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Research Article

Incidence and Outcomes of Postoperative Junctional Ectopic Tachycardia in Pediatric Patients Undergoing Tetralogy of Fallot Repair: A Retrospective Cohort Study

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Abstract

Background: *Junctional ectopic tachycardia (JET) is a well-recognized postoperative arrhythmia following congenital heart surgery, particularly after Tetralogy of Fallot (TOF) repair. It has been associated with increased postoperative morbidity and, in some cases, mortality. This study aims to assess the incidence of postoperative JET and evaluate its impact on hospital length of stay and mortality in pediatric patients undergoing TOF repair.*

Methods: *This retrospective cohort study was conducted at a tertiary pediatric cardiac center and included 100 pediatric patients who underwent complete TOF repair. Patients were classified into two groups based on the occurrence of postoperative JET: the JET group and the non-JET group. Demographic, perioperative, and postoperative data were collected. Statistical analyses included the Mann-Whitney U test and chi-square test for group comparisons, logistic regression analysis to assess the association between JET and mortality, and Cox regression analysis to evaluate its impact on hospital length of stay.*

Results: *JET was diagnosed in 14% of patients postoperatively. Patients who developed JET were significantly younger and had a lower body surface area (BSA) compared to those without JET ($p < 0.05$). JET was associated with a significantly prolonged hospital stay, as confirmed by Cox regression analysis (HR = 0.478; 95% CI: 0.252–0.908; $p = 0.024$). Logistic regression analysis demonstrated that JET was significantly associated with an increased risk of mortality (OR = 5.59; 95% CI: 1.10–28.36; $p = 0.038$). However, the overall mortality rate in the cohort was 7%, which is higher than previously reported rates in the literature, potentially due to variations in institutional perioperative care and healthcare resource limitations.*

Conclusion: *Postoperative JET following TOF repair is associated with increased morbidity, reflected in prolonged hospitalization, and a significantly higher risk of mortality. Younger age and smaller BSA were identified as significant risk factors. These findings underscore the importance of vigilant perioperative management and early intervention strategies for high-risk patients. Future multicenter prospective studies are needed to validate these findings and optimize preventive and therapeutic approaches.*

Keywords: *Junctional ectopic tachycardia, Tetralogy of Fallot, congenital heart surgery, postoperative arrhythmias, pediatric cardiac surgery, hospital length of stay, mortality.*

Introduction

Junctional ectopic tachycardia (JET) is the most common arrhythmia observed in the early postoperative period following congenital heart surgery in pediatric patients, typically occurring within the first 72 hours after surgery (1). The reported incidence of JET ranges from 2% to 27%, with a notably higher occurrence following surgical procedures that involve direct manipulation of the atrioventricular (AV) conduction system, such as Tetralogy of Fallot (TOF) repair (2).

Despite its clinical significance, the precise pathophysiology of postoperative JET remains incompletely understood. It is believed to result from multiple contributing factors, including direct surgical trauma, ischemic injury, mechanical stress, and postoperative inflammatory responses that disrupt AV nodal function and surrounding conduction pathways (3-7).

Several perioperative factors have been identified as potential risk factors for the development of JET, including younger patient age, lower body weight, prolonged cardiopulmonary bypass (CPB) and aortic cross-clamp (ACC) durations, high-dose inotropic support, and electrolyte imbalances, particularly hypokalemia and hypomagnesemia (5,7-9). The occurrence of JET is strongly associated with hemodynamic instability, prolonged mechanical ventilation, extended intensive care unit (ICU) stay, and increased hospital length of stay (LOS), all of which contribute to higher healthcare resource utilization (8,9). In severe cases, JET can lead to low cardiac output syndrome (LCOS), multi-organ dysfunction, and increased postoperative mortality (5-7).

The management of postoperative JET requires a comprehensive approach aimed at stabilizing hemodynamics and minimizing arrhythmic burden. First-line strategies include reducing inotropic support when possible, optimizing sedation and analgesia, and correcting electrolyte imbalances (6,10,11). In refractory cases, atrial pacing may be employed to restore AV synchrony (6,12,13). Pharmacologic management primarily relies on intravenous amiodarone, which is considered the gold standard for treating hemodynamically significant JET (6,13-15). Additionally, recent research has explored the prophylactic use of dexmedetomidine, magnesium sulfate, and amiodarone in high-risk patients, demonstrating their potential in reducing postoperative JET incidence (16-20).

Given the potential impact of JET on postoperative morbidity and mortality, a deeper understanding of its clinical consequences following complete TOF repair remains essential. Therefore, this study aims to:

1. Determine the incidence of postoperative JET following complete TOF repair.

2. Evaluate the clinical impact of JET by investigating its association with:

• Length of hospital stay (LOS).

• Postoperative mortality rates.

Materials and Methods

Study Design and Setting

This retrospective cohort study was conducted at the Pediatric Cardiac Intensive Care Unit (PCICU) of the University Children's Hospital in Damascus, Syria, between 2017 and 2021. The medical records of 100 pediatric patients who underwent complete surgical repair of Tetralogy of Fallot (TOF) at the hospital's Cardiothoracic Surgery Unit were reviewed. Ethical approval was obtained from the hospital's Institutional Ethics Committee before initiating the study.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Pediatric patients younger than 13 years undergoing complete surgical repair of TOF.

Exclusion Criteria

- Patients with preoperative arrhythmias or documented conduction abnormalities.

Patient Classification

Patients were categorized into two groups based on the postoperative occurrence of junctional ectopic tachycardia (JET):

- JET Group: Patients who developed postoperative JET.
- Non-JET Group: Patients who did not develop postoperative JET.

Surgical Procedure

All surgical procedures were performed using standard cardiopulmonary bypass (CPB) techniques under mild systemic hypothermia (32–34°C). The approach for right ventricular outflow tract (RVOT) reconstruction was determined intraoperatively based on the anatomical findings.

In all cases, ventricular septal defect (VSD) closure was performed via a transatrial approach to minimize ventricular manipulation and reduce the risk of conduction disturbances.

To relieve RVOT obstruction, one or more of the following techniques were applied as needed:

1. Pulmonary valvotomy or commissurotomy followed by dilation with Hegar dilators in cases of valvular pulmonary stenosis.
2. Complete resection of the infundibular muscle to address subvalvular obstruction.
3. Transannular patch (TAP) placement, utilizing autologous pericardium or polytetrafluoroethylene (PTFE) when other techniques did not provide sufficient RVOT relief.

The choice of additional interventions was based on intraoperative hemodynamic assessments and the degree of RVOT obstruction to ensure optimal surgical outcomes.

Data Collection and Definitions

Patient records were systematically reviewed to extract relevant clinical data from preoperative, intraoperative, and postoperative periods.

Preoperative Data

- Demographics: Age (years), gender, weight (kg), height (cm), and body surface area (BSA, m²).
- Clinical History: Presence of cyanotic spells before surgery and the use of prophylactic propranolol.

Intraoperative Data

- Cardiopulmonary bypass (CPB) duration: Measured in minutes.
- Aortic cross-clamp (ACC) duration: Measured in minutes.
- Pulmonary annular incision: Documented if performed.

Postoperative Data

- Occurrence of JET: Diagnosed and recorded accordingly.
- Mechanical ventilation duration: Measured in hours.
- Hospital length of stay (LOS): Measured in days.
- Presence of low cardiac output syndrome (LCOS): Documented when present.
- Requirement for high-dose inotropic support:
  - Defined as follows for patients in the pediatric cardiac ICU:
    - Epinephrine/Norepinephrine: > 0.5 mcg/kg/min.
    - Dopamine/Dobutamine: > 10 mcg/kg/min.
- Postoperative mortality: Recorded for all patients.

Definition of Postoperative Low Cardiac Output Syndrome (LCOS)

LCOS was diagnosed if two or more of the following criteria were met:

1. Serum lactate concentration exceeding 3 mmol/L.
2. Urine output less than 0.5 mL/kg/hour.
3. A skin-to-core temperature difference greater than 5°C.
4. Hypotension, defined as blood pressure below the 5th percentile for age, weak pulses, or prolonged capillary refill time.
5. Tachycardia exceeding normal age-specific reference ranges.

JET Diagnosis and Monitoring

Continuous electrocardiographic (ECG) monitoring was performed in the Pediatric Cardiac Intensive Care Unit (PCICU) using Dräger Infinity Delta Kappa monitors. Standard 12-lead ECGs were performed at three key time points:

1. Preoperatively to assess baseline cardiac rhythm.
2. Upon ICU admission for immediate postoperative evaluation.
3. Whenever JET was clinically suspected.

The diagnosis of postoperative JET was confirmed based on the following criteria:

1. Narrow QRS complex tachycardia.
2. Heart rate exceeding 170 beats per minute.
3. Atrioventricular (AV) dissociation with a ventricular rate faster than the atrial rate.

These standardized definitions ensured objective assessment of postoperative clinical outcomes, allowing timely interventions to improve patient prognosis.

Management of JET

Management of postoperative JET was initiated immediately upon diagnosis to prevent hemodynamic deterioration and included a multifaceted approach addressing both underlying triggers and direct arrhythmia control.

Initial Measures:

- Correction of contributing factors such as electrolyte imbalances (hypokalemia, hypomagnesemia), hypovolemia, and anemia to restore physiological stability.
- Optimization of sedation and analgesia to minimize sympathetic stimulation, which could exacerbate tachycardia.
- Gradual reduction of inotropic support when clinically feasible to avoid excessive adrenergic stimulation that may sustain JET.

Pharmacologic Therapy:

Intravenous amiodarone was the primary pharmacologic intervention, administered according to the following protocol:

- Loading dose: 5 mg/kg infused over 1 hour.
- Maintenance infusion: 5 mcg/kg/min, continued until sinus rhythm was restored or a sufficient

reduction in heart rate was achieved with hemodynamic stability.

- If the response was inadequate, additional amiodarone boluses were given, up to a cumulative loading dose of 15 mg/kg.
- Weaning process: Once clinical stabilization was achieved, amiodarone infusion was gradually tapered over 3–5 days to prevent rebound arrhythmias.

This structured approach aimed to stabilize cardiac function, minimize JET-associated complications, and facilitate a smoother postoperative recovery.

Study Outcomes

Primary Outcome

- Incidence of postoperative JET after TOF repair.

Secondary Outcomes

- Impact of JET on hospital length of stay (LOS).
- Association between JET and postoperative mortality.

Statistical Analysis

All statistical analyses were conducted using IBM SPSS Statistics (version 26.0, Armonk, NY, USA).

Descriptive Statistics

- Categorical variables (e.g., gender, JET occurrence, cyanotic spells, beta-blocker prophylaxis, pulmonary annular incision, postoperative LCOS, high-dose inotropic support, mortality) were presented as frequencies and percentages.
- Continuous variables (e.g., age, height, weight, BSA, CPB and ACC durations, mechanical ventilation duration, hospital LOS) were summarized using median and interquartile range (IQR).

Comparative Analysis Between JET and Non-JET Groups

- Mann-Whitney U test was used to compare continuous variables between groups.
- Chi-square test was applied to compare categorical variables.
- A p-value <0.05 was considered statistically significant.

Assessment of JET Impact on Mortality

- Logistic regression analysis was conducted to evaluate the association between JET and postoperative mortality.

• Results were reported as odds ratios (OR) with 95% confidence intervals (95% CI).

Assessment of JET Impact on Hospital Length of Stay (LOS)

• Cox regression analysis was performed to determine the effect of JET on hospital LOS.

• Results were presented as hazard ratios (HR) with 95% confidence intervals (95% CI).

• A p-value <0.05 was considered statistically significant for all analyses.

Results

This study included a total of 100 pediatric patients who underwent complete surgical repair of Tetralogy of Fallot (TOF). Patients were classified into two groups based on the presence or absence of postoperative Junctional Ectopic Tachycardia (JET): the JET group (n=14) and the non-JET group (n=86).

Preoperative Patient Demographics

The preoperative demographic characteristics of both groups are summarized in Table 1. The median age at surgery for the overall cohort was 1.8 years (IQR: 1.1–2.88 years). However, patients who developed JET were significantly younger (median age: 1.1 years, IQR: 0.6–2.75) compared to those who did not (median age: 1.9 years, IQR: 1.2–3.0; p = 0.012).

Additionally, patients with JET had smaller body sizes, as reflected by shorter height (p = 0.026) and smaller body surface area (p = 0.045). Although the incidence of cyanotic spells prior to surgery was slightly higher in the JET group, this difference was not statistically significant (57.1% vs. 47.7%; p = 0.511).

However, prophylactic beta-blocker use was significantly less common among patients who developed JET (42.9% vs. 83.7%; p = 0.001), suggesting a potential protective role of beta-blockers in reducing the risk of postoperative JET.

Table 1: Preoperative Patient Demographics

Variable	JET Group (n=14)	Non-JET Group (n=86)	Total (n=100)	p-value
Male sex	10 (71.4%)	57 (66.3%)	67 (67.0%)	0.704
Age (years), Median (IQR)	1.1 (0.6–2.75)	1.9 (1.2–3.0)	1.8 (1.1–2.88)	0.012
Weight (kg), Median (IQR)	9.0 (7.5–12.2)	10.5 (8.7–13.1)	10.0 (8.5–12.88)	0.066

Height (cm), Median (IQR)	72 (68–80)	78 (73–89)	78 (72.25–89)	0.026
BSA (m²), Median (IQR)	0.42 (0.36–0.52)	0.47 (0.42–0.56)	0.46 (0.42–0.56)	0.045
Preoperative cyanotic spells	8 (57.1%)	41 (47.7%)	49 (49.0%)	0.511
Prophylactic beta-blocker use	6 (42.9%)	72 (83.7%)	78 (78.0%)	0.001

Operative Data

The operative parameters for both groups are summarized in Table 2. There were no statistically significant differences between the JET and non-JET groups regarding cardiopulmonary bypass (CPB) time (median: 125 vs. 117 minutes; $p = 0.115$), aortic cross-clamp (ACC) time (median: 92 vs. 88 minutes; $p = 0.218$), or the incidence of pulmonary annular incision (14.3% vs. 8.1%; $p = 0.456$). These findings suggest that intraoperative factors such as CPB duration, ACC time, and pulmonary annular incision were not independent contributors to the development of JET in this cohort.

Table 2: Operative Data

Variable	JET Group (n=14)	Non-JET Group (n=86)	Total (n=100)	p-value
CPB time (min), Median (IQR)	125.0 (108–150)	117.0 (99–138)	118.5 (101.25–142.5)	0.115
ACC time (min), Median (IQR)	92.0 (78–112)	88.0 (72–104)	90.5 (74–106.25)	0.218
Pulmonary annular incision	2 (14.3%)	7 (8.1%)	9 (9.0%)	0.456

Postoperative Outcomes

Postoperative outcomes are summarized in Table 3. The overall incidence of JET in this study was 14% (14 out of 100 patients). Patients in the JET group required significantly longer durations of mechanical ventilation (median: 48 vs. 18 hours; $p < 0.001$) and had prolonged hospital stays (median: 10 vs. 5.5 days; $p = 0.016$). Additionally, patients with JET had a markedly higher incidence of low cardiac output syndrome (LCOS) (64.3% vs. 19.8%; $p < 0.001$) and were more likely to require high-dose inotropic support (78.6% vs. 32.6%; $p = 0.001$).

Mortality rates were also significantly higher among patients who developed JET, with a postoperative mortality rate of 21.4% compared to 4.7% in the non-JET group ($p = 0.023$). These findings highlight the severe impact of JET on postoperative outcomes, emphasizing the need for early identification and targeted management strategies to mitigate its complications.

Table 3: Postoperative Outcomes

Variable	JET Group (n=14)	Non-JET Group (n=86)	Total (n=100)	p-value
High-dose inotropic support	11 (78.6%)	28 (32.6%)	39 (39.0%)	0.001
LCOS	9 (64.3%)	17 (19.8%)	26 (26.0%)	<0.001
Mechanical ventilation (hrs), Median (IQR)	48.0 (22–120)	18.0 (6–32)	20.0 (8–30)	<0.001
Hospital LOS (days), Median (IQR)	10.0 (7–15)	5.5 (4–9)	6.0 (5–10)	0.016
Mortality	3 (21.4%)	4 (4.7%)	7 (7.0%)	0.023

Regression Analysis of JET Impact on Mortality and Hospital Stay

Our analysis revealed a strong association between postoperative JET and adverse clinical outcomes. Logistic regression demonstrated that JET significantly increased the risk of mortality (OR = 5.59; 95% CI: 1.10–28.36; p = 0.038), indicating that patients who developed JET were approximately 5.6 times more likely to experience postoperative mortality compared to those who did not.

Similarly, Cox regression analysis confirmed that JET was a significant predictor of prolonged hospitalization (HR = 0.478; 95% CI: 0.252–0.908; p = 0.024). Patients with JET had a considerably lower likelihood of early discharge, leading to extended hospital stays and increased resource utilization.

These findings underscore the critical role of JET as an independent risk factor for both increased mortality and prolonged hospitalization in pediatric patients undergoing TOF repair. This highlights the urgent need for early recognition, effective preventive strategies, and prompt intervention to mitigate its impact and improve postoperative outcomes.

Discussion

Junctional ectopic tachycardia (JET) is a well-recognized complication following congenital heart surgery, particularly after Tetralogy of Fallot (TOF) repair, and is associated with significant postoperative morbidity and mortality. In our study, the incidence of JET was 14%, which falls within the range reported in previous research, where rates have varied between 2% and 27% **(**7-9**)**. The variability in JET incidence across studies can be attributed to differences in diagnostic criteria, surgical approaches, patient populations, and perioperative management strategies employed by different institutions **(**21**)**. These discrepancies highlight the need for standardized diagnostic and preventive protocols to optimize postoperative outcomes.

Our study identified younger age, lower body surface area (BSA), and shorter height as significant risk factors for developing JET. These findings align with previous research indicating that younger pediatric patients are more susceptible to postoperative conduction disturbances due to the fragility of their atrioventricular (AV) conduction system (7–9,22). The increased vulnerability in smaller patients may be attributed to the immaturity of conduction tissues, making them more prone to surgical trauma, ischemic injury, and inflammatory responses following cardiopulmonary bypass (CPB) (23). Additionally, studies by Dasgupta et al., Dodge-Khatami et al., and Paluszek et al. have similarly highlighted those prolonged ischemic times and certain surgical procedures, such as ventricular septal defect (VSD) closure and atrioventricular canal (AVC) repair, further elevate the risk of developing postoperative JET (22,24). These findings emphasize the importance of careful intraoperative planning and perioperative monitoring, particularly in younger and smaller patients undergoing congenital heart surgery.

One of the notable findings in our study was the protective effect of prophylactic beta-blocker therapy, specifically propranolol. The incidence of JET was significantly lower in patients who received prophylactic propranolol (7.7%) compared to those who did not (36.4%), reinforcing previous research that supports beta-blockers as an effective preventive strategy for JET (17). Propranolol's antiarrhythmic properties stem from its ability to reduce sympathetic activity, inhibit pacemaker potentials, and suppress spontaneous depolarization, thereby promoting stability within the cardiac conduction system (25). Additionally, the pharmacokinetics of propranolol may be altered during CPB, with changes in drug binding and metabolism potentially prolonging its protective effects into the immediate postoperative period (26,27). These findings emphasize the importance of considering beta-blocker prophylaxis, particularly in high-risk patients, as a strategy to mitigate the incidence of JET and its associated complications.

JET and Low Cardiac Output Syndrome (LCOS)

Our study identified a strong correlation between JET and both high-dose inotropic support and low cardiac output syndrome (LCOS). However, this relationship appears to be bidirectional high inotropic requirements and LCOS may create an electrically unstable myocardial environment, predisposing patients to JET, or conversely, JET itself may contribute to hemodynamic instability, exacerbating LCOS and necessitating increased inotropic support (5-7).

This intricate interaction was also emphasized in a study by Abdelaziz and Deraz, which highlighted the complex interplay between JET and postoperative hemodynamic deterioration. Their findings underscore the critical need for early detection and proactive arrhythmia management in patients undergoing congenital heart surgery (9). These insights reinforce the importance of close perioperative monitoring and targeted interventions to mitigate the impact of JET on cardiac function and overall patient outcomes.

Impact of JET on Hospital Stay and Resource Utilization

JET was significantly associated with an increase in hospital length of stay and prolonged mechanical ventilation duration. Cox regression analysis further confirmed that JET contributed to a longer hospital stay (HR = 0.478; 95% CI: 0.252–0.908). This finding is consistent with previous research indicating that postoperative arrhythmias, including JET, often result in prolonged hospitalization due to the increased need for extended mechanical ventilation, inotropic support, and intensive hemodynamic management (6,8).

Similar outcomes have been reported in studies by Ismail et al. and Rajput et al., both of which found that JET significantly increased ICU and overall hospital stay. Their findings highlight the considerable impact of JET on healthcare resource utilization, emphasizing the added burden on pediatric cardiac surgery units and the need for effective preventive strategies to reduce hospital stays and improve patient outcomes (8,19).

JET and Postoperative Mortality

In our study, the overall mortality rate was 7%, which is higher than the 0–3% range reported in previous studies (28,29). This increased mortality may be influenced by multiple factors, including limited healthcare resources due to economic sanctions, which have posed challenges in ensuring optimal postoperative care and intensive monitoring. Additionally, differences in sample size, perioperative management protocols, and patient demographics may have contributed to this discrepancy.

Logistic regression analysis further reinforced the critical impact of JET, demonstrating a significant association with increased mortality risk (OR = 5.59; 95% CI: 1.10–28.36), aligning with prior studies that identified JET as a key factor contributing to postoperative mortality (6,9). However, some studies, including Dasgupta et al., did not find a statistically significant correlation between JET and mortality, possibly due to variations in institutional management strategies, early detection, and proactive arrhythmia control measures (24).

This variability highlights the importance of adopting standardized yet adaptable management approaches, ensuring that institutions tailor their perioperative strategies based on their available resources while prioritizing early risk assessment and intervention in high-risk patients.

Study Strengths and Limitations:

This study has several notable strengths and limitations that should be considered when interpreting its findings.

Strengths:

One of the key strengths of this study is its exclusive focus on patients undergoing Tetralogy of Fallot (TOF) repair, ensuring a homogeneous patient population. By limiting the study to a single congenital heart defect, the influence of surgical complexity and variability was minimized, making it easier to assess the specific impact of junctional ectopic tachycardia (JET) on clinical outcomes. Additionally, rigorous statistical methods, including logistic regression and Cox regression analysis, were employed to evaluate the association between JET and key postoperative parameters such as hospital length of stay and mortality. These methodologies enhance the reliability of the findings and provide a robust framework for analyzing risk factors and outcomes.

Limitations:

Despite its strengths, this study has several limitations. First, its retrospective and single-center design may restrict the generalizability of the findings to other institutions with different perioperative management protocols and surgical approaches. Second, the relatively small sample size may have reduced the statistical power to detect subtler differences between patient groups, particularly in identifying risk factors with moderate effects.

Furthermore, some perioperative variables that could influence JET development such as anesthetic techniques, intraoperative temperature regulation, and perioperative fluid management were not systematically analyzed. These factors may contribute to arrhythmogenesis and should be considered in future investigations. Another important limitation is the lack of assessment of JET duration and severity, which could provide deeper insights into its impact on long-term cardiac function and recovery.

While the study identified prophylactic propranolol as a protective factor, the timing, optimal dosage, and pharmacokinetics of propranolol in this patient population were not systematically analyzed. Variability in these factors could influence the reproducibility of its effects across different patient subgroups. Additionally, although this study confirmed the association between JET and prolonged hospital stay, other research, such as that by Dasgupta et al., suggests that aggressive perioperative management may reduce JET-associated mortality, an aspect that warrants further investigation in prospective trials (24).

Despite these limitations, this study provides valuable clinical insights into the risk factors, outcomes, and potential preventive strategies for postoperative JET in pediatric patients undergoing TOF repair. To further validate these findings and optimize risk stratification and management protocols, large-scale, multicenter, prospective studies are necessary.

Conclusion

This study highlights that postoperative JET remains a significant complication following TOF repair, contributing to prolonged hospital stays, increased need for cardiovascular support, and higher mortality rates. Younger age, smaller body surface area, and the absence of prophylactic beta-blocker therapy were identified as key risk factors for JET development. Statistical analysis confirmed a strong association between JET and increased mortality risk, though findings from previous studies remain variable.

These results emphasize the importance of early risk assessment, proactive preventive measures such as beta-blocker prophylaxis, and standardized postoperative monitoring protocols. Developing evidence-based management strategies tailored to institutional resources and patient-specific risk factors could help mitigate complications and improve clinical outcomes. Further large-scale, multicenter, randomized studies are necessary to validate these findings and refine perioperative strategies for managing JET in pediatric cardiac surgery.

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