

# Arrhythmias Developing in Pediatric Patients After Cardiac Surgery: A Comprehensive Review on the Risk Factors, Prevention and Management Strategies

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**Abstract:** The most common complications post pediatric cardiac surgeries are postoperative arrhythmias. They greatly influence adverse postoperative events, duration of stay in intensive care unit (ICU), and patient outcome [1] [2].

Regardless of surgical advancements, perioperative care and pain management, the rate of arrhythmias in current patient populations is significant [2] [3].

This narrative review aims to investigate the risk factors of postoperative arrhythmias in pediatric cardiac surgery, highlight preventive strategies that are evidence-based and give an overview of prevalent management techniques.

Risk factors attributable to arrhythmogenesis are patient oriented or pertain to surgical specificities. Patient-related risks include age, prior cardiac abnormalities and electrolytic irregularities. Surgical risks encompass the type of procedure performed, time period undertaken for cardiopulmonary bypass procedures, and intraoperative myocardial ischemia [1] [2].

Preventive strategies involve conscientious perioperative monitoring, rectifying metabolic abnormalities, defensive approaches for the myocardium, and utilising prophylactic antiarrhythmic pharmacotherapy in high-risk patients. Continual electrocardiographic monitoring is an effective means of early diagnosis, aiding in diminishing advancements of arrhythmias to hemodynamic damage [3]. Several types of arrhythmia require distinct therapeutic techniques. Therapeutic strategies range from pharmacotherapy with amiodarone, to using pacemakers.

Perioperative protocol developments, better intraoperative monitoring technologies, and advancing pharmacotherapy, showcase promise in improving preventive and management methods. Research in longevity and durability of the studies is required, along with multicenter collaborations to produce uniform protocols and predictive prototypes customised for the Pediatric population.

Future directions emphasise on refining risk prediction tools, assessing new therapies, and incorporating biomarker-based risk stratification into clinical practice. Providing current evidence and focusing on blind spots, makes this review beneficial for clinicians and researchers, with practical comprehension for better discernment, encouraging further research in Pediatric cardiac care.

**Keywords:** Pediatric Cardiac Surgery, Postoperative Arrhythmias, Junctional Ectopic Tachycardia, Risk Factors, Prevention, Management.

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## I. INTRODUCTION

Postoperative arrhythmias are one of the most common challenges faced in the field of Pediatric cardiac surgery, with incidence rates spanning from 7% to 50%, in accordance to factors related to the patient and surgery [3] [2]. Congenital heart defects (CHD) put children at greater risk as a result of the abnormalities involving the anatomy of the heart and its conduction pathways [1]. There has been improvement in survival after performing intricate surgical repairs, however, the longevity of this outcome greatly relies on reducing adverse perioperative conditions such as arrhythmias [2]. Arrhythmias can have numerous consequences inclusive of hemodynamic instability, longer stays in the ICU, requirement of subsequent surgical operations and mortality [3] [1]. There are some arrhythmias that may resolve spontaneously, however, there are many others such as junctional ectopic tachycardia (JET), atrial flutter, or complete AV block, that necessitate immediate intervention, antiarrhythmic agents, or the implantation of a pacemaker. Comprehension of their pathogenesis and utilisation of evidence-based preventive methods and management techniques are crucial in enhancing successful surgical outcomes.

This narrative review provides current evidence of literature on the incidence, risk factors, prevention strategies, and treatment methods of postoperative arrhythmias in Pediatric cardiac surgery. It also features some of the obstacles encountered during the process as well as giving further insight into future directions to provide the patient with optimal care.

## II. BACKGROUND

### ➤ Epidemiology

Postoperative arrhythmias are a frequent complication of paediatric cardiac surgery done due to different cardiac pathologies, with reported rates between 7.5% up to 48% generally and differ with regard to onset and the reason for surgery [20]. The prevalence of postoperative junctional ectopic tachycardia ranged from 2.0% to 8.3% depending on variation in age distribution, including only cases of postoperative junctional ectopic tachycardia in patients less than 12 months [25]. A study was done to evaluate postoperative arrhythmias following congenital heart surgery, on a 12-lead electrocardiography and Holter monitoring and it was found that about 43.5% of the patients developed arrhythmias after surgery. It was noted that no arrhythmias were observed in neonates. Supraventricular extrasystoles were reported as the predominant postoperative arrhythmia, observed in nearly two-thirds of affected patients. Their occurrence was most often linked to corrective surgery for congenital heart defects, particularly secundum atrial septal defect (32.3%), ventricular septal defect (25%), and Tetralogy of Fallot (14.7%) [26]

### ➤ Pathophysiology

Postoperative arrhythmias in pediatric cardiac surgery arise from a combination of surgical trauma, inflammation, and physiological stress on the heart's conduction system.

Direct manipulation or injury to conduction pathways during surgery, particularly near the atrioventricular node, can provoke arrhythmogenesis [20]. The use of cardiopulmonary bypass (CPB) and aortic cross-clamping induces ischemia–reperfusion injury and triggers a systemic inflammatory response. This inflammatory cascade, marked by elevated cytokines and oxidative stress, contributes to myocardial stunning and disrupts electrical stability [27] [28] [42]. Additionally, postoperative factors—such as electrolyte imbalances, acidosis, catecholamine surges, hypoxia, and hemodynamic instability—further irritate the conduction system, increasing arrhythmia susceptibility [20]. Some specific tachyarrhythmias, like junctional ectopic tachycardia (JET), result from abnormal automaticity in tissues near the AV node, often triggered by surgical proximity and myocardial trauma [20] [43].

## III. METHODOLOGY

A systematic search of the literature was conducted using electronic databases including PubMed, and Google Scholar. The search strategy employed combinations of keywords and Boolean operators, such as “junctional ectopic tachycardia” OR “JET” AND “paediatric cardiac surgery” OR “postoperative arrhythmia.”

The search covered studies published from January 1976 to August 2025, ensuring inclusion of the most up-to-date evidence. Only articles published in English were considered. Studies were included if they reported on the epidemiology, pathophysiology, diagnostic criteria, risk factors, or management in paediatric populations undergoing cardiac surgery. Exclusion criteria comprised case reports with insufficient detail, conference abstracts without full texts, and articles not involving paediatric patients.

Screening was performed in two stages: first by reviewing titles and abstracts to assess relevance, followed by full-text evaluation of selected articles.

From each included study, information was collected on epidemiology (prevalence, incidence, demographics), pathophysiology (surgical trauma, inflammation, ischemia, electrolyte disturbances), risk factors (type of defect, age, procedure), prevention and management strategies (pharmacological treatment, pacing, intraoperative monitoring), and future perspectives (emerging therapies, research gaps). Relevant data were summarised manually for inclusion in the review.

## IV. RESULTS & DISCUSSION

### ➤ Risk Factors

#### • Patient Factors:

After a cardiac surgery, the infants and very young children have a higher risk of post-operative arrhythmias. This is due to the immature cardiac conduction system and also since they require more complex surgeries. Since they have even a lower body weight this correlates with higher risk and is due to overall fragility and increases surgical stress. A

study has shown that the younger age and the lower body weight are significant risk factors for arrhythmias, with junctional ectopic tachycardia (JET) and supraventricular tachycardia, which is a common post operative arrhythmia. [29] [30]

Some children with pre-existing arrhythmias or certain genetic syndromes such as Down's Syndrome or 22q11 deletion syndrome have an increased susceptibility to arrhythmias after surgery. These particular syndrome affects cardiac anatomy and conduction tissue. These patients have longer surgeries and complex postoperative courses. Unfortunately they have higher rates of complications, including arrhythmias, infections and longer hospital stays. [31]

- *Surgical Factors:*

An increased risk of postoperative arrhythmias has been closely associated with longer CPB and cross-clamp durations. These lengths of time are indicative of the procedure being complex and more invasive, which may result in cardiac tissue, particularly conduction pathways, suffering ischaemia and reperfusion damage. Research continuously shows that the risk of postoperative arrhythmias, particularly JET and atrioventricular block, is much increased by extended bypass and cross-clamp periods. [29-31]

Some surgeries near the cardiac conduction system area, such as repairs close to the atrioventricular node or His Bundle, raise the risk of arrhythmias. The procedures inherently carry risk due to extensive surgical manipulation and possibility for injury to conduction tissue. [30]

- *Postoperative Factors:*

There is an increased arrhythmia risk which is associated with low potassium and magnesium levels after surgery. When there is Hypokalemia, it can alter the cardiac cell electrophysiology and it will promote things like ventricular arrhythmias. Hypomagnesemia is common following pediatric cardiac surgery because of cardiopulmonary bypass and is correlated with a higher incidence of arrhythmias. [33][34]

Then there are Inotropic drugs which are used to support heart function following a heart surgery and will have pro-arrhythmic effects. Dopamine increases the pulmonary vascular resistance and has vasoconstrictive properties. And then we have isoproterenol which acts as a pulmonary vasodilator however it does seem to significantly increase the heart rate and this could possibly cause arrhythmias. And it would be of best interest if we monitor these agents. [35][36]

There could be cardiac irritability that is exacerbated by postoperative hypoxia and systemic infections like sepsis. Some things like sepsis induced atrial fibrillation and arrhythmias are linked with higher morbidity and mortality. What causes arrhythmias to increase is the inflammatory response and metabolic stress, therefore we must be vigilant in postoperative care. [37]

## ➤ *Prevention*

- *Myocardial Protection:*

Optimal cardioplegia, temperature control. During surgery what is found to be essential is the Optimal Myocardial protection. We use solutions like Specialized Cardioplegia (Del Nido), which protects the immature heart, along with careful temperature control, because by doing this we cool the heart to reduce oxygen demand and helps to prevent damage and arrhythmias. [6][14]

- *Perioperative Electrolyte Management:*

Frequent monitoring and correction. Another method to reduce arrhythmia risk would be to have regular monitoring and correction of electrolytes such as Potassium, Magnesium and Calcium during and after surgery. There will be electrolyte balance with proper fluid management. [7] [17]

- *Prophylactic Antiarrhythmics:*

Amiodarone prophylaxis for high-risk JET. There is a common postoperative arrhythmia in children called Junctional Ectopic Tachycardia (JET), and the incidence of this can be significantly lowered by administering amiodarone prophylactically. Amiodarone can be given intraoperatively and continued postoperatively under careful monitoring [12][38]

- *Pacing Wires:*

Routine placement for temporary pacing if needed. There are pacing wires (temporary epicardial pacing wires) which are often placed during the surgery and we use it as a precaution to manage potential arrhythmias. However this depends upon risk assessment by some centers. And this pacing wire will be removed usually few days after maintaining stable heart rhythm. [5][9]

## ➤ *Management*

- *JET:*

We can cool the patient to mild hypothermia to around 34-35, and then providing adequate sedation and then starting an amiodarone infusion at 5-15 mcg/kg/min. We use something called "overdrive pacing which paces the atrium slightly faster than the tachycardia rate to restore atrioventricular synchrony. [6][10][13]

- *AV Block:*

Temporary epicardial pacing is used at first. An implantation of a permanent pacemaker should be considered if there is an AV block that persists more than 7 days. [41]

- *Atrial Arrhythmias:*

By often using beta-blockers or digoxin we can control the rate. Synchronized Cardioversion is indicated to restore the sinus rhythm when the patient is hemodynamically unstable. [8][16]

- *Ventricular Arrhythmias:*

Crucial steps such as correcting underlying triggers such as electrolyte imbalance and ischaemia are required. Antiarrhythmic drugs such as lidocaine and amiodarone are

commonly used. And Defibrillation is required for sustained ventricular tachycardia or ventricular fibrillation. [8][16]

#### ➤ *Multidisciplinary Care*

Surgeons, cardiologists, intensivists, anesthesiologists and electrophysiologists should get together for discussions about optimal patient outcomes. This is because each specialist will provide unique expertise and effective communication and coordination to ensure smooth perioperative care. The teamwork will allow for enhancing decision making, reducing errors and improving surgical success rates. [11][39]

There are certain standards and protocols that define roles, promote shared goals and motivate to have frequent interdisciplinary meetings which are key to improving outcomes. Having these guidelines will assist the teams approach to complex cases and post operative care and in turn will enrich trust and give consistent communication across specialities. [11][39]

Teamwork is especially critical in pediatric cardiac care due to the different challenges of the congenital heart diseases which go over a wide range of anatomy and also patient ages. Another important factor is the leadership shown by surgeons in the operating room and coordination beyond surgery, this includes planning preoperative and postoperative management and this ensures comprehensive patient-centered care. [18]

## V. FUTURE PERSPECTIVES

#### ➤ *Bio/Molecular Markers Research*

Research studies into cardiac bio/molecular markers such as high-sensitivity troponins, BNP/NT-proBNP, and inflammatory markers may enhance early identification of myocardial stress or injury that leads to arrhythmias [1]. Additionally, detecting genetic forms related to ion channel function and conduction system deformities could support in pinpointing children at higher danger for postoperative arrhythmias [19]. These improvements could allow more individualized risk stratification and targeted prophylactic methods [20].

#### ➤ *Improved Monitoring Technologies*

The growth of non-disturbing everlasting non-stop monitoring systems, which include wearable telemetry, on-body surface ECG mapping, and intelligent embeddable sensors, is reshaping and adding success to post-surgical care [20]. These instruments and devices may aid and enable early involvement in arrhythmias and intervention, both in the hospital and during outpatient follow-up [1]. The combination of AI procedures to examine results involved with rhythmic data can furthermore add to improving diagnostic precision and decrease clinician workload [20].

#### ➤ *Refined Clinical Guidelines*

As of now, there are evident changes in how antiarrhythmic drugs are used preventatively in pediatric patients [1]. Future research studies should help establish understandable, evidence-based regulations adapted to

individual risk factors for example the type of surgery, the time it takes for bypass to occur, and cardinal cardiac disease [1]. The formation of risk assessment equipment that include clinical, surgical, and genetic results will be very important to leading more precise and successful treatment protocols [20].

#### ➤ *Multicenter Collaborative Trials*

There is a powerful demand for huge, multicenter prospective studies to be able to detect and find out the best practices for controlling postoperative arrhythmias in children [1]. Such tests could set side by side different treatment methods, assess long-term results, and support in developing standardized definitions and care techniques, specifically for high-risk approaches and procedures such as single-ventricle repairs or reoperations [19].

#### ➤ *Genetic Counseling and Screening*

With developing, fast growing acknowledgement of inherited arrhythmia disorders, genetic consultation is a key requirement and is expected to become a routine part of preoperative judgement and evaluation for selected patients [19]. Focusing and identifying familial arrhythmia risks can help us get familiar and let us know exactly about both surgical planning and long-term follow-up [20]. Screening of first-degree relatives may also be validated in certain cases, allowing early intervention and preventive care across generations [1].

## VI. SUGGESTIONS

- Hospitals should develop perioperative arrhythmia care pathways which helps to standardize early recognition, doing investigation and management of arrhythmias. Pathways like this can improve the coordination between the care teams and reduce the response times. [4]
- Create arrhythmia prediction tools by including clinical risk factors and the genetic data could make it better for early identification of high-risk patients and allowing for targeted monitoring and preventative strategies. [40]
- Training workshops designed for pediatric cardiac care providers should be advertised to help improve skills in early arrhythmia recognition and suitable intervention, which enhances the patient's safety and the outcomes. [15]
- Encouraging use of simulation labs allows healthcare workers to rehearse arrhythmia emergencies in an environment which is controlled, improving the team communication and confidence and makes the professional more prepared during the real life cases. [15]

## VII. CONCLUSION

To conclude, postoperative arrhythmias massively affect and contribute to morbidity in pediatric cardiac surgery [20]. Being able to have the ability of understanding complex multifactorial risk factors, watchful perioperative care, and opportune interventions are crucial [23]. Future research studies must aim to target and focus on predictive models and imaginative and creative therapies to further decrease the risks and complications of arrhythmia burden and improve outcomes to impact life positively [24].



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