

## Open Access

# Mechanical Circulatory Support to Control Medically Intractable Arrhythmias in Pediatric Patients After Cardiac Surgery

Won Kyoung Jhang, MD, Seung-Cheol Lee, MD, Dong Man Seo, MD and Jeong-Jun Park, MD

Division of Pediatric Cardiac Surgery, Asan Medical Center, College of Medicine, University of Ulsan, Seoul, Korea

## ABSTRACT

Postoperative intractable arrhythmia can result in high morbidity and mortality. This report describes our experiences using mechanical circulatory support (MCS) to control medically intractable arrhythmias in three pediatric patients with congenital heart disease (CHD), after palliative or total corrective open-heart surgery. (**Korean Circ J 2010;40:471-474**)

**KEY WORDS:** Extracorporeal membrane oxygenation; Arrhythmia.

## Introduction

Postoperative arrhythmia is a recognized complication after pediatric cardiac surgery, reported to occur in 15-48% of cases.<sup>1,2)</sup> Patients with congenital heart disease (CHD) are especially vulnerable to rhythm disturbances. Transient low cardiac output syndrome is frequently observed in the early postoperative period, which can result in significant morbidity and mortality.

The present report describes our experiences using mechanical circulatory support (MCS) for pediatric patients with postoperative medically intractable arrhythmias (Table 1).

## Cases

### Case 1

A 10-month-old boy with tetralogy of Fallot (TOF) and juxtaductal left pulmonary artery (LPA) stenosis was admitted for a total corrective operation. During the induction of anesthesia, supraventricular tachycardia (SVT) developed with a

heart rate of >200 beats/min, and then spontaneously resolved. The major procedures performed were ventricle septal defect (VSD) patch closure, right ventricular outflow tract obstruction relief and LPA angioplasty. All were completed without any remarkable events. During cardiopulmonary bypass (CPB) weaning, however, SVT recurred. Initially the SVT was controlled by a single adenosine dose, but it again recurred immediately and repeatedly and was accompanied by hemodynamic compromise. These latter events could not be controlled using adenosine, electric cardioversion or body cooling. A transesophageal pacing trial revealed an ectopic atrial tachycardia which was not terminated by overdrive pacing (Fig. 1A). After loading 5 mg/kg/hr of amiodarone, 5 mg/kg/day of amiodarone was continuously infused for rate control. Following, the heart rate appeared to decrease slightly but was not completely controlled. Two days after the operation, the heart increased to a consistent rate >220 beats/min, and was accompanied by hypotension. MCS was provided using extracorporeal membrane oxygenation (ECMO, centrifugal pump, Bio-console<sup>®</sup> 560, Medtronic Inc., Minneapolis, MN, USA. All patients in this report were supported with this). After approximately 48 hours of ECMO support and without any antiarrhythmic agent, the heart rhythm converted to sinus rhythm. ECMO was weaned successfully after 4 days. Following MCS, brain magnetic resonance imaging (MRI) showed a small chronic subdural hemorrhage, however, no definite clinical neurological deficit was observed. The patient has been followed-up for 6 years, during which time there have been no arrhythmic events, and he is now a 7-year-old-boy in a good general condition.

**Received:** January 3, 2010

**Revision Received:** January 27, 2010

**Accepted:** February 19, 2010

**Correspondence:** Jeong-Jun Park, MD, Division of Pediatric Cardiac Surgery, Asan Medical Center, College of Medicine, University of Ulsan, 86 Asanbyeongwon-gil, Songpa-gu, Seoul 138-736, Korea  
Tel: 82-2-3010-3587, Fax: 82-2-3010-6811  
E-mail: pkjj@ amc.seoul.kr

© This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

**Table 1.** Patient characteristics

	Case 1	Case 2	Case 3
Diagnosis	TOF	FSV	VSD, PS
Body weight (kg)	7.9	9.3	5.4
Operation	Total correction	LMBT	Patch closure, RVOTR
CPB time (minutes)	167	No	104
ACC time (minutes)	88	No	37
Pre-MCS Electrolyte			
K <sup>+</sup> (mmol/L)	3.0	4.8	4.6
Mg <sup>2+</sup> (mg/dL)	2.62	1.63	
Ca <sup>2+</sup> (mg/dL)	10.9	9.4	9.9
Pre-MCS CPR duration		120 minutes	140 minutes
Mechanical support type	ECMO	VAD	ECMO
Arterial cannula	Asc. Ao	Asc. Ao	Asc. Ao
Venous cannula	RAA (single)	RAA (single)	RAA (single)
Assist time	110 hours 2 minutes	114 hours 3 minutes	204 hours 12 minutes
Major complication	Subdural hemorrhage		Subdural hemorrhage
ACT (seconds)	334.73±29.16	261.49±31.81	256.7±55.28
Pre-assist EKG	EAT	CAT	JET
Post-assist EKG	NSR	NSR	NSR
Sinus conversion time	ECMO #3	VAD #3	ECMO #3

TOF: tetralogy of Fallot, FSV: functional single ventricle, VSD: ventricular septal defect, PS: pulmonary stenosis, LMBT: left modified Blalock-Taussig, RVOTR: right ventricular outflow tract reconstruction, CPB: cardiopulmonary bypass, ACC: aorta cross clamp, RAA: right atrial appendage, EAT: ectopic atrial tachycardia, CAT: chaotic atrial tachycardia, JET: junctional ectopic tachycardia, NSR: normal sinus rhythm, MCS: mechanical circulatory support, VAD:ventricular assist device, ACT: activated clotting time, EKG: electrocardiogram, ECMO: extracorporeal membrane oxygenation.

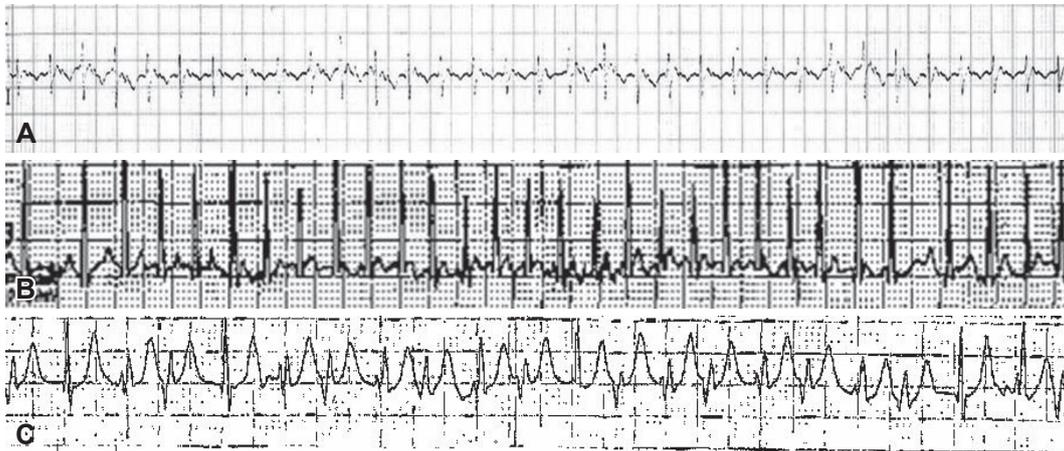
### Case 2

A male baby was born at 41 weeks gestation, weighing 3,200 g. The patient had CHD comprising of a functional single ventricle, an unbalanced complete atrioventricular septal defect, a double outlet right ventricle, pulmonary atresia and a bilateral superior vena cava. The patient also had multiple extracardiac anomalies such as a cleft palate and lip, an ear anomaly (low set right ear with microtia, left anotia and peripheral conduction defect), hemifacial microsomia and torticollis. During neonatal intensive care, he was also diagnosed with gastroesophageal reflux disease and tracheolaryngomalasia. A right modified blalock-Taussig (RMBT) shunt operation (3.5 mm graft via sternotomy) was performed at 13 days post-natal, and he was discharged on postoperative day 42. At 8 months old, a bilateral cavopulmonary shunt (BCS) was planned, but a preoperative CT revealed a severe long segment LPA stenosis. Therefore, we performed an left modified Blalock-Taussig (LMBT) shunt rather than a BCS. The patient was extubated on postoperative day 6, but showed respiratory difficulty with chest wall retraction. A bronchoscopic examination revealed airway obstruction due to a right aryepiglottic fold abnormality. Intermittent self-limiting tachycardia and pericardial effusion developed, starting from postoperative day 11. Holter monitoring confirmed chaotic atrial tachy-

cardia (CAT) (Fig. 1B). At postoperative day 15, a sternal instability was discovered which resulted from the respiratory problem. Arrhythmia gradually worsened. After the operation of sternal fixation combined with laryngo microsurgery at postoperative day 18, sustained tachycardia developed which could not be controlled with body cooling or amiodarone continuous infusion. The prolonged tachyarrhythmia induced a cardiac arrest. The estimated duration of cardiopulmonary resuscitation (CPR) was about 120 minutes. During CPR, a ventricular assist device (VAD) was deployed and both shunts were kept in the open state to maintain pulmonary blood flow for gas exchange. VAD flow was maintained in the range of 150% of assumed cardiac output. The patient reverted to sinus rhythm approximately 96 hours after commencing VAD. VAD was removed 6 days after implantation. Brain MRI showed an acute focal infarction in the thalamus. The child subsequently underwent 2 further open-heart surgery procedures: a BCS at 2 years old and an extracardiac conduit Fontan operation at 5 years old. He also underwent 4 plastic surgery operations to correct facial and ear anomalies. The latter operations proceeded with no significant arrhythmic events.

### Case 3

A 3-month-old boy with a VSD and pulmonary stenosis



**Fig. 1.** Tachyarrhythmia EKG of the three patients. A: EKG tracing of case 1 showing ectopic atrial tachycardia which was not terminated by transesophageal overdrive atrial pacing. B: EKG from holter monitoring of case 2. Narrow QRS tachycardia with several different P waves that indicates chaotic atrial tachycardia. C: lead II from EKG tracing of case 3. Narrow QRS complex with atrioventricular dissociation that present junctional ectopic tachycardia. EKG: electrocardiogram.

(PS) was admitted for surgery. We performed a VSD patch closure, right ventricular outflow tract relief (RVOTR) and main pulmonary artery (MPA) angioplasty. During CPB weaning, a narrow QRS tachycardia developed with a heart rate >200 beats/min. The tachycardia could not be controlled using adenosine, digoxin, verapamil or epicardial defibrillations, though it appeared to be converted to sinus rhythm after left atrial auricle stimulation. The patient was transferred to the intensive care unit (ICU) with an atrial pacing wire. Immediately upon arrival in the ICU the tachycardia again occurred, and was found to be junctional ectopic tachycardia (JET), with a heart rate of 220-260 beats/min (Fig. 1C). With body cooling, an amiodarone continuous infusion (5 mg/kg/day) was commenced after 5 mg/kg/hr of loading, but it did not control the tachycardia, and the hemodynamic collapse progressed. After 140 minutes of CPR, ECMO was applied. The heart rhythm converted to a sinus rhythm after approximately 72 hours of ECMO. An echocardiogram showed improved heart function. The patient was weaned successfully from ECMO and decannulated after approximately 204 hours. On postoperative day 15, JET again developed and was controlled using a continuous amiodarone infusion. From postoperative day 16, a normal sinus rhythm was maintained without any medication. Brain MRI showed hypoxic ischemic encephalopathy, mild diffuse brain atrophy and multiple staged subdural hemorrhages (SDH). A subduoperitoneal shunt operation for SDH was performed when the patient was 8 months old, and the shunt was removed 6 months later. The patient is now 4 years old, and shows mild developmental delay with good cardiac function.

## Discussion

A variety of arrhythmias can develop in pediatric patients after congenital heart surgery.<sup>3,4)</sup> The etiology of arrhythmias

is, in many cases, multi-factorial. CPB, the type of surgery, younger age, aorta cross clamp time, some medical treatments such as high-dose inotropics, and electrolyte imbalances have been identified as important provoking factors.<sup>5-7)</sup> In our study there was no specific intraoperative events or perioperative electrolyte imbalances. Postoperatively only a low dose inotropic (dopamine 5 ug/kg/min) agent was needed in all three patients.

JET is the most common tachyarrhythmia in the postoperative course of congenital heart surgery in children. Although it may be transient, despite vigorous treatments it can sometimes be associated with a high rate of morbidity and mortality. The cause of CAT is still unclear,<sup>8,9)</sup> and cannot be controlled easily; it can induce congestive heart failure. Sometimes multi-antiarrhythmic drug therapy is needed to control it. Pediatric patients are vulnerable to tachyarrhythmias, especially during the early postoperative period, often resulting in hemodynamic instability.<sup>6)</sup> Acute cardiovascular collapse in pediatric patients with CHD carries a poor prognosis, having an estimated survival rate of 14-41%.<sup>10)</sup> Therefore, in order to maintain a proper postoperative cardiac output and better surgical outcomes, it is necessary to aggressively manage tachyarrhythmia associated with unstable vital signs. Medical management of tachyarrhythmia includes discontinuation of high-dose of inotropics, hypothermia, correction of electrolyte imbalances, and use of anti-arrhythmic agents. Among pharmacologic managements, several studies reported the efficacy and safety of amiodarone in use for postoperative arrhythmias.<sup>11,12)</sup> In our experiences, these medications served no purpose in any of these three patients. If medical treatments fail to control the tachyarrhythmia, immediate MCS such as ECMO or VAD should be considered as therapeutic options.<sup>5,13)</sup>

ECMO has traditionally been utilized for preoperative, intraoperative or postoperative cardiac failure, and cardiomy-

opathies.<sup>14)15)</sup> More recently, the indications for ECMO have expanded to patients with acute cardiovascular decompression including intractable arrhythmias.<sup>16)17)</sup> In these cases, MCS was used to give the heart a period of rest and decompression, until the arrhythmia could be controlled. MCS may also provide sufficient time to achieve efficacy and rate control of the arrhythmia by medical management.

In this study, neurologic complications arose in two patients, because prolonged CPR was performed before MCS was initialized. Although the upper limit of duration of CPR before MCS to predict survival or acceptable neurologic recovery is unknown,<sup>18)</sup> <60 minutes of CPR followed by MCS could be a reasonable, acceptable survival rate.<sup>19)</sup> For a more favorable survival and neurologic outcome, a specialized MCS team and a prepared ECMO circuit would be useful, to decrease the time of CPR to MCS.

Recent technical advances have reduced the frequency of device-related problems associated with MCS. However, complications associated with ECMO therapy still exist. For example, the need for aggressive anticoagulation carries a substantial risk of hemorrhage and stroke. Close monitoring should take place during MCS to reduce the likelihood of these complications.

## Conclusion

Postoperative arrhythmias in pediatric cardiac surgery patients are one of the major causes of morbidity and mortality. MCS should be considered when conventional medical management fails to control arrhythmias. Early intervention and prompt termination of hemodynamically unstable tachyarrhythmia is important for both better survival and a favorable neurologic outcome.

## REFERENCES

- 1) Delaney JW, Moltedo JM, Dziura JD, Kopf GS, Snyder CS. *Early postoperative arrhythmias after pediatric cardiac surgery. J Thorac Cardiovasc Surg* 2006;131:1296-300.
- 2) Lan YT, Lee JC, Wetzel G. *Postoperative arrhythmia. Curr Opin Cardiol* 2003;18:73-8.
- 3) Valsangiacomo E, Schmid ER, Schupbach RW, et al. *Early postoperative arrhythmias after cardiac operation in children. Ann Thorac Surg* 2002;74:792-6.
- 4) Rekawek J, Kansy A, Miszczak-Knecht M, et al. *Risk factors for cardiac arrhythmias in children with congenital heart disease after surgical intervention in the early postoperative period. J Thorac Cardiovasc Surg* 2007;133:900-4.
- 5) Cohen MI, Gaynor JW, Ramesh V, et al. *Extracorporeal membrane oxygenation for patients with refractory ventricular arrhythmias. J Thorac Cardiovasc Surg* 1999;118:961-3.
- 6) Yildirim SV, Tokel K, Saygili B, Varan B. *The incidence and risk factors of arrhythmias in the early period after cardiac surgery in pediatric patients. Turk J Pediatr* 2008;50:549-53.
- 7) Andreasen JB, Johnsen SP, Ravn HB. *Junctional ectopic tachycardia after surgery for congenital heart disease in children. Intensive Care Med* 2008;34:895-902.
- 8) Salim MA, Case CL, Gillette PC. *Chaotic atrial tachycardia in children. Am Heart J* 1995;129:831-3.
- 9) Gouin S, Ali S. *A patient with chaotic atrial tachycardia. Pediatr Emerg Care* 2003;19:95-8.
- 10) Thourani VH, Kirshborn PM, Kanter KR, et al. *Venoarterial extracorporeal membrane oxygenation (VA-ECMO) in pediatric cardiac support. Ann Thorac Surg* 2006;82:138-45.
- 11) Kovacicova L, Hakacova N, Dobos D, Skrak P, Zahorec M. *Amiodarone as a first-line therapy for postoperative junctional ectopic tachycardia. Ann Thorac Surg* 2009;88:616-22.
- 12) Haas NA, Camphausen CK. *Impact of early and standardized treatment with amiodarone on therapeutic success and outcome in pediatric patients with postoperative tachyarrhythmia. J Thorac Cardiovasc Surg* 2008;136:1215-22.
- 13) Tsai FC, Wang YC, Huang YK, et al. *Extracorporeal life support to terminate refractory ventricular tachycardia. Crit Care Med* 2007;35:1673-6.
- 14) Park YH. *Current mechanical circulatory support devices for end stage heart failure. Korean Circ J* 2009;39:1-10.
- 15) Park JI, Jeon ES. *Mechanical circulatory supports in the treatment of fulminant myocarditis. Korean Circ J* 2005;35:563-72.
- 16) Walker GM, McLeod K, Brown KL, Franklin O, Goldman AP, Davis C. *Extracorporeal life support as a treatment of supraventricular tachycardia in infants. Pediatr Crit Care Med* 2003;4:52-4.
- 17) Darst JR, Kaufman J. *Case report: an infant with congenital junctional ectopic tachycardia requiring extracorporeal mechanical oxygenation. Curr Opin Pediatr* 2007;19:597-600.
- 18) Shin JS, Lee SW, Han GS, Jo WM, Choi SH, Hong YS. *Successful extracorporeal life support in cardiac arrest with recurrent ventricular fibrillation unresponsive to standard cardiopulmonary resuscitation. Resuscitation* 2007;73:309-13.
- 19) Shinn SH, Lee YT, Sung K, et al. *Efficacy of emergent percutaneous cardiopulmonary support in cardiac or respiratory failure: fight or flight? Interact Cardiovasc Thorac Surg* 2009;9:269-73.