Venoarterial extracorporeal membrane oxygenation and implantable cardioverter-defibrillator implantation in a hemodynamically unstable infant with ventricular tachycardia from multiple cardiac rhabdomyomas

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Introduction

Tuberous sclerosis complex (TSC) is a neurocutaneous disorder characterized by benign tissue hamartomas in multiple organ systems, including cardiac rhabdomyomas.[1] Though prevalent in TSC, cardiac tumors are rare in children, occurring in about 0.03%–0.17%. Rhabdomyomas are the most common, accounting for 45%.[2,3] When present, they are multiple and in the ventricular myocardium.[4] Frequently, they regress and surveillance is all that is required until spontaneous regression.[5] Intervention is necessary when life-threatening obstruction or hemodynamically significant refractory arrhythmias occur. This case highlights the course of a 6-month-old infant with TSC and cardiac rhabdomyomas who presented in refractory ventricular tachycardia (VT) with decompensation and cardiac arrest necessitating venoarterial extracorporeal membrane oxygenation (VA-ECMO), complex antiarrhythmic therapy, and ultimately implantable cardioverter-defibrillator (ICD) implantation.

Case report

Our patient was found to have intracardiac tumors by a fetal echocardiogram at 34 weeks gestation. Postpartum, an echocardiogram and electrocardiogram (ECG) were completed. The ECG showed normal sinus rhythm with normal intervals and voltages, with J point and ST elevation in the inferolateral leads, consistent with benign early repolarization. His echocardiogram confirmed multiple rhabdomyomas along the interventricular septum and left ventricular myocardium, and in the anterior outlet septum extending into the right ventricular outflow tract, but without inflow or outflow obstruction of either ventricle (Figure 1). Additionally, a head ultrasound was concerning for intracranial tumors. These findings raised high suspicion for TSC and he was referred for further testing. He developed infantile spasms and was started on vigabatrin for management. At 3 months of age, his ECG was unchanged and echocardiogram displayed minimal regression of the tumors. At that visit, a 6-month cardiac follow-up with repeat testing was recommended.

At 6 months of age, he awoke from a nap crying and lost consciousness and motor tone for 2 minutes, described as "unlike his infantile spasms." On emergency medical services arrival, he was alert but upset. A cardiac monitor revealed a wide complex tachycardia (WCT) with a heart rate >300 beats per minute (bpm). At the local emergency department he was given 3 doses of adenosine (single dose of 0.1 mg/kg and 2 doses of 0.2 mg/kg), without any effect on the WCT. His ECG (Figure 2) was consistent with monomorphic VT and an esmolol infusion (50 mcg/kg/min) was initiated at the recommendation of the on-call pediatric cardiologist. The patient was then transferred to our center and during transport remained stable on room air with appropriate capillary refill (<2 seconds). Upon arrival, an emergent echocardiogram showed no evidence of obstruction or pericardial effusion, with inability to comment on systolic function secondary to the heart rate. He remained in VT at 280–330 bpm and his esmolol drip was titrated to 150 mcg/kg/min. An additional dose of adenosine (0.2 mg/kg) was administered without notable change. He received 7 mg of ketamine and 7 mg of rocuronium. Calcium chloride (100 mg) was given prior to an amiodarone bolus (5 mg/kg) in an attempt to chemically cardiovert the rhythm. His rhythm suddenly deteriorated into ventricular fibrillation (VF) and cardiopulmonary resuscitation was initiated. Two 15 J shocks were administered with conversion to sinus, but rhythm immediately reverted back into VT with a palpable pulse. He was intubated and

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KEY TEACHING POINTS

- Arrhythmias are a rare but known complication of cardiac rhabdomyomas and require periodic ambulatory rhythm surveillance, independent of size or number of the tumors.
- Cardioversion/defibrillation is the indicated treatment for unstable ventricular tachycardia and requires forethought in regard to local resources to support an unstable pediatric patient, should cardiovascular collapse occur.
- Implantable cardioverter-defibrillator placement in a pediatric patient requires a collaborative effort between electrophysiologists and cardiothoracic surgeons with expertise in pediatric patients, with considerations of the limitations and long-term complications of transvenous devices.

placed on a ventilator. His perfusion worsened, with evidence of cardiogenic shock. The decision was made to place him on VA-ECMO for continued support (flow started at 100 mL/kg). After cannulation, he went into VF (total time about 5 minutes after full extracorporeal membrane oxygenation [ECMO] flows) and was defibrillated with 15 J and successfully cardioverted to sinus rhythm.

Once cardioverted, he was cooled and placed on morphine and dexmedetomidine infusions to decrease metabolic demand. A repeat echocardiogram showed severely reduced biventricular systolic function, prompting initiation of calcium chloride (5 mg/kg/hr) and milrinone (0.5 mcg/kg/min). He was loaded with oral amiodarone through a nasogastric tube at 20 mg/kg/day with frequent ECG monitoring. His mean arterial pressures (MAP) increased, necessitating a nitroprusside (0.3 mcg/kg/min) drip. Ventricular function improved over 1–2 days and his MAPs normalized, allowing transfer to the nearest quaternary children's hospital for further management. After transfer, he had another episode of sustained monomorphic VT that responded to synchronized cardioversion and was maintained on esmolol. The following day, he had increasing amounts of premature ventricular contractions and nonsustained VT and was transitioned to a lidocaine infusion (20 mcg/kg/min) without additional ensuing events. He was decannulated on his third hospital day and started on mexiletine with plans to wean him off his lidocaine infusion over 1 week. However, he continued to have breakthrough VT while on mexiletine (15 mg/kg/day) and amiodarone, as the amiodarone maintenance dose was decreased to 5 mg/kg/day. After discussion with surgeons, intensivists, and electrophysiologists, he underwent placement of a dual-chamber epicardial ICD.

At the time of ICD implantation (Medtronic Evera, Minneapolis, MN), our patient was 7.7 kg and 70 cm. Bipolar 25-cm steroid-eluting leads (Medtronic 4968) were sutured to the epicardial surface of the right atrial appendage and left ventricular apex with the ICD coil (Medtronic 6937A) placed in the pericardium and oriented for a ventricular vector from the left superior aspect of the pericardium, similar to a previously reported case.[6] The generator was positioned in the right upper quadrant, beneath the anterior rectus sheath, where the leads and coil were tunneled (Figure 3). The ICD was programmed with a VF zone at 270 ms, fast VT at 250 ms, and slow VT at 320 ms. Detection was programmed with initial 30/40 beats and redetect at 12/16 beats. Antitachycardia pacing (ATP) was programmed in burst mode with 8 pulses at 81% of the tachycardia cycle length. Five shocks were programmed at 1 J, 10 J, 20 J, 20 J, and 20 J. No therapies were programmed for slow VT. The pacing parameters were AAI-DDD with lower rate limit of 60 bpm and upper tracking rate of 150 bpm.

After the procedure, he had further episodes of sustained VT that successfully terminated with ICD shocks. His mexiletine was discontinued and transitioned to oral flecainide. Subsequent episodes of VT all terminated with pacing and very low energy shocks (0.4 J) with his device after transition to flecainide. After this medication change, the fast VT zone (via VF) was changed to 210 ms. This would allow the device to treat any arrhythmia 222–286 bpm with ATP for 1 round, as it would be classified as fast VT. Afterward, shocks at 0.4 J, 1 J, 10 J, 15 J, and 20 J would be delivered if it did not terminate. Above 286 bpm, the device would treat the arrhythmia in this zone as VF and administer 3 rounds of ATP. Shocks would then be delivered at 0.4 J, 1 J, 5 J, 10 J, and 20 J if the arrhythmia was classified in this zone. The delivered energy dosage was chosen to deliver the lowest dosage allowable (0.4 J) initially and then in escalating dosage in the event of defibrillation failure. With titration of flecainide to 5 mg/kg/day and an amiodarone dose of 5 mg/kg/day, he has remained stable, free from recurrent VT. At his last postdischarge follow-up visit, at 9 months of age, he has continued to do well, with a reassuring repeat ECG showing sinus rhythm without ECG signs of flecainide toxicity or interval changes secondary to amiodarone.

Discussion

Cardiac tumors (even rhabdomyomas) are rare in children, and they typically do not cause symptoms or hemodynamic compromise in the majority of patients. However, they can become symptomatic, depending on the number, position, and size of the tumors. Some may obstruct flow and lead to ventricular or valvular dysfunction with subsequent heart failure. They may also compress or interrupt the conduction system, leading to arrhythmia, heart block, sinus node dysfunction, and/or preexcitation.[5,7,8] In this report, we detail a patient with rhabdomyomas with abrupt development of significant arrhythmogenesis and hemodynamic collapse. With aggressive treatment including hemodynamic bridging with VA-ECMO, antiarrhythmic therapy, and long-term protection with an ICD, the patient was stabilized and is doing well with outpatient management.

Miyake and colleagues[9] reported a series of 106 rhabdomyoma cases in which hemodynamic changes were reported

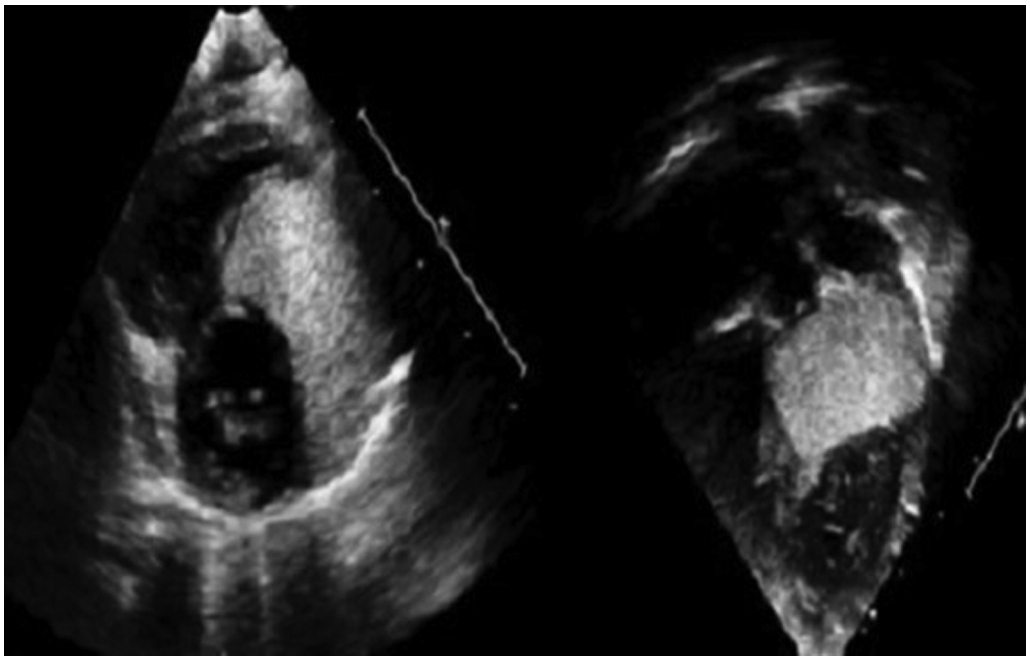

Figure 1 Postnatal echocardiogram showing multiple intramyocardial masses along the interventricular septum (parasternal short-axis view) and on the left ventricular free wall (apical view).

in 17% of the children and significant arrhythmias were found in 16%. These arrhythmias included VT (6%), ventricular preexcitation with sustained supraventricular tachyardia (SVT) (2%), ventricular preexcitation without SVT (8%), and sustained SVT (5%) without underlying preexcitation. Additionally, ventricular ectopic beats and couplets and brief nonsustained SVT were found in 12% and various other arrhythmias were found in 28% of the patients.[9] Józwiak and colleagues[10] evaluated 154 patients with TSC and found that of the 74 with cardiac rhabdomyomas, the main clinical manifestations of the tumors that did not remain silent or regress were arrhythmias (23%), murmurs (14.9%), and heart failure (5.4%).

Based on published literature, arrhythmia remains the most common symptomatic cardiac manifestation in individuals with TSC. Frequently, they are successfully treated with antiarrhythmic medications as an adjunct to careful follow-up, with eventual tumor regression, as seen in a retrospective single-center study conducted from 1968 to 2010.[9] Our patient presented with sustained intractable monomorphic VT that culminated in cardiac arrest from degeneration into VF. His management required early recognition of his

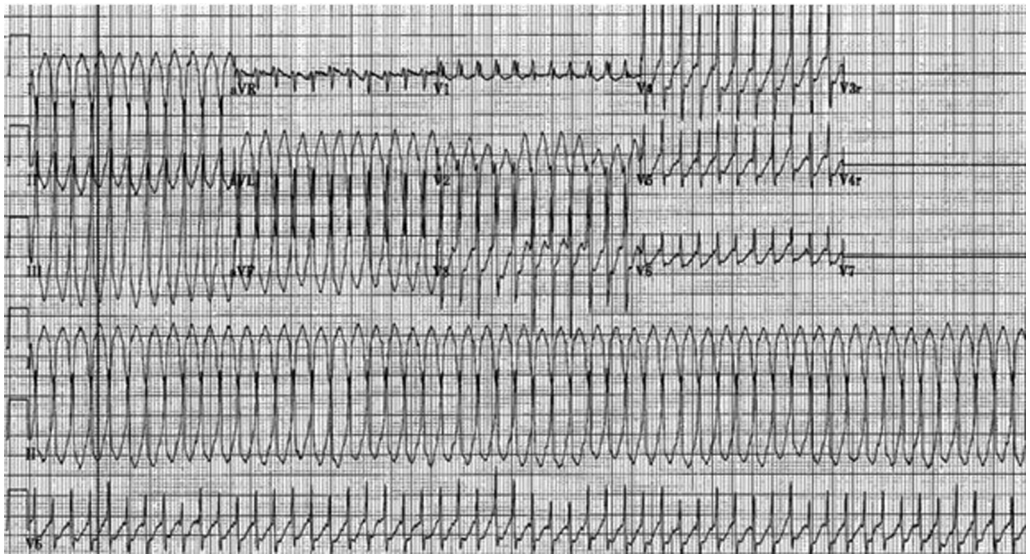

Figure 2 Electrocardiogram on initial hospital presentation via arrival by emergency medical services.

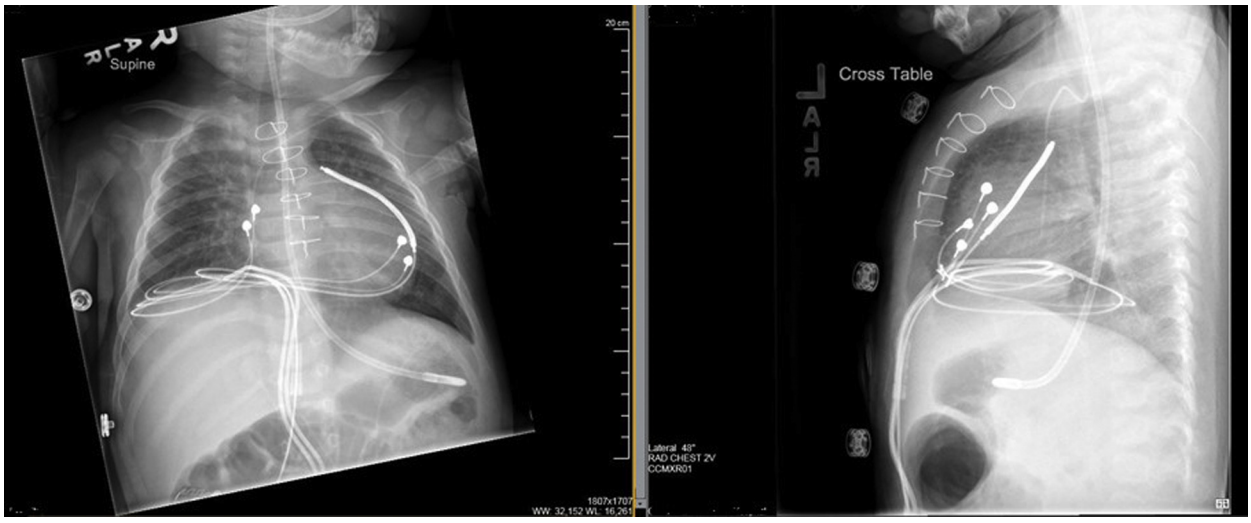

Figure 3 Chest radiograph post implantable cardioverter-defibrillator implantation.

rhythm and transfer to a center with pediatric subspecialty care. With intensive care, defibrillation on VA-ECMO, numerous antiarrhythmic medications, and epicardial ICD implantation, the child was able to survive and is doing well in follow-up.

The workup of wide complex tachycardia can be challenging in young patients, particularly if hemodynamically tenuous. Pediatric patients can have extremely fast ventricular rates compared to adults, and the QRS complexes may not be recognized as wide by standard ECG machines or providers who are unfamiliar with pediatric ECGs. The majority of wide complex tachycardias in pediatric patients are due to aberrant SVT, and therefore adenosine is part of the Pediatric Acute Life Support algorithm for wide complex tachycardia if the patient is stable.[11] The ECG showed right bundle branch morphology with an inferior axis that is also rightward (negative in leads I and aVL), suggesting the VT was from the left ventricular outflow tract. There was no concordance in the precordial leads to make VT more likely, but using the aVR criteria, there is an initial R wave that made VT more likely. The historic clues to making the diagnosis were knowing the patient had a normal ECG at 2 months of age and he had significant rhabdomyomas in his ventricular myocardium. With no change in tachycardia cycle length or QRS morphology with adenosine administration, VT was the most likely rhythm.

The mechanism of the VT was presumed to be triggered activity as well as reentry, but not definitively proven. After defibrillation (prior to ECMO cannulation), the patient would shortly revert back into VT after a sinus beat. After placement of the ICD, the tachycardia would terminate with ATP in the ventricle, supporting reentry as a contributing mechanism. The patient's history and known presence of rhabdomyomas in the ventricles made verapamil-sensitive (fascicular) VT unlikely.

This is the first report of hemodynamically significant VT due to cardiac rhabdomyomas in a pediatric patient leading to VA-ECMO and ICD implantation. The natural history of these tumors would suggest that observation is prudent in most cases; however, our patient required significant antiarrhythmic therapy and an ICD owing to his arrest from VT. The patient's case was discussed at our combined surgical/cardiology conference after he was on ECMO and transferred to a pediatric quaternary center where we have an established partnership for care of patients. Tumor resection was not an option owing to the extensive nature of the masses and extension into the crux of the heart and proximity to the coronary arteries. Resection of the left ventricular free wall was not feasible. Antitumor medications, such as sirolimus,[12–14] were considered, but the duration of treatment would be long and there was no guarantee a smaller tumor would equate to less or no VT. The risks of ICD implantation in a young patient were weighed carefully (frequent shocks as well as inappropriate shocks, infection risk, and future invasive procedures for generator changes/lead revisions). Transplantation was considered, but he was weaned successfully from ECMO and the decision was made to place an ICD after all possible options were considered.

For now, the patient is doing well and thriving on flecainide and amiodarone with close outpatient monitoring. Knowing that patients with TSC and cardiac rhabdomyomas can have life-threatening arrhythmias, it is worth considering more frequent ambulatory outpatient monitoring with pediatric cardiologists or electrophysiologists to survey for life-threatening rhythms. If sustained arrhythmias are seen, intervention might be warranted sooner than careful observation and waiting for regression of the masses.

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