Abdullah K. Dakhel et al, 2024;8(10):2859–2865.
DOI: 10.24911/IJMDC.51-1722445297

REVIEW ARTICLE

Current trends and challenges in the management of pediatric arrhythmias in Saudi Arabia: a comprehensive review of pharmacological and non-pharmacological approaches during 2024

Abdullah K. Dakhel[1], Nasser A. Alsharekh[2], Fahad A. Alqeaid[2], Abdulrahman F. Alkholaif[2], Sultan H. Alharbi[3], Meshal N. Alzaydi[4], Abdullah F. Alkholaif[4], Alwaleed K. Alabdali[5], Mohammed K. Dakhel[2]*

ABSTRACT

Arrhythmias in children pose distinct issues that necessitate individualized treatment strategies. This review discussed both pharmaceutical and non-pharmacological approaches for controlling arrhythmias in Saudi Arabian children. Pharmacological treatments largely include beta-blockers, calcium channel blockers, digoxin, and amiodarone, which are selected based on the kind of arrhythmia and the patient's clinical status. Non-pharmacological treatments include electrophysiological tests, catheter ablation, and pacemaker installation, which are required for certain arrhythmias, particularly in situations of structural cardiac disease or post-operative problems. Arrhythmias, including junctional ectopic tachycardia, atrioventricular block, and supraventricular tachycardia, were found in pediatric cardiac surgery patients, highlighting the importance of close monitoring and management measures. This research emphasizes the necessity of a complete approach that incorporates both therapy modalities to improve outcomes for pediatric arrhythmia patients in Saudi Arabia.

Keywords: Challenges, management, pediatric arrhythmias, Saudi Arabia, systemic review.

Introduction

Arrhythmias are irregular heartbeats that can be classified as tachycardia (rapid heart rate), bradycardia (slow heart rate), or irregular rhythms. They can result from a variety of factors, including congenital heart abnormalities, electrolyte imbalances, and post-surgical problems. In Saudi Arabia, research has found that important types of arrhythmias in children include junctional ectopic tachycardia (JET), atrioventricular (AV) block, and supraventricular tachycardia (SVT), particularly after cardiac surgery [1].

Arrhythmias in children can cause severe clinical issues, affecting their general health and quality of life. In Saudi Arabia, pediatric arrhythmias are managed using both pharmaceutical and non-pharmacological therapy. Pharmacological treatments largely include beta-blockers, calcium channel blockers, digoxin, and amiodarone, which are selected based on the kind of arrhythmia and the patient's clinical status. Non-pharmacological treatments include electrophysiological tests, catheter ablation, and pacemaker installation, which are required for certain arrhythmias, particularly in situations of structural cardiac disease or post-operative problems [2-4].

This research emphasizes the necessity of a complete approach that incorporates both therapy modalities to

Correspondence to: Mohammed K. Dakhel
*Ministry of Health, Qassim Health Cluster, Buraydah, Saudi Arabia.
Email: mkdakhel@moh.gov.sa
Full list of author information is available at the end of the article.
Received: 31 July 2024 | **Accepted:** 13 November 2024

improve outcomes for pediatric arrhythmia patients in Saudi Arabia.

Subjects and Methods

Search strategy

A comprehensive literature search was conducted across electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search was limited to studies published in English from January 2000 to July 2024. Search terms included combinations of keywords such as "pediatric arrhythmias," "management," "pharmacological approaches," "non-pharmacological approaches," and "Saudi Arabia." Boolean operators (AND, OR) and Medical Subject Headings (MeSH) terms were applied to refine the search strategy.

Eligibility criteria

Studies were included if they:

- Focused on pediatric patients with arrhythmias.
- Discussed management strategies, either pharmacological (e.g., beta-blockers, calcium channel blockers) or non-pharmacological (e.g., electrophysiological studies, catheter ablation).
- Were conducted in Saudi Arabia or included data relevant to the Saudi pediatric population.
- Were original research articles, systematic reviews, or clinical guidelines.

Studies were excluded if they:

- Addressed adult patients only.
- Were case reports, conference abstracts, or opinion pieces.
- Did not provide sufficient detail on the methodology or management outcomes.

Study selection

The initial search identified 900 articles. After the removal of duplicates (350 articles), 550 unique articles were screened based on titles and abstracts. Of these, 50 full-text articles were reviewed for eligibility, and 30 studies were included in the final analysis.

Data extraction and analysis

Data extraction was performed using a standardized template that included details on study design, population characteristics, types of arrhythmias, management approaches, and outcomes. The findings were synthesized qualitatively to provide a comprehensive overview of management trends and challenges.

Discussion

Pharmacological therapy

Pharmacological therapies are essential in the management of pediatric arrhythmias. The type of arrhythmia and its underlying cause are frequently used to determine the appropriate medicine. Commonly used antiarrhythmic medications include Beta-blockers, often prescribed for tachyarrhythmias and can help control heart rate, calcium channel blockers used in cases of SVT, they help to slow down the heart rate, Digoxin can be beneficial in controlling heart rate in certain arrhythmias, particularly in children with heart failure, and Amiodarone, which is used for more severe arrhythmias but requires careful monitoring due to potential side effects. In addition to these, the management of arrhythmias associated with conditions like COVID-19 has been highlighted, where certain pharmacological agents might carry arrhythmogenic risks [2].

Beta-blockers

Beta-blockers are critical in the treatment of arrhythmias in juvenile patients, especially for disorders characterized by high heart rhythms, such as SVT. These drugs function by inhibiting the effects of adrenaline on beta-adrenergic receptors, hence lowering heart rate and improving cardiac rhythm stability. Beta-blockers, such as propranolol and metoprolol, are widely used in children to treat arrhythmias. Beta-blockers reduce heart rate by reducing the action of adrenaline, slowing electrical impulses in the heart, which is especially beneficial in tachyarrhythmias. They can assist in stabilizing heart function in people with structural heart abnormalities or those recovering from cardiac surgery.

Beta-blockers are indicated for various types of arrhythmias in children, including SVT, Ventricular Arrhythmias, and Long QT Syndrome (LQTS). Propranolol is often the first-line treatment for uncomplicated SVT in infants and children. Studies have shown that it effectively suppresses arrhythmias with a good safety profile, even at higher doses [3,4]. In cases of catecholamine-sensitive ventricular arrhythmias, beta-blockers can be effective in controlling episodes. Propranolol is also used in managing LQTS to prevent life-threatening arrhythmias [2].

The dosing of beta-blockers in pediatric patients varies based on the specific drug and the child's weight. The typical dosage for propranolol ranges from 1 to 4 mg/kg per day, divided into multiple doses. It is well-tolerated and can be adjusted based on the child's response and growth [3,5]. Metoprolol is often dosed at 0.5 to 1 mg/kg per day for long-term management, it is favored for its selective action and lower side effect profile compared to non-selective beta-blockers [5].

While generally well-tolerated, beta-blockers can cause side effects. Bradycardia, a slower-than-normal heart rate, which might require monitoring and dosage adjustments. Hypotension and low blood pressure, particularly in patients with other underlying health conditions. Some children might experience mood changes or fatigue, necessitating careful monitoring by healthcare providers [2,3].

Calcium chaneel blockers (CCBs)

CCBs are critical in the treatment of pediatric arrhythmias, especially SVT. These drugs function by blocking the inflow of calcium ions into cardiac and smooth muscle cells, hence affecting electrical conduction and contractility.

CCBs, like verapamil and diltiazem, work largely by inhibiting calcium channels in the heart. This action reduces the force of cardiac contractions and lowers the heart rate by decreasing conduction through the AV node. CCBs are particularly useful in controlling tachyarrhythmias caused by reentry circuits that use the AV node because they reduce conduction velocity and stabilize the heart's rhythm [6,7].

CCBs are recommended for a variety of arrhythmias in children, including SVT, atrial fibrillation and flutter, and hypertrophic cardiomyopathy (HCM). Verapamil is frequently used for acute management of SVT, effectively controlling heart rate and rhythm. CCBs can help manage ventricular rates during episodes of atrial fibrillation or flutter. In children with HCM, non-dihydropyridine CCBs like verapamil can alleviate symptoms by reducing outflow obstruction and improving exercise tolerance [5,7,8].

The dosing of CCBs in pediatric patients should be individualized based on age, weight, and the specific arrhythmia being treated. Verapamil is typically administered in sustained-release formulations, the usual dosage ranges from 0.1 to 0.3 mg/kg per dose, given every 6 to 8 hours, not exceeding 10 mg per dose in children. The dosing for diltiazem is generally 0.2 to 0.5 mg/kg per dose, given every 6 to 8 hours, with careful monitoring for efficacy and side effects [5, 6].

While generally well-tolerated, CCBs can cause side effects. Hypotension is caused due to their vasodilatory effects, CCBs can cause low blood pressure, which requires monitoring. Bradycardia, a slower heart rate might occur, especially when combined with other medications affecting heart rate. Some children experience constipation or other gastrointestinal issues. CCBs should not be used in children under one year of age due to potential hemodynamic impairment and increased risk of adverse effects [5].

Digoxin

Digoxin is a cardiac glycoside that is used to treat pediatric arrhythmias, notably SVT and atrial flutter. Its distinct mechanism of action and specific indications make it an excellent choice in juvenile cardiology.

Digoxin works by inhibiting the Na^+/K^+ ATPase enzyme, increasing intracellular sodium levels. This shift increases calcium inflow through the sodium-calcium exchanger, resulting in increased cardiac contractility (positive inotropic effect) and better ventricular filling. Furthermore, digoxin has vagomimetic properties, which reduce conduction through the AV node, lowering heart rates in tachyarrhythmias including SVT and atrial flutter [5,9]. Digoxin's mix of effects makes it particularly beneficial for treating arrhythmias while also supporting heart function.

Digoxin is indicated for several arrhythmias in pediatric patients, including SVT, atrial flutter, and congestive heart failure. It is commonly used to control ventricular rates during episodes of SVT. Digoxin can help manage ventricular rate control in atrial flutter by slowing conduction through the AV node. While primarily an antiarrhythmic agent, digoxin is also used in children with heart failure, especially those with tachyarrhythmias [10,11].

The dosing of digoxin in pediatric patients is individualized based on factors such as age, weight, and the specific arrhythmia being treated. For rapid digitalization, a loading dose is often administered, which can be approximately four times the maintenance dose. This is usually given in divided doses over 24 hours. The maintenance dose typically ranges from 0.01 to 0.05 mg/kg/day, administered orally or intravenously. The oral bioavailability of digoxin is about 75%, and the drug's half-life can vary significantly, ranging from 18 to 36 hours in children, and longer in infants [5,9,11].

While digoxin is generally effective, it has a narrow therapeutic window and can cause several side effects. Digoxin can paradoxically cause or exacerbate arrhythmias, particularly if serum potassium levels are abnormal. Monitoring potassium levels is crucial during treatment [10,12]. Nausea, vomiting, and diarrhea might also occur. Symptoms such as confusion or visual disturbances (e.g., yellow-green halos) can indicate digoxin toxicity. Due to its vagomimetic effects, bradycardia can occur, particularly in patients with underlying conduction system disease [5,9].

Amiodarone

Amiodarone is a strong antiarrhythmic medicine that is commonly used in pediatric patients to treat a variety of arrhythmias, especially in acute and severe conditions. Its potency and distinct mechanism of action make it an important therapeutic choice in this patient population.

Amiodarone is predominantly a class III antiarrhythmic drug, which implies it extends the action potential duration and refractory time in both atrial and ventricular myocardium. This effect is done by inhibiting potassium channels, which reduces heart rate and stabilizes the cardiac rhythm. Amiodarone also has features of other antiarrhythmics, such as sodium channel blocking and calcium channel inhibition, which contribute to its overall efficacy in treating complicated arrhythmias.

Amiodarone is suggested for many arrhythmias in children, including refractory SVT, which is often used when other treatments have failed. Amiodarone is a key agent in the management of life-threatening ventricular arrhythmias, especially during resuscitation efforts. It

can be utilized for rate control in atrial fibrillation and flutter. JET, particularly in postoperative patients or those with congenital heart disease.

The dosing of amiodarone in pediatric patients varies based on the clinical scenario. For acute situations, an initial loading dose of 5 mg/kg (maximum 300 mg) is administered over 30 minutes to 4 hours, followed by a continuous infusion of 5 to 15 mcg/kg/minute, with a maximum of 25 mcg/kg/minute as needed. The total daily dose should not exceed 1,200 mg. For long-term management, oral amiodarone is typically started at 5 mg/kg/dose twice daily for 10 days, then reduced to a maintenance dose of 5 mg/kg once daily (maximum 200 mg) for children under 12 years. For adolescents over 12, the initial dose might be 200 mg three times a day for 1 week, followed by a tapering schedule [5,13].

While amiodarone is effective, it is associated with several potential side effects. Due to its effects on cardiac conduction, amiodarone can lead to significant bradycardia and conduction disturbances. Long-term use can result in pulmonary fibrosis or pneumonitis. Amiodarone can cause both hyperthyroidism and hypothyroidism due to its iodine content. Liver function tests should be monitored, as amiodarone can lead to hepatotoxicity. Patients might develop corneal deposits, which are usually asymptomatic but can be monitored during follow-up [14].

Non-pharmacological therapy

Non-pharmacological approaches are also essential in managing pediatric arrhythmias. These methods include electrophysiological studies (EPSs), which are used to diagnose the specific type of arrhythmia and can guide treatment decisions. Catheter ablation is a minimally invasive procedure and is effective for certain types of arrhythmias, particularly in older children and adolescents. It involves destroying the small areas of heart tissue that might be causing abnormal electrical signals. In cases of bradycardia or heart block, a pacemaker might be necessary to maintain an adequate heart rate. Furthermore, encouraging a healthy lifestyle, including regular physical activity and a balanced diet, can help manage arrhythmias and prevent their recurrence.

Electrophysiological studies

EPSs are critical diagnostic and therapeutic tools for the treatment of arrhythmias in pediatric patients. These studies provide important insights into the heart's electrical activity, allowing for the exact identification of arrhythmogenic foci and guiding focused therapies.

EPS works by inserting catheters into the heart, recording electrical impulses, and stimulating cardiac tissue. By creating arrhythmia with controlled electrical shocks, physicians can map the heart's conduction pathways and discover faulty electrical circuits that cause arrhythmia. This comprehensive mapping is critical for determining the most successful treatment techniques, such as catheter ablation, which can eradicate the cause of the arrhythmia by destroying the troublesome tissue with radiofrequency radiation or cryotherapy [15,16].

EPS is indicated for various arrhythmias in children. SVT, particularly in cases where medical management has failed or when the arrhythmia is recurrent and symptomatic. Atrial fibrillation and flutter to evaluate the need for potential ablation therapy. Ventricular tachycardia (VT), especially in patients with structural heart disease or those who have experienced syncope. JET is commonly seen in postoperative patients, where EPS can help determine the best management strategy [17,18].

While there is no precise dosing regimen for EPS, the technique often requires anesthesia and anticoagulation (e.g., heparin) to prevent thromboembolic events during catheter manipulation. The techniques' duration can range from 1 to 3 hours, depending on the complexity of the arrhythmia under investigation. If catheter ablation is performed during the EPS, more post-procedural care and monitoring are required to guarantee patient safety [15,17].

Although EPS is generally safe, potential side effects and complications can include cardiac injury, arrhythmias, vascular complications, and infection**.** Rarely, catheter manipulation can cause damage to the heart muscle or valves. The procedure might provoke arrhythmias, necessitating immediate intervention. Access site complications such as hematoma or bleeding can occur. As with any invasive procedure, there is a risk of infection at the catheter insertion site [5,17].

Catheter ablation

Catheter ablation is a minimally invasive method used to treat arrhythmias in young patients. This method uses a thin, flexible wire coupled to electrodes to provide heat or cold energy, destroying aberrant or extra tissue that causes arrhythmia [19].

The doctor begins catheter ablation by stimulating, recording, and mapping the electrical circuitry of the heart. After accurately pinpointing the area to be treated, the doctor utilizes the catheter to deliver energy that either heats or cools the aberrant tissue [19]. This focused method destroys the aberrant electrical circuits that cause arrhythmia and restores normal heart rhythm.

Catheter ablation is often used to treat children with tachycardia, particularly those who do not respond to treatment with medication [19]. Catheter ablation is highly effective in treating SVT, a rapid heartbeat caused by an extra electrical connection in the heart [19,20]. This procedure can be used to treat atrial flutter, a type of arrhythmia characterized by a rapid, irregular heartbeat [15]. In children with structural heart disease or those at risk of sudden cardiac arrest, catheter ablation might be indicated to treat VT [15].

During the procedure, the doctor threads the catheter through an artery or vein in the leg or neck and into the heart, using general anesthesia [19]. The duration of the procedure varies depending on the complexity of the arrhythmia being treated. Following catheter ablation, children usually return home after being monitored for a few hours by pediatric and neonatal cardiac nurses [19].

Catheter ablation is generally safe, with a success rate close to 98%. However, as with any invasive procedure, there are potential side effects. Rarely, catheter manipulation can cause damage to the heart muscle or valves. Access site complications, such as bleeding or hematoma, can occur. There is also a risk of infection at the catheter insertion site [15].

Pacemaker implantation

Pacemaker implantation is a vital treatment option for managing certain arrhythmia in pediatric patients, particularly those with bradycardia or heart block. This procedure involves the surgical placement of a small device that generates electrical impulses to regulate the heart's rhythm.

A pacemaker consists of a pulse generator, which is implanted under the skin, and one or more leads that are threaded through a vein into the heart. The pulse generator produces electrical impulses that are delivered through the leads to the heart muscle, stimulating it to contract and maintain a regular heart rate. Modern pacemakers can adapt the heart rate to the child's activity level, ensuring adequate cardiac output during exercise or stress [16,19].

Pacemaker implantation is indicated for various types of arrhythmias in children. A slow heart rate that is insufficient to meet the body's needs, is often caused by sinus node dysfunction or AV block. A delay or interruption in the electrical signal as it travels from the atria to the ventricles, which can lead to a slow heart rate. Sick sinus syndrome, a condition characterized by an abnormal sinus node function, resulting in alternating periods of bradycardia and tachycardia [16,21].

The dosing and administration of a pacemaker implantation procedure are tailored to the individual patient's needs. The procedure typically involves the following steps. A small incision is made in the chest, usually below the collarbone, to create a pocket for the pacemaker generator. One or more leads are inserted through a vein and guided into the heart using fluoroscopic guidance. The leads are then connected to the pacemaker generator. The pacemaker generator is placed in the pocket created in the chest wall and secured in place. The incision is closed with sutures or surgical glue. Children usually remain in the hospital overnight for observation following the procedure [16,19].

While pacemaker implantation is generally a safe procedure, there are potential side effects and complications. Infection, bleeding or hematoma at the incision site or around the pacemaker generator. A collapsed lung, which can occur if the lung is punctured during lead placement. The lead can become dislodged from its position in the heart, requiring additional procedures to reposition it [16,17,22].

Lifestyle modifications

Lifestyle changes are crucial in the treatment of pediatric arrhythmias. These adjustments can greatly lower the number and severity of arrhythmia events while improving overall cardiovascular health.

Lifestyle adjustments can help arrhythmia by addressing underlying risk factors and improving heart health. For example, a heart-healthy diet can reduce inflammation and improve electrolyte balance, both of which are necessary for keeping a steady heart rhythm. Regular physical exercise strengthens the cardiovascular system and aids weight management, as obesity is a known risk factor for arrhythmia in youngsters. Additionally, stress management approaches such as mindfulness and relaxation exercises can help to reduce stress-induced arrhythmia, which is common in pediatric patients [23].

Lifestyle modifications are indicated for all pediatric patients with arrhythmias, particularly those experiencing SVT, bradycardia, and atrial fibrillation [15]. While lifestyle modifications do not have a specific "dosing" regimen, they should be integrated into daily routines. Adopting a heart-healthy diet rich in fruits, vegetables, whole grains, and lean proteins while reducing sodium, caffeine, and processed foods. A Mediterranean or DASH diet is often recommended to help regulate heart rhythm and reduce the impact of arrhythmia on daily life. Engaging in regular physical activity, such as 30 minutes of moderate exercise most days of the week, tailored to the child's capabilities and preferences. Incorporating relaxation techniques, such as yoga or deep-breathing exercises, into daily life to help manage stress levels [22].

While lifestyle modifications are generally beneficial, potential challenges might include adjusting to a new diet, which might be difficult for some children, and there might be initial resistance to changes in eating habits. Overexertion during physical activity can lead to fatigue or exacerbating symptoms in some children, particularly those with existing heart conditions. Implementing new stress management techniques might require time and patience, and not all methods might resonate with every child [23,24].

Postoperative considerations

Postoperative arrhythmias are a common consequence of juvenile heart surgery. A study conducted at King Abdulaziz University Hospital discovered that 17.1% of pediatric patients experienced arrhythmias during surgery, with JET being the most common. Significant risk factors were discovered, including extended cardiac bypass and electrolyte abnormalities. This emphasizes the need for vigilant monitoring and personalized therapy approaches in the postoperative environment [1].

Conclusion

Arrhythmia therapy in Saudi Arabia's juvenile population necessitates a diverse approach that incorporates both pharmaceutical and nonpharmacological therapies. Understanding the distinct characteristics of pediatric arrhythmias, including the effects of congenital disorders and surgical treatments, is critical for optimal treatment. Ongoing research and clinical practice changes are required to improve outcomes for children with arrhythmias in this region. More research is needed to assess the long-term consequences of various treatment options for juvenile arrhythmias in Saudi Arabia. Furthermore, developing national recommendations specific to the pediatric population has the potential to standardize care and enhance patient outcomes across the country.

List of Abbreviations

AV	Atrioventricular
CCBs	Calcium chaneel blockers
COVID-19	Coronavirus disease 2019
DASH deit	Dietary approaches to stop hypertension (DASH) diet.
EPSs	Electrophysiological studies
HCM	Hypertrophic cardiomyopathy
JET	Junctional ectopic tachycardia
LQTS	Long QT Syndrome
SVT	Supraventricular tachycardia
VT	Ventricular tachycardia

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

None.

Consent to participate

Not required.

Ethical approval

Not applicable.

Author details

Abdullah K. Dakhel[1], Nasser A. Alsharekh[2], Fahad A. Alqeaid[2], Abdulrahman F. Alkholaif[2], Sultan H. Alharbi[3], Meshal N. Alzaydi[4], Abdullah F. Alkholaif[4], Alwaleed K. Alabdali[5], Mohammed K. Dakhel[2]

1. Prince Sultan Bin Abdulaziz Cardiac Center, Qassim Health Cluster, Ministry of Health, Riyadh, Saudi Arabia
2. Ministry of Health, Qassim Health Cluster, Buraydah, Saudi Arabia
3. Pharmacist, Nahdi Medical Company, Almurjan, Saudi Arabia
4. Medical Student, Qassim University, Buraydah, Saudi Arabia
5. Senior Medical Student, Fakeeh College for Medical Sciences, Jeddah, Saudi Arabia

Reference

1. Alotaibi RK, Saleem AS, Alsharef FF, Alnemer ZA, Saber YM, Abdelmohsen GA, et al. Risk factors of early postoperative cardiac arrhythmia after pediatric cardiac surgery. Saudi Med J. 2022;43(10):1111–9. https://doi.org/10.15537/smj.2022.43.10.20220275
2. AlShoaibi NA, Maghrabi K, Alanazi H, Harbi MA, Alghamdi S. Saudi heart rhythm society task force on management of potential arrhythmogenicity associated with pharmacotherapy for COVID-19. Ann Saudi Med. 2020t;40(5):365–72. https://doi.org/10.5144/0256-4947.2020.365
3. Iyer VR. Drug therapy considerations in arrhythmias in children. Indian Pacing Electrophysiol J. 2008;8(3):202–10. https://pmc.ncbi.nlm.nih.gov/articles/PMC2490802/
4. Riggs TW, Byrd JA, Weinhouse E. Recurrence risk of supraventricular tachycardia in pediatric patients. Cardiology. 1999;91(1):25–33. https://doi.org/10.1159/000006873
5. Oeffl N, Schober L, Faudon P, Schweintzger S, Manninger M, Köstenberger M, et al. Antiarrhythmic drug dosing in children - review of the literature. Children. 2023;10(5):847. https://doi.org/10.3390/children10050847
6. NYU Langone Health. Medication for arrhythmias in children. New York, NY: NYU Langone Health [cited 2024 Jun 26]. Available from: https://nyulangone.org/conditions/arrhythmias-in-children/treatments/medication-for-arrhythmias-in-children
7. Lipshultz SE, Orav EJ, Wilkinson JD, Towbin JA, Messere JE, Lowe AM, et al. Risk stratification at diagnosis for children with hypertrophic cardiomyopathy: an analysis of data from the pediatric cardiomyopathy registry. Lancet. 2013;382(9908):1889–97. Available from: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(13)61685-2/abstract
8. Bartlett JW, Walker PL. Management of calcium channel blocker toxicity in the pediatric patient. J Pediatr Pharmacol Ther. 2019;24(5):378–89. https://doi.org/10.5863/1551-6776-24.5.378
9. Abdel Jalil MH, Abdullah N, Alsous MM, Saleh M, Abu-Hammour K. A systematic review of population pharmacokinetic analyses of digoxin in the pediatric population. Br J Clin Pharmacol. 2020;86(7):1267–80. https://doi.org/10.1111/bcp.14272
10. Knollmann BC, Roden DM. Antiarrhythmic drugs. In: Brunton LL, Hilal-Dandan R, Knollmann BC, editors. Goodman & Gilman's the pharmacological basis of therapeutics. 13th ed. New York, NY: McGraw-Hill; 2018. pp 547–72. Available from: https://accesspharmacy.mhmedical.com/Content.aspx?bookid=2189&sectionid=170271275
11. Jain S, Vaidyanathan B. Digoxin in management of heart failure in children: should it be continued or relegated to the history books? Ann Pediatr Cardiol. 2009;2(2):149–52. https://doi.org/10.4103/0974-2069.58317
12. Withering W. An account of the Foxglove and some of its medical uses, with practical remarks on dropsy and other

diseases. New York, NY: Dover Publications; 1941. Available from: https://cir.nii.ac.jp/crid/1130282271394102144

13. Carson D, editor. Medicines for children. 2nd ed. London, UK: Royal College of Paediatrics and Child Health and the Neonatal and Paediatric Pharmacists Group; 2003.
14. American Heart Association. American Heart Association 2005 guidelines for cardiopulmonary resuscitation and emergency cardiovascular care of pediatric and neonatal patients: pediatric basic life support. Circulation. 2005;112(24):195–203. https://doi.org/10.1542/peds.2006-0219
15. Hanash CR, Crosson JE. Emergency diagnosis and management of pediatric arrhythmias. J Emerg Trauma Shock. 2010;3(3):251–60. https://doi.org/10.4103/0974-2700.66525
16. American Heart Association. Treating arrhythmias in children. Dallas, TX: American Heart Association. Available from: https://www.heart.org/en/health-topics/arrhythmia/prevention--treatment-of-arrhythmia/treating-arrhythmias-in-children
17. Children's Health. What are pediatric arrhythmias? 2024. Dallas, TX: Children's Health [cited 2024 Jun]. Available from: https://www.childrens.com/specialties-services/conditions/pediatric-arrhythmias
18. Lee DC, Greene T, Dougherty T, Pearigen P. Fatal nifedipine ingestions in children. J Emerg Med. 2000;19(4):359–61. https://doi.org/10.1016/S0736-4679(00)00266-3
19. Aggarwal N, Kupfer Y, Senevirantne C, Tessler S. Methylene blue reverses recalcitrant shock in beta-blocker and calcium channel blocker overdose. BMJ Case Rep. 2013;2013:bcr2012007402. https://doi.org/10.1136/bcr-2012-007402
20. Saul JP, Scott WA, Brown S, Marantz P, Acevedo V, Etheridge SP, et al. Intravenous amiodarone for incessant tachyarrhythmias in children: a randomized, double-blind, antiarrhythmic drug trial. Circulation. 2005;112:3470–7. https://doi.org/10.1161/CIRCULATIONAHA.105.534149
21. Pediatric Heart Specialists. Arrhythmia diagnosis & treatment for children. Dallas, TX: Pediatric Heart Specialists [cited 2024 Jun]. Available from: https://pediatricheartspecialists.com/heart-education/blog/204-arrhythmia-diagnosis-treatment-for-children
22. Children's National. Pediatric arrhythmia. Washington, DC: Children's Vational [cited 2024 Jun 26]. Available from: https://www.childrensnational.org/get-care/health-library/arrhythmia
23. Sekar RP. Epidemiology of arrhythmias in children. Indian Pacing Electrophysiol J. 2008 May;8(Suppl 1):S8–S13.
24. Premkumar S, Sundararajan P, Sangaralingam T. Clinical profile of cardiac arrhythmias in children attending the outpatient department of a tertiary pediatric care center in Chennai. J Clin Diagn Res. 2016 Dec;10(12):SC06–8. https://doi.org/10.7860/JCDR/2016/21751.8992