APERP, accessory pathway effective refractory period; IQR, interquartile range; SPERRI, shortest pre-excited R–R interval during atrial fibrillation; SPPCL, shortest pre-excited paced cycle length during rapid atrial pacing.

Multivariable Analysis

In multivariable logistic regression including age, sex, symptom status, pre-excitation pattern, and Ebstein anomaly, intermittent pre-excitation remained independently associated with lower odds of documented high-risk electrophysiological characteristics compared with persistent pre-excitation (adjusted OR, 0.30; 95% CI, 0.20–0.47; $p < 0.001$) (Table 3).

Table 3
Multivariable Logistic Regression Analysis of High-Risk Electrophysiological Characteristics

Variable	Adjusted OR	95% CI	P value
Age, per year	0.98	0.94–1.02	0.290
Male sex	1.45	1.08–1.95	0.012
Symptomatic presentation	0.99	0.74–1.32	0.963
Intermittent pre-excitation	0.30	0.20–0.47	< 0.001
Ebstein anomaly	0.48	0.20–1.12	0.088

The dependent variable was the presence of high-risk electrophysiological characteristics, defined as an accessory pathway effective refractory period (APERP) ≤ 250 ms, a shortest pre-excited R–R interval during atrial fibrillation (SPERRI) ≤ 250 ms, and/or a shortest pre-excited paced cycle length during rapid atrial pacing (SPPCL) ≤ 250 ms. Reference categories were female sex, asymptomatic presentation, persistent pre-excitation, and absence of Ebstein anomaly. Age was entered as a continuous variable. CI, confidence interval; OR, odds ratio.

Male sex was independently associated with higher odds of high-risk electrophysiological characteristics (adjusted OR, 1.45; 95% CI, 1.08–1.95; p = 0.012). Age (adjusted OR, 0.98; 95% CI, 0.94–1.02; p = 0.290), symptomatic presentation (adjusted OR, 0.99; 95% CI, 0.74–1.32; p = 0.963), and Ebstein anomaly (adjusted OR, 0.48; 95% CI, 0.20–1.12; p = 0.088) were not independently associated with the outcome.

Accessory Pathway Distribution Among Patients With High-Risk Characteristics

Among the 297 patients with documented high-risk electrophysiological characteristics, the most frequently represented AP location was the right posteroseptal region (n = 54, 18.2%), followed by coronary sinus–related locations (n = 40, 13.5%), left posterolateral and left lateral regions (n = 30, 10.1% each), and the left posterior region (n = 26, 8.8%) (Fig. 1a).

Redo Procedure Analysis

The pediatric redo cohort comprised 65 patients undergoing a repeat EPS after a previous unsuccessful ablation or recurrence of AP conduction. Median age at the redo procedure was 11.7 years (IQR, 8.6–14.7 years; range, 0.4–17.9 years), and 41 patients (63.1%) were male. Persistent pre-excitation was present at the time of the redo procedure in 61 patients (93.8%), whereas 4 patients (6.2%) had intermittent pre-excitation.

Right-sided pathways accounted for 39 of 65 redo procedures (60.0%), whereas 17 (26.2%) were left-sided. Coronary sinus–related pathways were identified in 7 patients (10.8%), and a noncoronary aortic cusp location was identified in 2 (3.1%). The anatomical distribution of pathways encountered during redo procedures is shown in Table 4 and Fig. 1b.

Table 4
Characteristics of Redo Procedures (n = 65)

Variable	Value
Demographics	
Age, years, median (IQR; range)	11.7 (8.6–14.7; 0.4–17.9)
Male sex, n (%)	41 (63.1)
Female sex, n (%)	24 (36.9)
Pre-excitation pattern at the redo procedure	
Persistent pre-excitation, n (%)	61 (93.8)
Intermittent pre-excitation, n (%)	4 (6.2)
Accessory Pathway Location	
Right-sided pathways, n (%)	**39 (60.0)**
Right anterior	8
Right posteroseptal	7
Right anterolateral	6
Para-Hisian	5
Right posterior	5
Right anteroseptal	4
Right midseptal	3
Right posterolateral	1
Left-sided pathways, n (%)	**17 (26.2)**
Left posterior	5
Left posteroseptal	5
Left posterolateral	4
Left anterior	1
Left anterolateral	1
Left lateral	1

Data are presented as median (interquartile range; range) or n (%), as appropriate. Right-sided pathways included right free-wall, right septal, and para-Hisian locations. Coronary sinus–related pathways included six pathways arising from a coronary sinus diverticulum and one pathway arising from the coronary sinus ostium. IQR, interquartile range.

Variable	Value
Demographics	
Coronary sinus–related pathways, n (%)	**7 (10.8)**
Noncoronary aortic cusp, n (%)	**2 (3.1)**

Data are presented as median (interquartile range; range) or n (%), as appropriate. Right-sided pathways included right free-wall, right septal, and para-Hisian locations. Coronary sinus–related pathways included six pathways arising from a coronary sinus diverticulum and one pathway arising from the coronary sinus ostium. IQR, interquartile range.

DISCUSSION

This large pediatric single-center cohort yielded four principal findings. First, children with intermittent pre-excitation had longer APERP and a substantially lower prevalence of high-risk electrophysiological characteristics than those with persistent pre-excitation. Second, intermittent pre-excitation remained independently associated with lower odds of high-risk characteristics after adjustment for age, sex, symptom status, and Ebstein anomaly. Nevertheless, approximately one in six children with intermittent pre-excitation met at least one invasive high-risk criterion. Third, high-risk electrophysiological characteristics were similarly prevalent in symptomatic and asymptomatic patients, both overall and within the intermittent and persistent subgroups. Finally, right-sided pathways were frequently represented among redo procedures, supporting the distinction between electrophysiological risk and procedural complexity.

Intermittent loss of ventricular pre-excitation has traditionally been regarded as a favorable marker because it is generally associated with longer accessory pathway refractory periods [1, 5]. Our findings support this concept to an extent: median APERP was significantly longer in children with intermittent than persistent pre-excitation, and intermittent pre-excitation was independently associated with substantially lower odds of high-risk electrophysiological characteristics. However, intermittent conduction should not be regarded as uniformly benign. Loss of manifest pre-excitation may reflect a genuinely long accessory pathway refractory period, but may also be influenced by autonomic tone, concealed conduction, transient changes in pathway conduction, linking, or supernormal conduction[12].

Importantly, 15.2% of children with intermittent pre-excitation still fulfilled the prespecified invasive high-risk criterion, compared with 36.9% of those with persistent pre-excitation. Thus, intermittency markedly reduced the probability of rapid antegrade accessory pathway conduction but did not exclude it. This finding is consistent with previous pediatric evidence demonstrating that intermittent or abrupt loss of pre-excitation during noninvasive testing may coexist with high-risk invasive electrophysiological properties [6, 7]. Similar observations have been reported in more recent cohorts evaluating intermittent and noninvasive markers of pre-excitation [5, 8]. Accordingly, although intermittent pre-excitation remains a favorable finding, it should be interpreted as a risk-reducing rather than risk-excluding marker.

Our findings also reinforce the distinction between clinical symptoms and electrophysiological pathway risk. High-risk characteristics were present in 32.1% of symptomatic and 32.8% of asymptomatic children, and symptom status was not independently associated with the primary outcome in multivariable analysis. The same pattern was observed within both pre-excitation groups: high-risk characteristics occurred in 36.5% versus 37.5% of symptomatic and asymptomatic patients with persistent pre-excitation and in 15.3% versus 15.0% of those with intermittent pre-excitation. Symptoms predominantly reflect the clinical expression of re-entrant tachyarrhythmias, whereas APERP, SPERRI, and SPPCL assess the capacity of an accessory pathway for rapid antegrade conduction. Therefore, the absence of symptoms should not be interpreted as evidence of favorable pathway physiology. Previous pediatric studies have likewise demonstrated that life-threatening events may occur without preceding symptoms attributable to ventricular pre-excitation [4, 13].

These findings do not imply that every asymptomatic child with ventricular pre-excitation requires invasive evaluation. Rather, they indicate that neither symptom absence nor intermittency should be used in isolation to exclude further risk assessment. Decisions regarding EPS should incorporate the overall clinical context, including age, pre-excitation pattern, noninvasive findings, activity level, associated cardiac disease, and the potential risks and benefits of EPS and catheter ablation [3, 14, 15]. The substantial variation reported in pediatric WPW risk-stratification practices further emphasizes the need for individualized assessment [9].

AP location provides a separate anatomical perspective. Among children with documented high-risk electrophysiological characteristics, the right posteroseptal region was the most frequently represented location, followed by coronary sinus–related, left posterolateral, and left lateral pathways. These findings should remain descriptive: the number of high-risk pathways observed at a given location is influenced by the underlying frequency of that location in the study population and does not establish an independent association between AP location and electrophysiological risk. Coronary sinus–related pathways are particularly relevant because they may involve the coronary sinus ostium, cardiac veins, diverticula, or other epicardial coronary venous connections[10].

The pediatric redo cohort showed a different anatomical pattern, with right-sided pathways accounting for 60.0% of repeat procedures. Right-sided, para-Hisian, and coronary sinus–related pathways may pose specific technical challenges because of catheter instability along the tricuspid annulus, proximity to the atrioventricular conduction system, and deep or epicardial pathway insertion. Previous pediatric experience has similarly demonstrated recurrence after initially successful ablation of right-sided APs [11]. However, our redo analysis was descriptive, and incomplete information regarding index procedures —particularly for patients initially treated at external centers—precluded calculation of a patient-level recurrence rate or identification of independent predictors of recurrence.

Importantly, frequent representation of a pathway location among redo procedures should not be interpreted as evidence of greater susceptibility to life-threatening arrhythmia. APERP, SPERRI, and SPPCL characterize antegrade accessory pathway conduction, whereas the need for repeat ablation is

influenced by factors affecting durable lesion formation, including catheter stability, pathway depth, proximity to the atrioventricular conduction system, coronary venous anatomy, and energy delivery. Electrophysiological risk and procedural complexity therefore represent related but distinct dimensions of AP behavior.

This study has several limitations. First, its retrospective, single-center design and inclusion of patients referred for invasive EPS limit generalizability, and the observed prevalence of high-risk characteristics should not be extrapolated to all children with intermittent or asymptomatic ventricular pre-excitation. Second, APERP, SPERRI, and SPPCL were not available in all patients, and missing measurements were not imputed. Patients without a documented parameter meeting a prespecified high-risk threshold remained in the denominator but were not classified as having documented high-risk characteristics; consequently, the reported prevalence may underestimate the true prevalence of high-risk pathways. Third, classification of intermittent and persistent pre-excitation depended on available preprocedural ECG and ambulatory monitoring records and may have been influenced by differences in the type and duration of monitoring. Fourth, the study evaluated invasive electrophysiological surrogate markers rather than prospectively observed life-threatening arrhythmic events. Therefore, APERP, SPERRI, or SPPCL values ≤ 250 ms should not be interpreted as equivalent to a future clinical event. Long-term outcome data were insufficient to define the natural history of children with intermittent pre-excitation and high-risk electrophysiological properties who did not undergo ablation. Finally, incomplete index-procedure data in the redo cohort prevented assessment of patient-level recurrence rates and independent predictors of repeat procedures.

CONCLUSION

Intermittent pre-excitation was independently associated with lower odds of high-risk electrophysiological characteristics in children, but approximately one in six patients still met an invasive high-risk criterion. Symptom absence likewise did not identify a low-risk pathway. These findings support using intermittency and clinical presentation as components of risk assessment rather than isolated markers capable of excluding high-risk AP physiology.

Abbreviations

AP	Accessory pathway
APERP	Accessory pathway effective refractory period
CI	Confidence interval
ECG	Electrocardiogram
EPS	Electrophysiological study
IQR	interquartile range
OR	Odds ratio
SCD	Sudden cardiac death
SPERRI	Shortest pre-excited R–R interval during atrial fibrillation
SPPCL	Shortest pre-excited paced cycle length during rapid atrial pacing
WPW	Wolff–Parkinson–White

Declarations

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics Approval

This study was performed in accordance with the principles of the Declaration of Helsinki. Approval was granted by the Scientific Research Ethics Committee of Istanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital (July 6, 2026; No. 106).

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Author Contribution

Conceptualization: C.A. and M.M.A.; Methodology:A.Z.Q and H.C.K.; Formal analysis: M.M.A and A.H.; Writing—original draft preparation: M.M.A.; Writing—review and editing: M.M.A and Y.E.; Supervision: C.A. and Y.E. All authors read and approved the final manuscript.

Data Availability

The data supporting the findings of this study are available from the corresponding author on reasonable request, subject to institutional and ethical restrictions.

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Figures

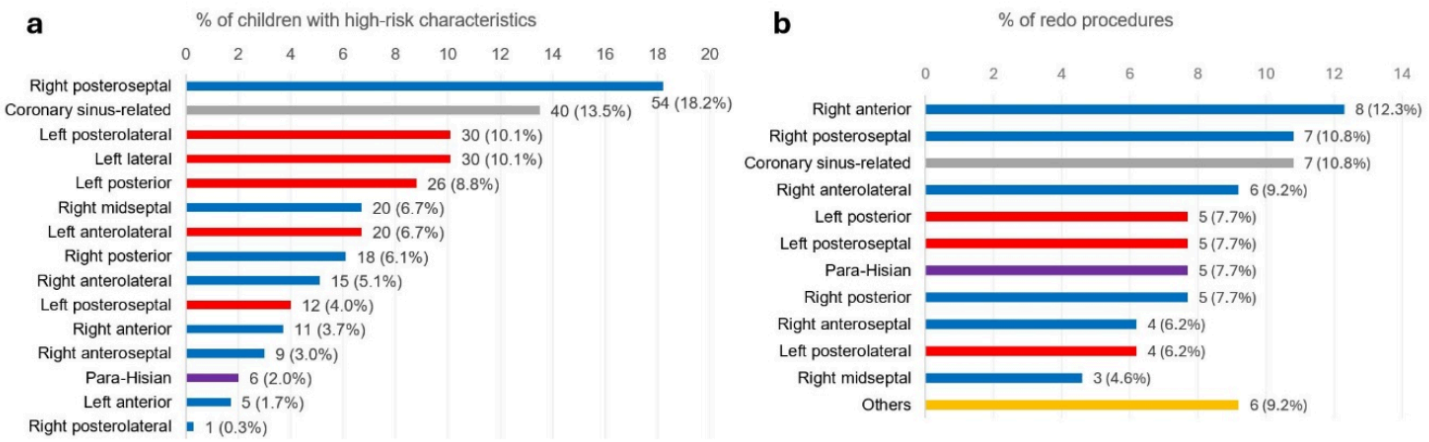


Figure 1

Distribution of accessory pathway locations among children with high-risk electrophysiological characteristics and during pediatric redo procedures. **a)** Accessory pathway locations among 297 children with documented high-risk electrophysiological characteristics, defined as APERP ≤250 ms, SPERRI ≤250 ms, and/or SPPCL ≤250 ms. **b)** Accessory pathway locations identified during 65 pediatric redo procedures. In panel b, the “Others” category comprised noncoronary aortic cusp (n=2), left anterior (n=1), left anterolateral (n=1), left lateral (n=1), and right posterolateral (n=1) pathways. Coronary sinus–related pathways included pathways arising from the coronary sinus ostium, middle cardiac vein ostium, coronary sinus diverticulum, or other coronary venous/epicardial sites. Bar colors indicate anatomical groups: blue, other right-sided pathways; red, left-sided pathways; gray, coronary sinus–related pathways; purple, para-Hisian pathways; and yellow, the “Others” category in panel b