Original Article

http://journals.sbmu.ac.ir/jpn
https://doi.org/10.22037/jpn.v8i4.31621

Diagnosis and Management of Common Arrhythmias in Pediatric Chronic Kidney Disease; A Review

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Abstract

Cardiovascular disease (CVD) was recognized as a major cause of mortality and morbidity in adults with chronic kidney disease (CKD). Recent data indicate that cardiac complications are already present in children with advanced CKD. The main risk factors associated with cardiovascular mortality in adults include Coronary artery disease, left ventricular hypertrophy. Little is known regarding the specific risk factors for developing CVD morbidity and mortality in children. Based on recent reports, arrhythmia and cardiac arrest followed by cardiomyopathy and congestive heart failure were the leading causes of cardiac death in this pediatric population. This review summarizes the current literature on causes and pathophysiologic mechanisms of arrhythmias in the pediatric population with CKD, as the most common and life-threatening cardiac events. Herein, we focused our discussion on prompt diagnosis and management of common arrhythmias in children with CKD.

Keywords: Arrhythmia; Cardiac disease; Chronic kidney disease; Pediatric.

Conflict of interest: The author declares no conflict of interest.
Please cite this article as: Isa Tafreshi, R. Diagnosis and Management of Common Arrhythmias in Pediatric Chronic Kidney Disease; A Review. J Ped Nephrol 2020;8(4):1-11. https://doi.org/10.22037/jpn.v8i4.31621

Received: July, 2020
Revised: August, 2020
Accepted: August, 2020

Introduction

Although the life span of the patients with chronic kidney disease (CKD) has increased by using new supportive care, the survival of the children remains lower than that of age-matched population. A risk 1000 times higher was estimated in the pediatric CKD compared with the age-matched non-CKD population (1).

Cardiovascular disease (CVD) is a significant cause of mortality and morbidity in adult patients with CKD (2, 3). Coronary artery disease and left ventricular hypertrophy (LVH) are common cardiovascular-related conditions in adults. (4-6) However, there is little information regarding the main CVD associated morbidity or mortality in children with CKD. It has been identified that the main causes of cardiac death are slightly different in children compared with those in adults (7, 8). As CKD is an uncommon disease in childhood, it is often difficult to fully determine predicting factors of cardiovascular complications. However, the American Heart Association's guidelines for cardiovascular risk reduction in high-risk pediatric patients classified children with CKD in the highest risk group for the development of CVD (9). Previous studies indicated that over the last decade, CVD was one of the most common causes of death in children on chronic dialysis and also in patients with kidney transplantation (10, 11). Clinical studies showed that cardiovascular abnormalities begin early in the course of renal impairment in children and rapidly progress when dialysis is initiated (12). CVD in this population arises from a combination of traditional (e.g. dyslipidemia, diabetes, etc) and CKD-related risk factors (e.g. increased calcium-phosphorus product, electrolyte imbalances, anemia) (12). Moreover, previous studies have revealed that cardiac morbidity is caused by myocardial disease, arrhythmogenic drugs, and hemodynamic changes during hemodialysis (12, 13). Appropriate control of these risk factors could improve the survival of the patients. Based on recently published data, arrhythmias and the cardiac arrest followed by

cardiomyopathy and congestive heart failure were the leading causes of cardiac death in this group (10, 11). But, the prevalence of arrhythmias, including the subset that is clinically more significant and the preventable events during dialysis, is not yet recognized completely.

This report provides a brief overview of the current literature on the causes and pathophysiologic mechanisms of arrhythmias as the most common and serious cardiovascular complications in children with CKD. Herein, we focused our discussion on the clinical approach and prompt management of common arrhythmias in children with CKD.

Risk factors for cardiac death

Nearly all of the cardiovascular abnormalities that occur in adults with CKD are also present in children (14). The most important difference between the two groups is the lower prevalence of classic atherosclerosis risk factors in the pediatric population. Recent studies have shown that several modifiable risk factors, including hyperphosphatemia, hyperparathyroidism, anemia, and hypertension, independently predict the presence of cardiovascular anomalies in patients with CKD (15). Based on recent reports, endothelial dysfunction is an early component of cardiovascular remodeling, appears early in the course of renal failure. Moreover, arterial stiffening is commonly found in older patients and is associated with classic risk factors for atherosclerosis, such as diabetes mellitus, high cholesterol levels, and inflammation (16, 17). On the other hand, diffuse arterial stiffening is more often due to medial calcification and is strongly associated with long term uremia and high serum phosphate levels (18). Furthermore, the common risk factors such as LVH, myocardial dysfunction and hypertension have been described for progressive cardiovascular mortality and morbidity (3, 5, 6). LVH is the most common cardiac abnormality in children with CKD, and it occurs even during the early stages of renal failure (19). Myocardial hypertrophy initially causes diastolic dysfunction, systolic dysfunction and heart failure may occur subsequently. Furthermore, hypertrophic changes of the myocardium may influence the conduction system and promote significant rhythm disturbances (14, 20, 21). In the preexisting diseased myocardium, mainly in patients on chronic dialysis, electrolyte imbalances become an important trigger for the occurrence of transient or sustained ventricular arrhythmia (13, 21). It has been shown that the imbalance between intracellular and extracellular concentration of potassium, calcium, and magnesium was able to induce arrhythmia. Hyperkalemia is observed frequently in CKD patients and is associated with progressive ECG abnormalities and final idioventricular rhythm. Also, hyperkalemia in combination with hypocalcemia and hyperphosphatemia may promote reentrant tachycardia (22).

In summary, data from recent studies show that multiple pathophysiologic mechanisms for cardiac damages are present, to some extent, in children with CKD.

Sudden cardiac death

Previous studies have been indicated the high incidence of cardiac arrest in the children on chronic dialysis. Also, sudden cardiac death (SCD) was observed more commonly in the early childhood (10). The mechanism of this high rate of SCD in infants and children is poorly understood. In adults, the pre-existing atherosclerotic disease has been known as a basic mechanism for developing myocardial ischemia and subsequent rhythm disturbances (23, 24). Similarly, a serious arrhythmia is the probable cause of SCD in infants and children (24, 25). It is believed that the origin of this final event in children is hypertrophic or dilated cardiomyopathies. As reported previously, the structural abnormalities in cardiomyopathies were associated with electrical instability that may initiate any type of benign or malignant dysrhythmias (23, 25). Otherwise, the possible role of myocardial hypertrophy for increasing SCD in children is not fully recognized. Besides, acute and significant changes in cardiac extra and intracellular ionic concentrations are another possibility for developing SCD. (13, 26) These roles may be more pronounced during the days between dialysis. It has been observed that the patients after kidney transplantation have a lower risk of SCD than dialysis patients. However, the cardiac mortality rate in transplanted patients was still higher than the normal population (26).

Rhythm disturbances

In the study of Chavers et al., in a large population of pediatric CKD patients, arrhythmias were the

most common cardiac event. Its incidence was higher in children receiving dialysis. Using 24-hours Holter ECG monitoring, they have reported a high incidence of sinus tachycardia, atrial or ventricular ectopic beats, and atrioventricular block in CKD pediatric population. Also, they reported an increased incidence of arrhythmia and cardiomyopathy in patients on chronic dialysis and also during adolescence age (10). Likewise, Rantanen et al. have identified more frequent attacks of tachyarrhythmia in adults during dialysis and the immediate post dialysis period. Clinically significant arrhythmias included persistent atrial fibrillation, nonsustained ventricular tachycardia, and bradycardia (26). Also, premature ventricular complexes were more common during dialysis (26, 28).

It has been shown that the main mechanism for developing arrhythmia and SCD is the high susceptibility of diseased myocardium to abnormal conduction that is more pronounced by additional triggers (25-28). Previous studies have been demonstrated that LVH and structural heart disease are associated with the development of fatal cardiac dysrhythmias. LVH is common in patients with ESRD and could consider as the main cause of reducing coronary blood flow and an increase in oxygen consumption of the myocardium (23, 29). This imbalance can subsequently lead to ischemia and electrical instability. Recent studies have been shown a significant association between atherosclerotic risk factors and also coronary artery disease with an increased risk of serious arrhythmia (13, 24).

Furthermore, dialysis-related factors are important leading causes of arrhythmia development. Significant changes in serum electrolytes concentration, sympathetic over activity in addition to fluid and blood pressure changes are occurred during and after dialysis. All of these conditions have been found to be triggered serious dysrhythmia (23-26).

ECG changes are used for evaluating patients at risk for fatal arrhythmias. Heart rate variability, prolonged QT interval, and ischemic changes in ECG are considered as important markers for cardiac mortality (26, 27). Bosch et al. reported a higher prevalence of prolonged QT interval in patients on hemodialysis that those with peritoneal dialysis (29).

As reported by Malik et al., the CKD patients with prolonged QTc interval have particularly increased risk of lethal cardiac events (30).

Common tachycardia in pediatric patients with CKD

Recent studies have revealed that the sinus tachycardia followed by atrial or ventricular dysrhythmias are common in the pediatric population with CKD. Generally, the most rhythm disturbances in this age group are benign and well-tolerated (10, 13, 22). The majority of the patients presenting with tachycardia have a febrile illness, dehydration, or anxiety. Clinical presentation is dependent upon age. The most common symptoms include palpitations, chest pain, abdominal pain in children or irritability, lethargy, and poor feeding in infants. History of structural heart disease or a family history of sudden death significantly increases the likelihood of serious atrial and ventricular arrhythmias. Cardiac arrhythmias become an emergent condition when they produce hemodynamic deterioration.

Supraventricular tachycardia (SVT) is defined as an abnormally rapid heart rhythm originating above the ventricles, often with a narrow QRS complex (31). The most common form of SVT in children is reentrant tachycardia. Other forms of SVT include atrial tachycardia, junctional tachycardia, atrial flutter, and atrial fibrillation. But, the term of "SVT" often refers to tachycardia when the mechanism is atrioventricular or atrioventricular node reentry. Wide QRS tachycardia including ventricular tachycardia (VT) is rare in childhood and is most commonly associated with structural heart disease, metabolic disturbances, and severe systemic diseases. Based on previous studies, using 24-hours ECG Holter monitoring, sinus tachycardia and supraventricular/ ventricular tachyarrhythmia were common in children with CKD (10, 27, 28).

A. Narrow QRS Tachycardia

A.1. Sinus Tachycardia

Sinus Tachycardia is characterized by an increase in the rate of electrical impulses arising from the sinoatrial node. Normal sinus rhythm is considered in infants with the heart rate usually between 110 and 160 bpm, with gradual slowing over the pediatric ages. The normal sinus P wave demonstrates an upright P wave in leads I, II and aVF, and a negative P wave in lead aVR. Sinus

tachycardia generally involves a regular rhythm with a P wave before all QRS complexes. Sinus tachycardia rates can exceed 180 bpm in infants but are usually less than 200 to 210 bpm (Figure 1).
The most common cause of sinus tachycardia is a normal response to stress or exercise. However, in a child with tachycardia, the important etiologies to consider would be heart failure, fever, anemia, volume depletion/shock, severe infectious disease, hyperthyroidism, hypoxia, or ingestions of stimulants (eg; caffeine, salbutamol, amphetamines). Prolonged sinus tachycardia is an important finding because of its reducing effect on cardiac output by shortening ventricular filling time in addition to increased myocardial oxygen consumption (10).

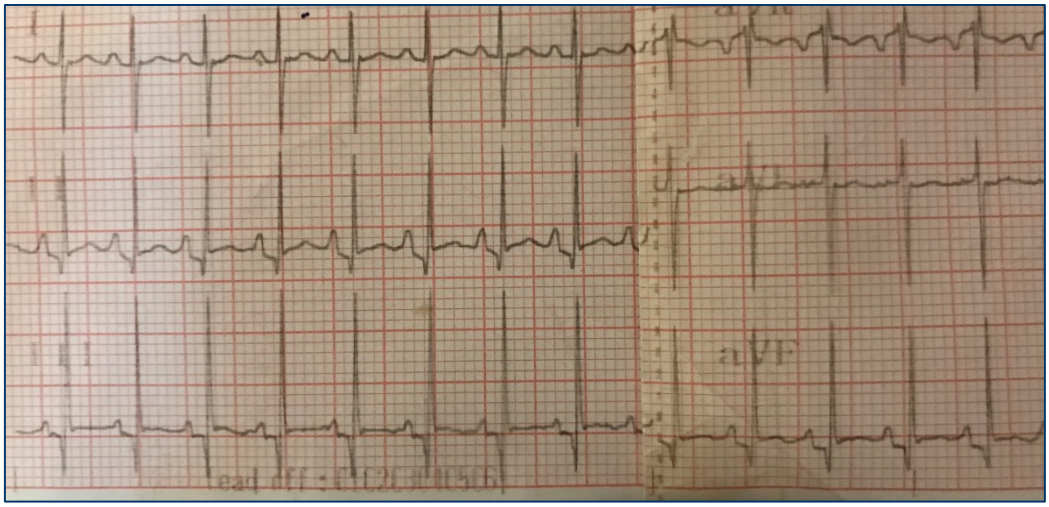

Figure 1. Sinus tachycardia

Side effects of long time tachycardia become more prominent in the presence of pre-existing myocardial disease or LVH. Also, the presence of electrolyte imbalances in conjunction with lower left ventricular compliance of the diseased myocardium can be induced significant hemodynamic instability associated with tachycardia (29).
Treatment is primarily aimed at the underlying disorder.

A.2. Supraventricular Tachycardia

These are the most common tachycardia seen in children (31, 32).
Three mechanisms of tachycardia have been described. In the most common, re-entry tachycardia, the circuit can originate within the atrium producing atrial flutter or fibrillation, the circuit at the level of the atrioventricular node [AV node reentry tachycardia (AVNRT)], or the circuit via an accessory pathway between the atrium and the ventricle [AV re-entry tachycardia (AVRT)].
Sinus tachycardia can be differentiated from SVT by the presence of a normal sinus wave preceding every QRS complex.

A.2.1. Atrioventricular Reentry Tachycardia (AVRT)

Atrioventricular Reentry Tachycardia (orthodromic reciprocating tachycardia) is the most common type of SVT seen in children, representing 80% of arrhythmias occurring during infancy (33, 34). AVRT involves two separate pathways between the atria and ventricles. AV node and accessory pathway, which create an electrical reentry circuit proceeding down the AV node and then up an accessory pathway outside the AV node creating a narrow QRS complex tachycardia. The antidromic tachycardia reverses the direction of conduction, with the transmission down the accessory pathway and up the AV node, creating a widened QRS complex. After termination of tachycardia, 50% of patients manifest a Pre-excitation pattern. Pre-excitation refers to early activation of the ventricles due to impulses, bypassing the AV node, via an abnormal conductive cardiac tissue (accessory pathway) between the atrium and ventricles. The main ECG findings of pre-excitation include shortening of the PR interval and a delta wave, consistent with Wolf-Parkinson-White syndrome

(WPW). The remainder of patients has a "concealed" pathway that is not evident during sinus rhythm. The WPW pattern is estimated to occur in 0.1 to 0.25 percent of the general population, though it may be less frequent in young children. Most asymptomatic patients with the WPW pattern on ECG remain asymptomatic. However, there is a risk of symptomatic arrhythmia, including sudden death (34, 35).

A.2.2. Atrioventricular Node Reentry Tachycardia (AVNRT)

This is also due to a re-entry circuit but with two pathways within the AV node, those are designated fast and slow. The fast pathway has a short conduction time but a long refractory period. In this tachycardia, a "slow" pathway usually conducts antegrade, and the fast pathway usually conducts retrogradely. This accounts for 15% of SVT in the pediatric age group, increases with age, and is rarely seen in infants (35).

Clinical features:

SVT is usually paroxysmal and characterized by abrupt onset and termination. Most SVT episodes occur at rest and without any predisposing factors, although exercise, fever, or stress can be a trigger in some patients. The duration of attacks varies from only one minute to several hours. Persistent SVT can occur in infants, in whom tachycardia can go unrecognized, resulting in gradual cardiovascular deterioration. Orthodromic AVRT and AVNRT together account for > 80 percent of SVTs in childhood.

These two types of tachycardia are often clinically indistinguishable, typically have a narrow QRS complex, and also have similar rates. Signs and symptoms of SVT vary according to the age of patients:

Infant: lethargy, irritability, pallor, poor feeding, and cyanosis. The symptoms can be subtle, and tachycardia may go unrecognized for long periods.

Children and adolescents: palpitation, dizziness, chest pain, lightheadedness, and syncope. Syncope is less common and may be a warning sign for increased risk of sudden death (34).

ECG findings:

- Heart rates during SVT are age-dependent. Infants: 220 to 280 bpm. Children and adolescents: 180 to 240 bpm (Figure 2);
- Regular rhythm (no variation in the RR interval) In most cases;
- The QRS complex is narrow (<80 msec); (An exception is antidromic atrioventricular reentrant tachycardia (AVRT), which is associated with a wide complex tachycardia);
- Atrioventricular ratio 1:1.

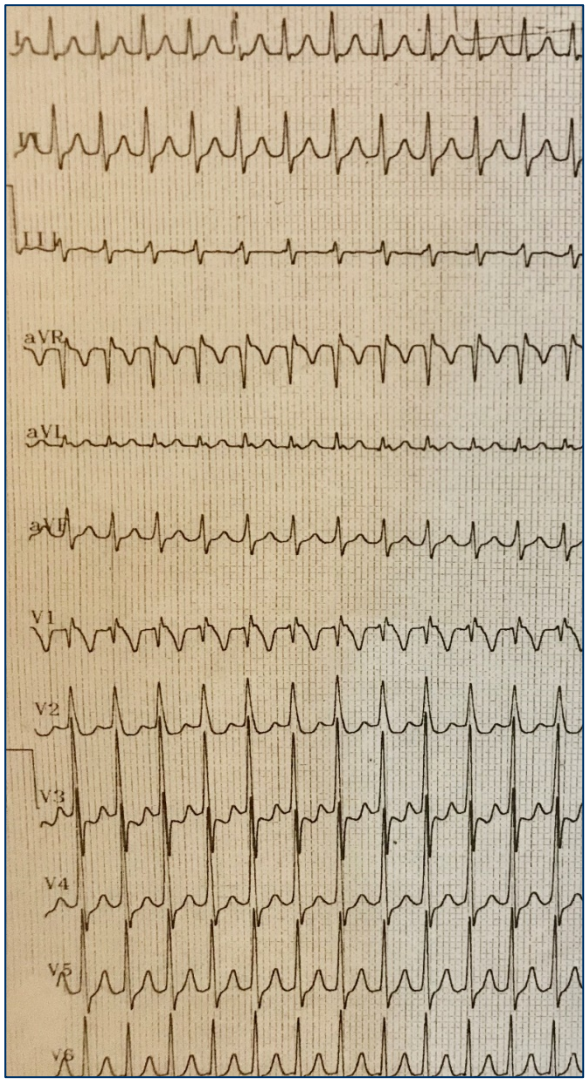

Figure 2. Supraventricular tachycardia.

ECG in sinus rhythm– In sinus rhythm, patients with WPW syndrome exhibit pre-excitation with a characteristic delta wave, widening of the QRS, and short PR interval (Figure 3). The ECG in sinus rhythm is normal in patients with concealed accessory pathways or AVNRT.

Acute Management:

An infant or child who presents with a tachyarrhythmia should have an immediate

hemodynamic assessment for signs of hemodynamic instability including hypotension, heart failure, or decreased level of consciousness. The patients with compensated heart failure or those with pre-existing myocardial disease secondary to chronic renal failure have a significant risk for rapidly progressive hemodynamic disturbances. Also, continuous ECG monitoring during therapeutic maneuvers provide an understanding of the basic mechanisms of tachycardia. Unstable patients require immediate intervention to terminate the rhythm (31-33).

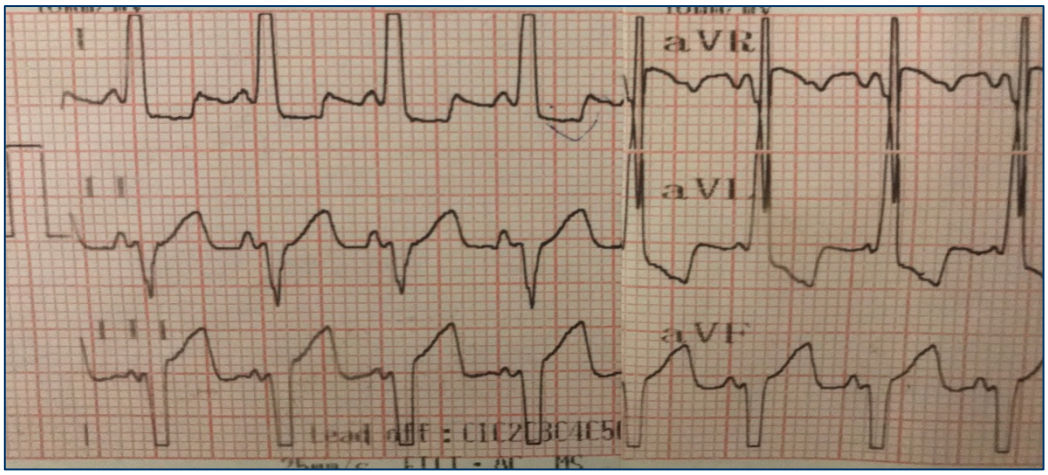

Figure 3. Wolff-Parkinson-White (WPW) syndrome.

Hemodynamically unstable conditions:

Cardioversion is the definitive intervention in unstable patients with hemodynamic compromise. The child should be given adequate analgesia and sedation before cardioversion. Direct-current cardioversion is performed using an energy dose of 0.5 to 1 J/kg, which can be increased to 2 J/kg if the lower dose is ineffective**.** The synchronous mode should be selected for the management of a narrow complex tachycardia (3).

Hemodynamically stable conditions:

Attempt vagal maneuvers to terminate the tachyarrhythmia. Vagal maneuvers are usually successful (31-34).

- In infant: application of a bag filled with ice and cold water over the face for 15 to 30 seconds.
- In older children: bearing down (Valsalva maneuver), blowing into an occluded straw, or assuming a head-down position for 15 to 20 seconds. Carotid massage and orbital pressure should not be performed in children.
- If the vagal maneuvers were not effective, adenosine is given. Adenosine acts on both of the SA node and AV node. This interrupts the reentrant circuit of tachycardia that requires the AV node for reentry (12). The usual initial dose is 0.1 mg/kg IV (maximum dose of 6 mg). Adenosine should be administered by rapid IV injection at a site as close to the central circulation as possible followed immediately by a 5 mL normal saline flush.

The patient should have continuous ECG and blood pressure monitoring. If no response is seen within two minutes, the dose should be doubled (0.2 mg/kg IV). The maximum dose is 12 mg.

- For refractory SVT to adenosine: Synchronized DC cardioversion, starting at 0.5 J/kg. The drug of choices for IV antiarrhythmic therapy includes procainamide and amiodarone.

Work-up:

1-All patients under 1 year of age and those with unstable SVT should be admitted for observation.

2- A Cardiology follow-up is recommended for all new patients.

3- Initiation of maintenance therapy would depend on patient age and severity of symptoms and recurrence.

Prophylactic medical therapy is recommended for infants and young children <15 kg who have frequent episodes of SVT or who become symptomatic during infrequent episodes. In children who are ≥15 kg, radiofrequency ablation (RFA) rather than chronic antiarrhythmic medication therapy is suggested. RFA is an effective treatment

for most types of SVT, and it avoids the adverse effects of chronic pharmacologic therapy (33, 34).

Prognosis:

Sudden death is uncommon in patients with SVT who have structurally normal hearts. Ventricular fibrillation (VF) can be the first manifestation of WPW syndrome, though this is uncommon (35).

Maintenance therapy includes the use of beta-blockers, flecainide, sotalol, or amiodarone in cases of recurrent or prolonged tachycardia. Digoxin and calcium channel blockers should not be prescribed in patients with WPW. Pro-arryhthmogenic effect of drugs in the presence of acid- base and electrolytes imbalances should be considered in the patients with CKD.

The probability of complete resolution of SVT is dependent on the age of onset. Catheter ablation allows for definitive therapy for SVT beyond the toddler years.

A.2.3. Atrial Tachycardia

Atrial tachyarrhythmia is a subgroup of supraventricular tachycardia that arises from the atrium and atrioventricular node. The tachyarrhythmia mechanism is defined as macro re-entry, micro reentry, enhanced automaticity, and triggered. Atrial fibrillation and atrial flutter, although fulfilling this definition, are usually not included in the designation of atrial tachyarrhythmia. Atrial tachyarrhythmia is most commonly seen in children with congenital heart disease and may result in significant morbidity. Ectopic atrial tachycardia is one of the most common types of atrial tachycardia.

a. Ectopic Atrial Tachycardia

Ectopic atrial tachycardia is due to enhanced automaticity of single or multiple foci outside the sinus node and is often refractory to medical therapy and cardioversion. It is the most common cause of tachycardia-induced cardiomyopathy because of its chronic nature. Clinical presentation depends on the extent of cardiac dysfunction, with most patients presenting with minor symptoms in the setting of preserved function (34).

Clinical features:

Infants may present with feeding difficulties, sweating, or respiratory distress. Older children may present with exercise intolerance, chest pain, palpitations, pre-syncope.

ECG findings:

- Atrial rate that is inappropriately rapid for age;
- Usually abnormal P wave morphology and axis.

Management:

- Asymptomatic patients can be treated conservatively.
- Beta-blockers can be useful by slowing AV node conduction and improving symptoms. More aggressive treatment consists of flecainide, amiodarone, or sotalol.
- Patients who fail medical therapy can undergo catheter ablation.

b. Atrial Flutter

It is most common in children who have undergone cardiac surgery. Atrial flutter involves a single macro reentry circuit around the boarders of the tricuspid valve. This arrhythmia usually has a 2:1 atrioventricular conduction relationship. It manifests as a saw tooth pattern on ECG. The severity of hemodynamic deterioration is determined by the duration of arrhythmia and the degree of AV block. The most significant instability was observed in patients with a rapid ventricular response (34).

Clinical features

- Infants may present with nonspecific signs of heart failure including, irritability, lethargy, poor feeding, diaphoresis, and pallor;
- Older children may complain of palpitations, chest pain, nausea, vomiting, and dizziness.

ECG findings:

- Usually has a 2:1 atrioventricular (AV) conduction relationship resulting in Regular atrial rates of 240–360 bpm and ventricular rate 120–240bpm;
- Typical saw tooth pattern may be seen in lead II, III and aVF;
- Variable but generally regular AV conduction;
- Normal appearing QRS complex.

Acute management:

- Vagal maneuvers or adenosine do not convert this rhythm but may increase the degree of AV block, unmasking underlying flutter waves (33).
- Synchronized direct current (DC) cardioversion is preferred to antiarrhythmic drug cardioversion (amiodarone).

- Elective DC cardioversion starting at 0.5J/kg, increasing to 1–2 J/kg if needed.
- Anticoagulation therapy for episodes >48 hours is recommended.

Maintenance therapy:

- Options for chronic treatment include pharmacologic therapy and catheter ablation (34).
- Rhythm control with drugs such as amiodarone and flecainide or;
- Control of ventricular response with beta-blockers, digoxin, or calcium channel blockers.

B. Wide QRS Tachycardia

B.1. Ventricular Tachycardia

This arrhythmia is a potentially life-threatening arrhythmia that is uncommon in the pediatric population. Wide QRS complex tachycardia should generally prompt consideration of ventricular tachycardia. However, in children, most wide QRS complex tachycardia represents antidromic AVRT, not VT. VT is defined as a tachycardia originating below the bundle of His. Episodes lasting less than 30 seconds are named as non-sustained VT and those more than 30 seconds as sustained VT. VT can further be classified as monomorphic or polymorphic VT. Monomorphic VT is defined with a regular rate and a single QRS morphology. Polymorphic VT, with variability in rate and QRS morphology, may result from electrolyte abnormalities (hyperkalemia, hypocalcemia, and hypomagnesemia), LVH, myocarditis, myocardial ischemia, drug toxicity, and congenital heart disorders. Also, vascular calcification may be a basic effect in the pathophysiology of ventricular arrhythmias in CKD patients (17, 18).

Clinical features:

- VT may present with variable symptoms ranging from dizziness and palpitations to syncope and cardiac arrest.

ECG findings:

- Prolonged QRS duration for age;
- VA dissociation (ventricular rates exceeding atrial rates);
- Rates range from 110 to over 200 bpm (Figure 4);
- Complexes may appear uniform or vary from beat to beat as in polymorphic VT;
- Variation in RR interval and presence of fusion complexes are consistent with VT rather than SVT with aberrant conduction.

Acute management:

- If unstable, synchronized cardioversion is started at 2 J/kg and repeated, increasing the dose if needed.
- If stable, may attempt amiodarone at 5 mg/kg IV over 30–60 minutes or procainamide at 15 mg/kg IV over 30–60 minutes (33).

Follow up:

- ECG in normal sinus rhythm should assess to rule out underlying abnormalities including long QT, Brugada syndrome, arrhythmogenic right ventricular cardiomyopathy, electrolyte abnormalities, and myocardial ischemia;
- Echocardiographic evaluation is performed to rule underlying structural heart disease.
- Chronic treatment depends on the type of VT and the presence of long QT.
- Antiarrhythmic therapy or implantable cardioverter-defibrillator (ICD) placement is required for life-threatening VT.

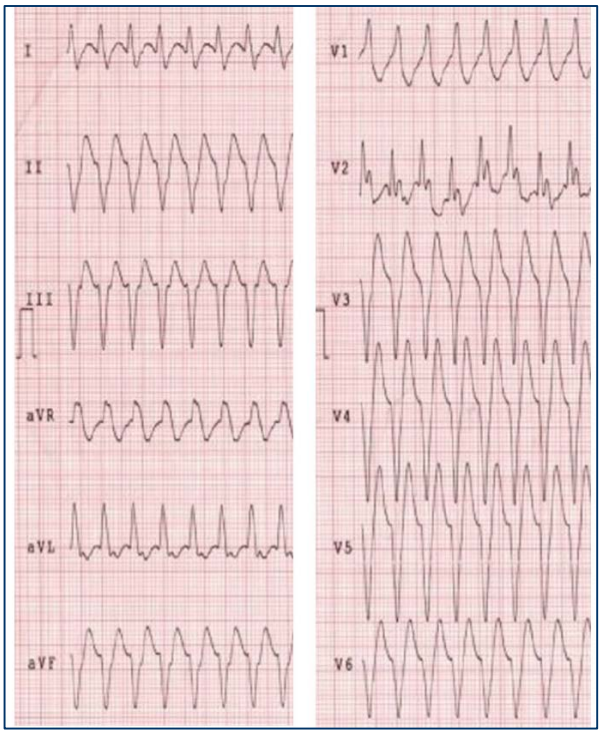

Figure 4. Ventricular tachycardia.

B.2. Long QT syndrome

QT interval prolongation is a known risk factor for serious ventricular tachycardia and also SCD in the general population. It is a congenital or acquired condition. Prolongation of the rate- corrected QT (QTc) interval is defined based on age- and sex-specific criteria. A QTc interval of ≥500 msec is associated with a significantly increased risk of life-threatening arrhythmia in adulthood (34).

The congenital long QT syndrome is a genetic abnormality in ion channels resulting in prolonged cardiac repolarization that may lead to syncope, cardiac arrest, or sudden death. This syndrome is often associated with increased risk of a unique form of polymorphic ventricular tachycardia, torsades de pointes (TdP), characterized by changes in the amplitude of QRS complexes around the isoelectric line. Pathogenic variants in up to 17 genes have been recognized. The three most important genetic subtypes are designated LQT1 through LQT3. A scoring system for the diagnosis of congenital LQTS, also called the Schwartz score, should be calculated in all patients in whom congenital LQTS is suspected (34).

Acquired forms of Long QT syndrome are usually aggravated by the presence of extrinsic factors such as electrolyte imbalances (hypokalemia, hypomagnesemia, hypocalcemia) that are commonly associated with renal dysfunction and also QT-prolonging drugs [eg: antihistamines, antibiotics (Chloroquine, Ciprofloxacin, Clarithromycin, Erythromycin), antidepressants, etc] (26, 30). Thus, the prevalence of acquired long QT syndrome is high in CKD patients. The more prevalence of long QTC is observed in patients with more severe renal dysfunction (36, 37). CKD related metabolic disturbances and uremia can cause significant cardiac dysfunction. Also, it has been shown that coronary artery calcification progression was a predictor of QT interval prolongation in patients with advanced CKD (37). Thus, various factors contribute to QTc prolongation in CKD and the prevalence of cardiovascular mortality is subsequently increased in CKD patients with prolonged QTc (30, 36, 37).

Clinical features:

- The first presenting symptom may be syncope, seizures, or cardiac arrest.
- Precipitating factors may include exercise, emotional stress, loud noises, or even sleep.

ECG findings:

- QTc best obtained from lead II or V5 (Figure 5). (Bazett Formula QTc=QT Interval/√-RR);
- The 99th percentile QTc values are 460 msec in the prepubertal child, 470 msec and 480 msec in postpubertal males and females, respectively;
- The average QTc among patients with genetically confirmed LQTS is > 470 msec;
- Borderline QTc>440 msec in the setting of clinical symptoms and/or family history should be investigated;
- Asymptomatic patients with calculated QTC exceeding 450 msec should be evaluated for congenital LQT syndrome;
- Abnormal T wave morphology including T wave alternans, notched T wave and low amplitude;
- Bradycardia for age;
- Torsade de Pointes (Figure 6) (31).

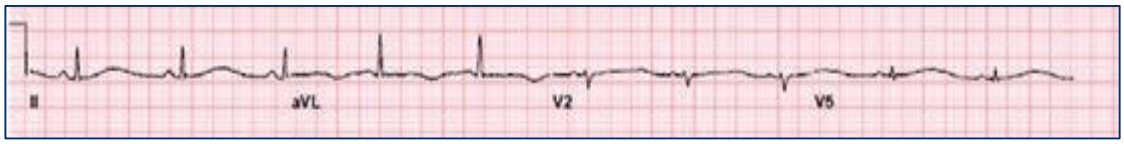

Figure 5. Prolonged QT syndrome.

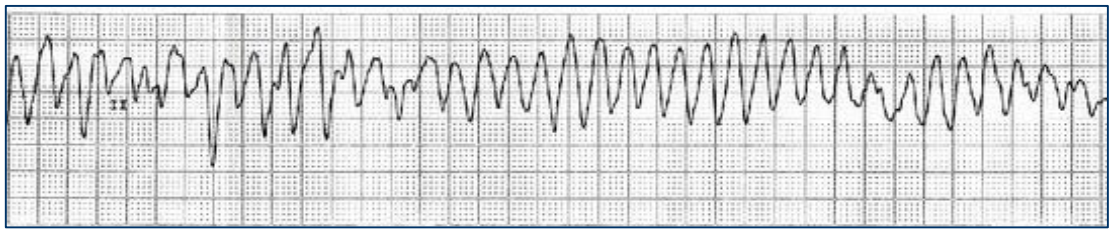

Figure 6. Torsades de pointes (TdP).

Management:

- The removal of QT-prolonging risk factors and correcting electrolyte abnormalities are the cornerstone of management;
- CKD Patients with QT prolongation should undergo continuous ECG monitoring;
- ECG signs of impending torsade de pontes: QTc prolongation >500 ms, QT-U prolongation and distortion after a pause, the onset of ventricular ectopy and couplets, macroscopic T-wave alternans;
- Maintenance of high normal serum potassium levels is recommended.

Acute management:

- For torsades de pointes, perform emergent defibrillation followed by administration of magnesium sulfate and possibly lidocaine (33).

Chronic management:

- For all patients with a history of syncope or seizures, treatment with a beta-blocker (propranolol or nadolol) is recommended;
- All patients with resuscitated sudden cardiac death should be treated with a beta-blocker and also an ICD implantation;
- The avoidance of QT-prolonging drugs;
- The aggressive treatment of electrolyte imbalances;
- Restrict all competitive or exhausting activity.

Prognosis:

β-blockers were associated with a significant reduction in cardiac events in LQT syndrome but do not eliminate it (33).

Conclusion

Although CKD is relatively uncommon in children, it can be a serious illness with long-term consequences. Cardiovascular anomalies begin early in the course of renal dysfunction and rapidly progress when dialysis is initiated. Cardiac complications are the leading cause of morbidity and mortality in patients. Various types of arrhythmias have been recognized in children with advanced CKD. Accurate diagnosis and emergency management of the various types of arrhythmias in children with underlying disease are still challenging. An understanding of the variety of diseases that can predispose children to more serious arrhythmias is essential for appropriate approach and treatment.

Acknowledgments

Not declared.

Conflict of Interest

The author declares no conflicts of interest.

Financial Support

Not declared.

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