Weathering an Adenosine Insensitive Right Ventricular Outflow Tract Ventricular Tachycardia (Ado-insensitive RVOT VT) Storm in an Adolescent Female: A Case Report

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Abstract

Introduction: Ventricular tachycardias (VT) are commonly associated with structural heart disease. However, 10% of VTs have no identifiable cause. Right ventricular outflow tract ventricular tachycardia (RVOT VT), a small subgroup of idiopathic VTs localized in the right ventricular outflow tract is highly sensitive to adenosine (ADO). Only 11% of RVOT VT is ADO-insensitive, posing a diagnostic challenge. We present a peculiar case of an ADO-insensitive RVOT-VT storm and the challenges of recognizing and managing it in a resource-limited setting.

Case summary: A 15-year-old female, asthmatic, complained of palpitations, lightheadedness, chest pain and dyspnea a few hours prior to admission. She had a similar episode a month ago, which necessitated ER admission, electrical cardioversion and amiodarone.

On admission, she was tachycardic but normotensive. She had diffuse wheezes. Cardiac exam was normal. ECG revealed a wide complex tachycardia (WCT). Work-up revealed a normal chest x-ray, thyroid function tests and electrolytes. Echocardiogram showed a structurally normal heart. She was managed as a case of viral myocarditis and SVT with aberrancy. Vagal maneuvers and adenosine was given which slowed down the tachycardia. She was then started on IV anti-arrhythmics however, sustained symptomatic VT recurred on the same day. ECG analysis showed a WCT, LBBB, AV dissociation with positive QRS complexes in inferior leads suggestive of VT originating from the RVOT. RVOT VT storm was considered and adenosine (maximum dose) was given. The patient did not revert to sinus, hence, ADO-insensitive RVOT VT was considered. Cardioversion terminated the VT storm.

On electrophysiology study, the VT was induced/localized at the RVOT via 3D mapping. Ablation of the RVOT focus was performed, immediately terminating the VT. Post ablation, the patient was asymptomatic and was discharged improved with excellent prognosis.

Discussion: This case report highlights two things. The ECG remains a reliable tool in recognizing and localizing VTs clinically. Secondly, it highlights the importance of prompt recognition of ADO-insensitive RVOT VT because its management and prognosis is very different from the common causes of VT.

Keywords: ventricular tachycardia, arrhythmia, electrocardiogram, VT ablation

Introduction

Ventricular tachycardias (VT) are commonly associated with structural heart disease. However, 10% of patients with VT have no identifiable structural or metabolic causes. In structurally normal hearts, VT commonly arises from the outflow tracts.[1]

Right ventricular outflow tract ventricular tachycardia (RVOT VT) comprises a small subgroup of idiopathic VTs that is localized in and around the right ventricular outflow tract (80% of all locations).[7] The arrhythmogenesis is due to calcium-dependent delayed after depolarizations that can lead to an underlying automatic focus, hence the tachycardia.[1] Usually manifesting at 30-50 years of age, exercise and emotional stress can trigger outflow tract VTs.[1] Its hallmark is its sensitivity to adenosine (ADO), a drug that causes suppression of atrioventricular conduction.[2] While adenosine is typically recommended as class one treatment for the management of stable supraventricular tachycardia[3], the sensitivity of RVOT VT to adenosine differentiates it from the typical VT consistent with its triggered mechanism.[2] This feature is a useful clinical information because adenosine can be given to undifferentiated wide complex regular tachycardias as a diagnostic tool, since majority of RVOT VT and aberrantly conducted supraventricular tachycardia will convert to sinus upon giving adenosine.[4] Exceptionally, only 11% of sustained RVOT VT is ADO-insensitive, posing a diagnostic challenge.

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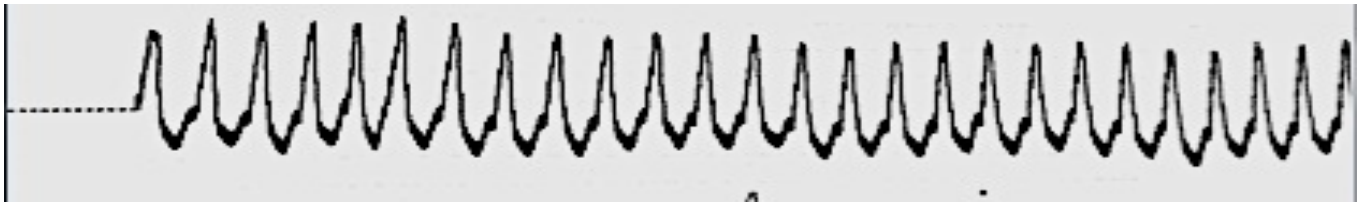

Figure 1. Cardiac monitor display showing a regular wide complex tachycardia (rate of 300 beats/min)

When compared to VT from structural heart disease, the prognosis for RVOT VT is generally favorable, but there is potential for developing PVC-related cardiomyopathy from the tachycardia and, rarely, sudden cardiac death.[1] While the disease can be suppressed with calcium channel blockers and anti-arrhythmic drugs, the long term and definitive management is to ablate the automatic focus where the ventricular tachycardia arise. Hence, prompt recognition and early ablation is curative and holds a low risk of serious complications.[7]

We present a peculiar case of an ADO-insensitive RVOT VT storm and the challenges in recognizing and managing it in a resource-limited hospital setting.

Case summary

This is a case of a 15-year-old female, known asthmatic, who had multiple doses of salbutamol nebulization for asthma exacerbation prior to consult. She complained of persistent palpitations, lightheadedness, chest pain and dyspnea a few hours prior to admission. She had a similar episode of incessant palpitations a month prior, which necessitated emergency room (ER) admission and electrical cardioversion. The patient was managed as a case of supraventricular tachycardia (SVT). She was started on oral amiodarone and was discharged improved. She has no family history of a similar disease or sudden cardiac death. Her developmental history is at par with age. She was a high school student, who denied vices and use of recreational drugs.

On admission at the emergency room, the patient was awake and coherent yet in cardiorespiratory distress. She was tachycardic (240 beats/min), normotensive (110/70 mmHg), tachypneic (30 cycles/min) and non hypoxemic (SpO^2 98%). She had no anterior neck mass or distended neck veins. Chest examination revealed wheezes on bilateral lung fields. No rales was noted. She had an adynamic precordium, soft heart sounds, undisplaced apex beat and no murmur. Abdominal physical examination was unremarkable. The peripheral pulses were faint. Cardiac monitoring revealed a regular wide complex tachycardia (Figure 1).

She was initially managed as a case of myocarditis with symptomatic supraventricular tachycardia with aberrancy by the primary service. Vagal maneuvers were employed

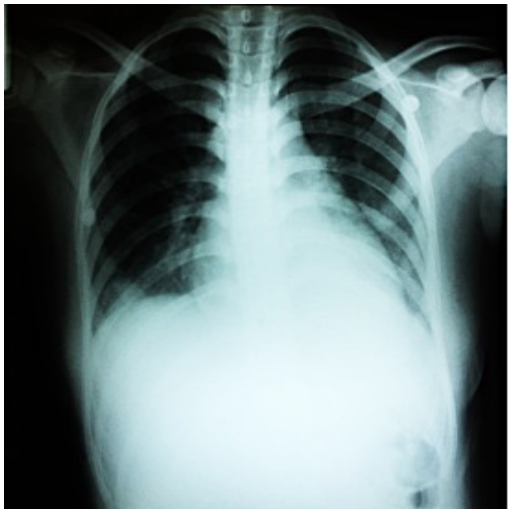

Figure 2. Chest x- ray findings revealed a normal cardio-thoracic ratio, absence of pulmonary congestion or pulmonary parenchymal infiltrates

and adenosine (0.2 mg/kg, maximum dose of 12 mg) was given which slowed down the tachycardia to 180 beats/min only momentarily. She was then started on IV amiodarone (5mg/kg) and diltiazem (1.5 mg/kg/day). Work-up revealed a normal chest x-ray (Figure 2), thyroid function tests, serum electrolytes, urinalysis and complete blood count. Echocardiogram showed a structurally normal heart with acceptable systolic function. Echocardiographic features of arrhythmogenic right ventricular cardiomyopathy such as bulging dyskinesia of the right ventricle, dilated right ventricle or reduced right ventricular systolic function were absent.

Despite the amiodarone drip, sustained symptomatic ventricular tachycardia recurred on the 13th hour of intensive care unit stay, yet she remained hemodynamically stable with no signs of central and peripheral hypoperfusion. (Figure 3) The patient was referred to Adult Cardiology – Electrophysiology for opinion and co-management.

Detailed analysis of the electrocardiogram (ECG) showed a wide complex tachycardia (QRS complexes >0.12 msec), with left bundle branch block morphology, AV dissociation with positive QRS complexes in inferior leads, suggestive of VT tachycardia originating from the RVOT. The patient was diagnosed with ventricular tachycardia storm (VT storm) and was given adenosine (maximum dose) since majority of RVOT VT are adenosine sensitive. However, the patient did not revert back to sinus, hence, ADO-insensitive RVOT VT was considered. Synchronous cardioversion (0.1 joule/kg) under intravenous sedation with propofol was

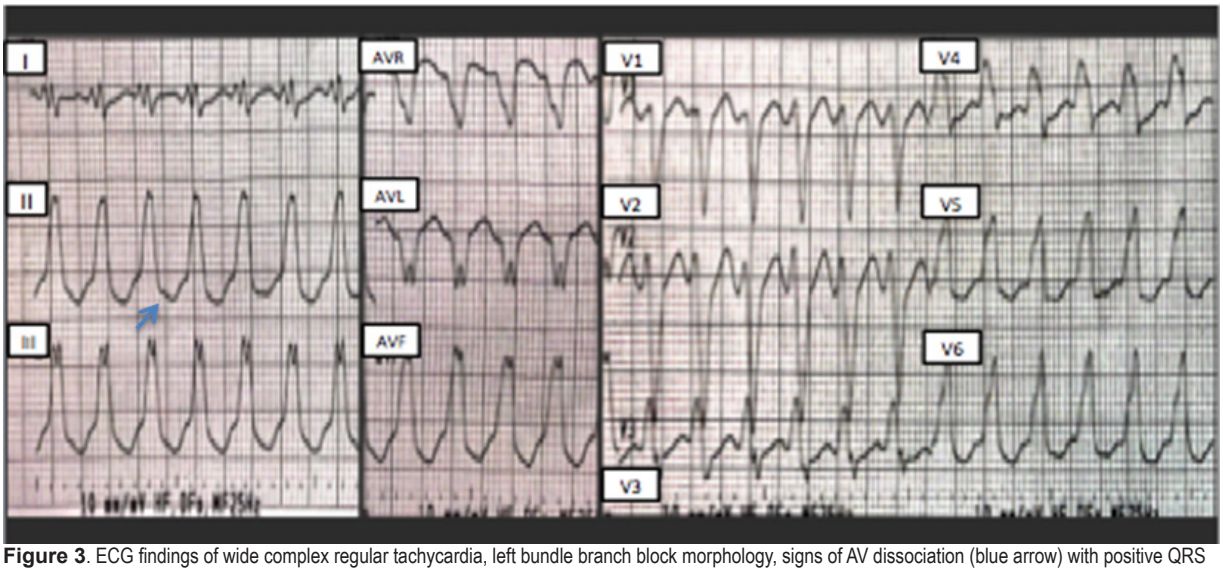

Figure 3. ECG findings of wide complex regular tachycardia, left bundle branch block morphology, signs of AV dissociation (blue arrow) with positive QRS complexes in inferior leads suggestive of ventricular tachycardia originating from the right ventricular outflow tract

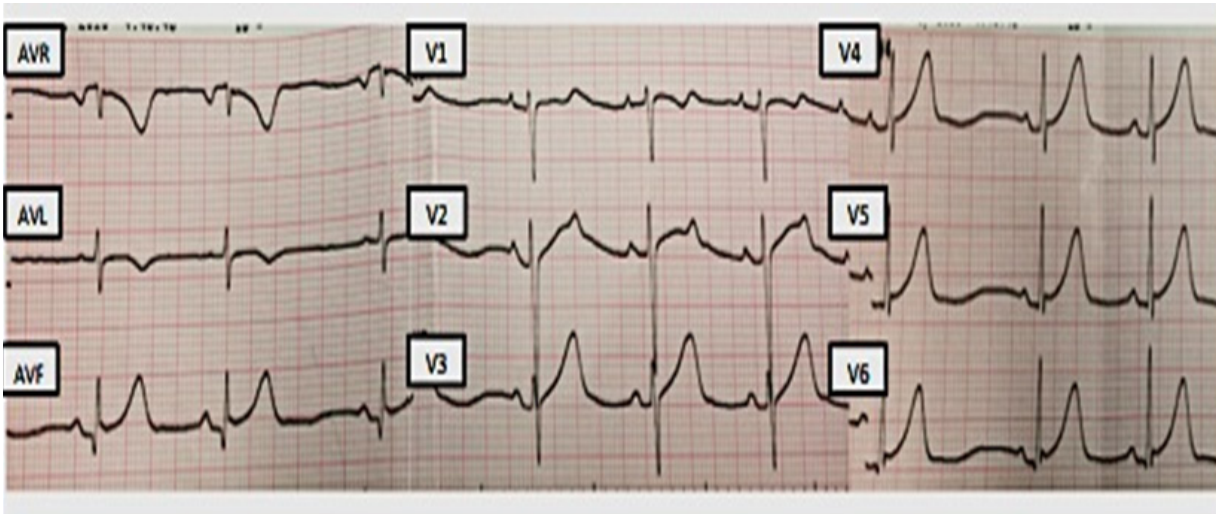

Figure 4. ECG findings post cardioversion revealed sinus arrhythmia, prolonged QT, peaked T waves, early repolarization change and non specific ST T wave change.

performed, which terminated the VT storm and converted the rhythm back to sinus (Figure 4). Post cardioversion, the patient's ECG revealed sinus arrhythmia, prolonged QT, peaked T waves, early repolarization change and non-specific ST T wave changes. The prolonged QT interval was attributed to the drug effect of amiodarone.

Due to the presentation of ventricular tachycardia storm, the patient was offered radiofrequency ablation of the automatic RVOT focus for definitive management. A cardiac EP study is a minimally invasive procedure that tests the electrical conduction system of the heart to assess the electrical activity and conduction pathways of the heart. The study is indicated to investigate the cause, location of origin and ablate the foci of the tachycardia. The patient underwent an electrophysiology study. The ventricular tachycardia was induced and localized at the RVOT via three dimensional (3D) electroanatomical mapping. (Figure 5 and 6)

Radiofrequency ablation of the RVOT focus was performed, immediately terminating the tachycardia (Figure 7). Post ablation, the patient was asymptomatic, with no VT recurrence and was discharged improved with excellent prognosis. The electrocardiogram post radiofrequency ablation was normal. The patient has been asymptomatic during the three-month follow up. Presently, all the anti-arrhythmic medications have been discontinued with no recurrence of the arrhythmia.

Discussion

The ECG remains an accessible and reliable tool in recognizing and localizing RVOT VT. The challenge in diag-

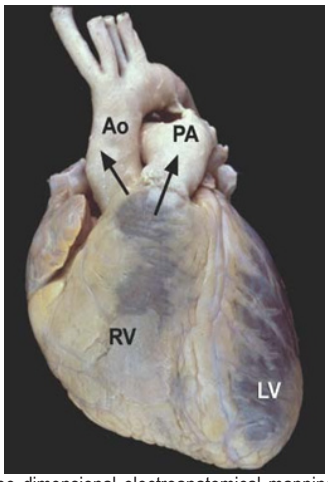

Figure 5. Three dimensional electroanatomical mapping of the right ventricle. An anatomic model of the heart showing the orientation of the right ventricle and its outflow tract.

nosing the patient's ECG tracing is to first identify if this is a ventricular tachycardia or an aberrantly conducted supraventricular tachycardia (SVT with a pre-existing bundle branch block). A baseline ECG during sinus rhythm could have been very helpful in clinching the diagnosis, however, it was not available for this patient.

If you look closely in the ECG (Figure 8), it is a wide QRS tachycardia (> 0.12 msec). The regularity of the tachycardia favors VT. Upon institution of vagal maneuvers, the tachycardia slowed down from a rate of 300 to 180 beats/minute but was not terminated. SVTs are typically slowed down by vagal maneuvers and by administration of adenosine. Looking closely at lead II, there is evidence of atrio-ventricular dissociation as evidenced by the P wave pointed by the blue arrow. This finding favors the diagnosis of ventricular tachycardia.

Understanding of this anatomic framework aids in understanding the electrocardiographic manifestation of outflow tract VT. The outflow tracts are superior structures, and activation originating from these sites is directed inferiorly, thereby producing a QRS appearance that is strongly positive in the inferior leads (II, III, and aVF) and negative wave in aVL and aVR1. In the patient's tracing, there was an LBBB morphology signifying that the site of VT origin is from the right side. There are positive QRS complexes on leads II, III and AVF while negative QRS complexes on aVL and AVR consistent with a RVOT origin. Additional leads (particularly leads V1 and I) can further refine the ECG localization within the outflow tracts.[1]

Lead V1 is right-sided and anterior lead. Since the RVOT is anterior and leftward within the body, when the impulse begins in the RVOT and spreads away posteriorly and leftward, V1 should manifest a predominantly negative complex.[5] Looking at our patient's tracing (Figure 9), there

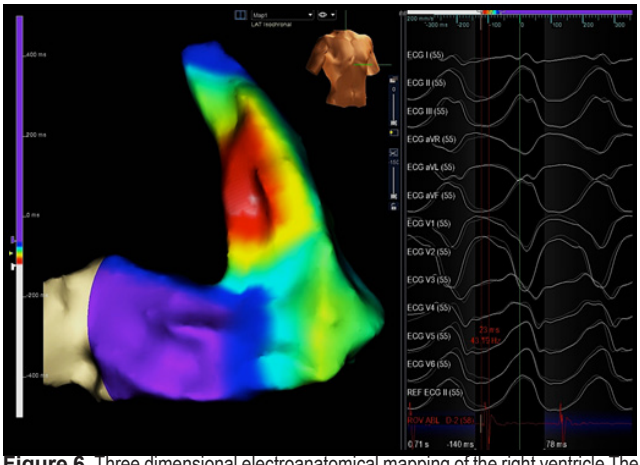

Figure 6. Three dimensional electroanatomical mapping of the right ventricle The different colors illustrate the various activation time of the right ventricle. The red focus on the right ventricular outflow tract shows the site of the earliest endocardial activation time during VT induction.

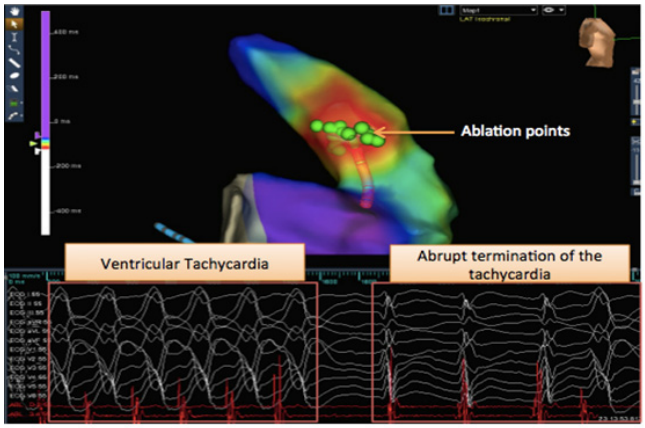

Figure 7. Three dimensional electroanatomical mapping of the right ventricle. The green circles represent the areas ablated in the RVOT. Below the diagram is an intracardiac ECG tracing. Note that on the left side is the induced ventricular tachycardia. Upon ablation of the RVOT focus (green dots) there was abrupt termination of VT occurring within 10 seconds

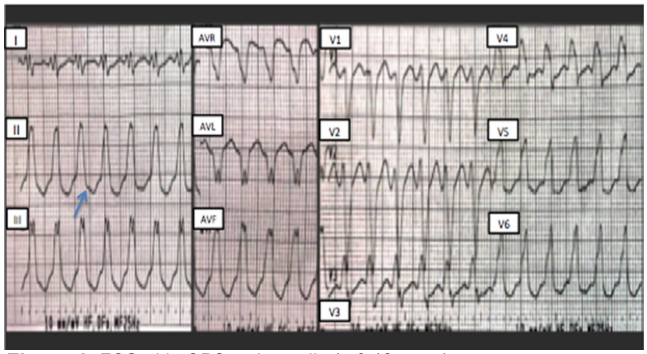

Figure 8. ECG wide QRS tachycardia (> 0.12 msec)

was a deep S wave on V1 consistent with an RVOT origin. The ECG localization of RVOT VT was confirmed during the electrophysiology study with 3D anatomic mapping.

Cytosolic calcium overload mediated by increased levels of cyclic adenosine monophosphate (cAMP) lead to delayed afterdepolarizations which, when reaching

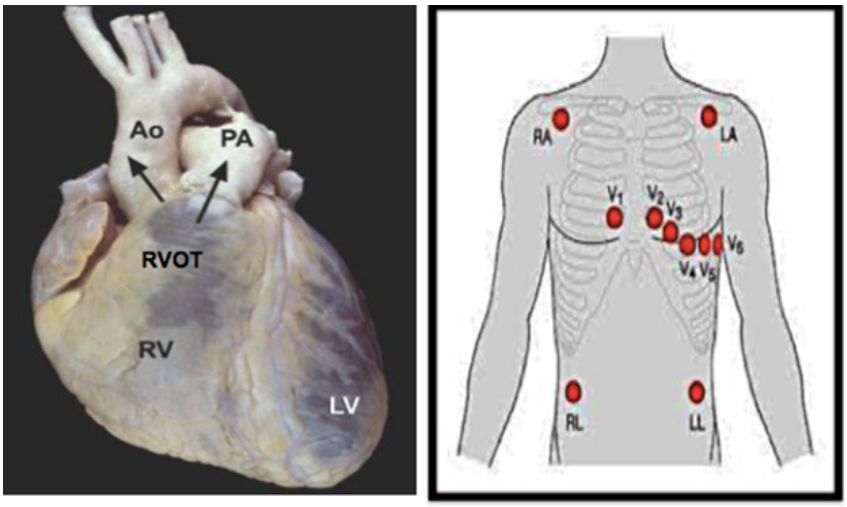

Figure 9. Patient's ECG localization

the cardiomyocyte threshold, may cause another action potential during the relative refractory period of the ventricle and may initiate a tachycardia.[7] The effectiveness of adenosine in terminating this triggered activity lies on its pharmacologic property of reducing cAMP. Beta agonists drugs such as salbutamol nebulization in this patient, increased the serum catecholamine levels. Both exogenous and endogenous catecholamines increase cAMP concentration through the modulation of adenylate cyclise and facilitate tachycardia induction[7], hence the RVOT VT storm was precipitated in this patient.

Albeit very rare, ADO-insensitive RVOT VT was well documented in this case as manifested by the lack of appropriate response to adenosine. In a study done by Cheung in 2014, 46 patients with inducible sustained RVOT VT were given adenosine and their clinical and electrophysiologic characteristics were compared. Five out of 41 patients (11%) had ADO insensitive RVOT VT. The electrophysiology study findings between ADO sensitive and ADO insensitive RVOT VT were similar6. The variant of ADO insensitive of RVOT VT has been linked to somatic myocardial mutations involving the A1 ADO receptor-associated cyclic adenosine monophosphate-mediated pathway.[6] Genetic testing was not performed in our patient to confirm this theory, because studies did not reveal significant phenotypic / electrophysiologic differences between ADO sensitive and ADO insensitive RVOT VT. Clinically, the presence of ADO insensitive RVOT VT limits the use of pharmacologic therapy in events of ventricular tachycardia. Since the patient is young and lacks structural heart disease, ablation was identified as the best long term solution for the RVOT VT.

Therapy is directed by the calcium-dependent delayed after-depolarizations that can lead to an underlying automatic focus. Although RVOT VT shows a better response to antiarrhythmic drugs than structural VT, their overall efficacy is moderate with 30 to 40% recurrences. Calcium channel blockade (verapamil or diltiazem) and beta blockers can be effective first line therapies, however, their efficacy has been proven to be from 25 to 50% with a synergistic effect when administered in combination.[8] Other alternative therapies such as flecainide, sotalol and amiodarone can be used however long term to life long therapy is not preferred in very young patients.

The automatic focus can be targeted for ablation by identifying the site of ventricular tissue that is activated earliest by a PVC. Catheter ablation of the automatic focus is an effective therapeutic option (class one, level of evidence C).[1] Acute success rate after radiofrequency ablation has been reported to be over 80%. After successful ablation, a 5% of VT recurrences has been reported, the majority within the first year and successfully ablated with a second procedure.[9] In the patient, we plan to monitor VT recurrence by closely following up this patient.

This case highlights the practical importance of prompt recognition of adenosine insensitive RVOT VT, because the management and prognosis is very different from the common causes of VT. By correctly managing this arrhythmia, long term complications such as tachycardia related cardiomyopathy and sudden death will be prevented.

Conclusion

This case highlights the practical importance of prompt recognition of adenosine insensitive RVOT VT, because the management and prognosis is very different from the common causes of VT. By correctly managing this arrhythmia, long term complications such as tachycardia related cardiomyopathy and sudden death will be prevented.

Patient's Perspective

The patient has had several emergency room visits due to palpitations and pre-syncope. Despite repeated consults, the patient and her mother has been unsatisfied with the diagnosis previously given as the symptoms would always recur despite anti-arrhythmics given. Thru radiofrequency ablation, it offered the patient a more lasting and possibly permanent solution to this arrhythmia and they were satisfied with the results.

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