Reversible cardiac dysfunction associated with physiologic high-rate dual-chamber pacing in an infant with acquired complete atrioventricular heart block

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Introduction

Pacing is relatively uncommon in the neonatal period, with the 2 main indications being either acquired postoperative complete atrioventricular block (CAVB) or congenital antibody-mediated CAVB.[1] The detrimental effect of pacing resulting in dilated cardiomyopathy (DCM) has been increasingly recognized in infants with CAVB requiring pacemaker implantation.[2,3] Minimizing the frequency of ventricular pacing and the use of cardiac resynchronization therapy (CRT) have been demonstrated to be effective interventions to invoke reverse remodeling in adults as well as infants with pacemaker-mediated DCM.[2,4–6] Despite a growing number of reports on infants with CAVB who progressed to develop pacemaker-mediated DCM, the mechanism for this pathology remains unclear and an evidence-based approach for management has yet to be described. Both electromechanical dyssynchrony due to single-site ventricular pacing and high ventricular paced rates have been proposed as potential mechanisms for these observations.[2,7] Most of the reports to date include patients with antibody-mediated AV block, with few describing cases of acquired CAVB. It has been described that patients with antibody-mediated AV block have a degree of myofibrillar hypertrophy prior to pacemaker insertion that can progress to mitochondrial morphologic changes, degenerative fibrosis, and fatty deposition with long-term pacing.[8] Since this could be a confounder in the assessment of ventricular function and remodeling, investigating cases of acquired, as opposed to antibody-mediated, CAVB may be more helpful to understand the underlying pathophysiology of pacemaker-mediated cardiomyopathy. We report a case of DCM in a patient with acquired CAVB that supports the concept that pacing activation at high rates within a normal physiologic range is a significant contributor to the development of DCM in the immature myocardium.

KEY TEACHING POINTS

- Neonates with an immature myocardium may be more susceptible to pacemaker-mediated dilated cardiomyopathy than older children and adults, as the sinus rate can be rapid.
- Both electromechanical dyssynchrony from single-site right ventricular pacing and high-rate ventricular pacing contribute to the development of dilated cardiomyopathy in patients with pacemakers for complete atrioventricular block.
- Pacemaker-mediated dysfunction and dilation from high-rate ventricular pacing is reversible by reducing the upper-tracking rate in a dual-chamber pacing mode.

Case report

A newborn male twin was born with an antenatal diagnosis of d-transposition of the great arteries with intact ventricular septum. Postnatally, the diagnosis was confirmed to be d-transposition of the great arteries with a small perimembranous ventricular septal defect (VSD). He initially underwent a balloon atrial septostomy followed by an arterial switch operation and VSD repair on day 5 of life. The VSD was repaired with a single pledgeted horizontal mattress suture and the cardiopulmonary bypass and cross-clamp times were 138 minutes and 75 minutes, respectively. The coronary arteries were identified intraoperatively to be in a usual orientation and the coronary transfer was uncomplicated. He weaned from cardiopulmonary bypass without inotropes in an

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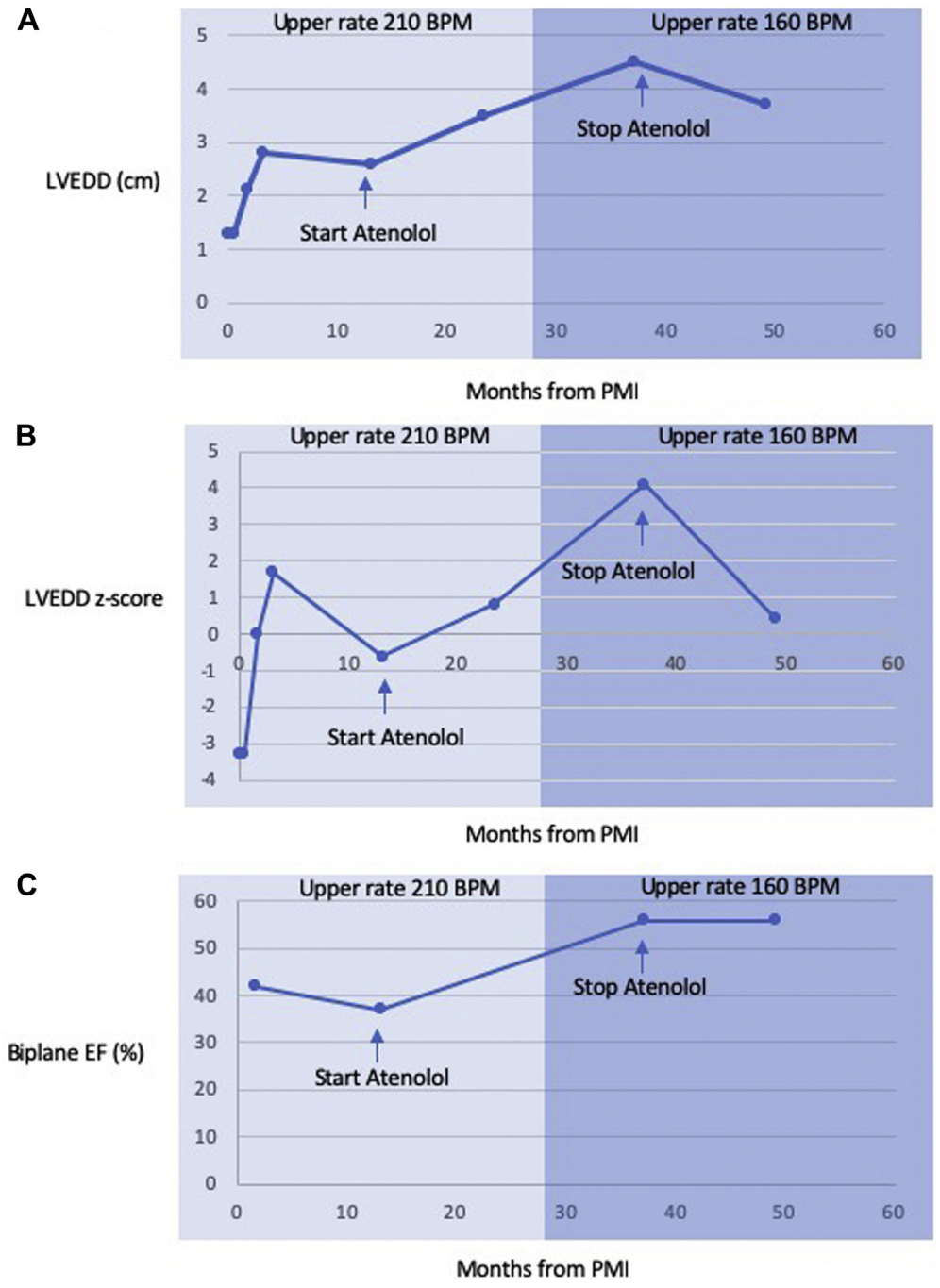

Figure 1 Progression of left ventricular end-diastolic dimension (LVEDD) based on **A:** diameter in cm and **B:** z-score, and **C:** ventricular function based on the biplane ejection fraction (EF) relative to the duration since pacemaker implantation (PMI). The start and discontinuation of atenolol is indicated by the *arrows* in each graph. The transition in shading represents the change in the pacemaker upper tracking rate from 210 to 160 beats per minute (bpm).

accelerated junctional rhythm, and was later found to have CAVB. On postoperative day 4, as per our institutional practice, a dual-chamber pacemaker implantation was performed owing to ongoing CAVB with a junctional escape of 65 beats per minute (bpm). Epicardial pacing leads were placed on the lateral surface of the right atrium and the anterior surface of the right ventricle near the right ventricular (RV) outflow tract. The device was initially set to a DDD mode with a lower rate of 100 bpm and upper tracking rate of 210 bpm and was A sensed and V paced the majority of the time. The lower rate was decreased to 80 bpm 2 weeks after implantation. At this time there was no evidence of ventricular dilation and the ventricular function was within normal limits based on an M-mode ejection fraction of 65%. After 2 months of follow-up, he remained clinically well but was found to have reduced left ventricular (LV) function with a biplane ejection fraction (BPEF) of 42% and ongoing septal dyskinesia (Figure 1). One year after pacemaker implantation, he

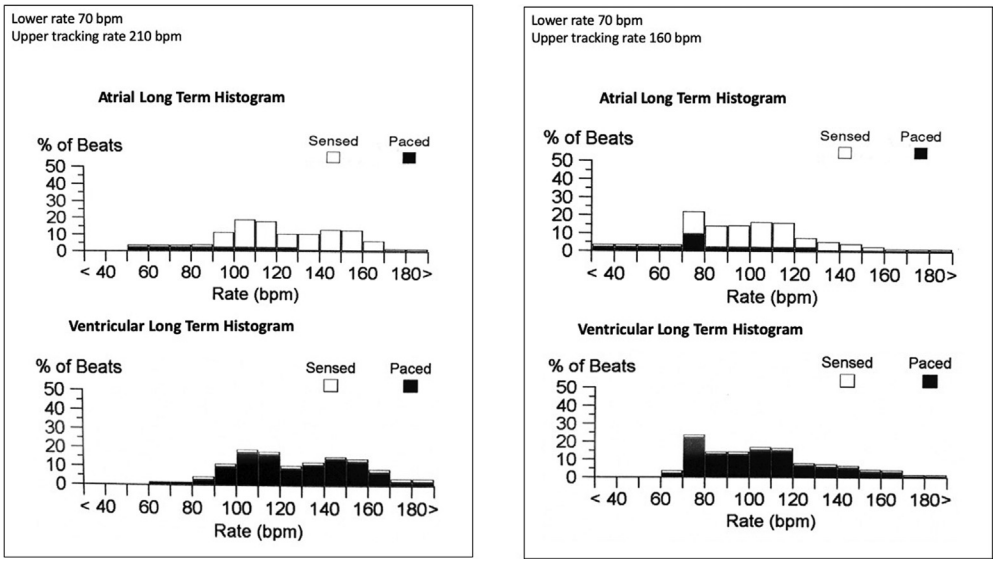

Figure 2 Long-term atrial and ventricular histograms displaying the percentage of sensed and paced beats when the upper tracking rates were programmed to 210 beats per minute (bpm) (left) and 160 bpm (right).

remained clinically well despite a further reduction in ventricular function to a BPEF of 37%. His underlying rhythm remained in CAVB and the pacemaker was programmed to DDD mode with lower rate of 70 bpm and upper rate of 210 bpm. There were no alternative causes for ventricular dysfunction identified, with no events captured on device interrogation that were consistent with an atrial tachyarrhythmia and no residual structural lesions following the arterial switch operation and VSD repair. In particular, there were no symptoms or regional wall motion abnormalities to suggest compromised coronary perfusion. Owing to the ongoing ventricular dysfunction at this time, with a concern that high-rate pacing may be contributing, he was started on atenolol. Over the following year, there was minimal improvement in cardiac function with beta-blocker therapy. Therefore, the upper tracking rate was reduced from 210 bpm to 160 bpm to reduce the average ventricular paced rate. The atrial and ventricular rate histograms from before and after the change in pacemaker settings are shown in Figure 2. The atrial rate distribution appears unchanged between the 2 conditions whereas the ventricular rate distribution shifted to the left, indicating less frequent high-rate pacing when the upper rate was reduced from 210 bpm to 160 bpm. Over a 2-year period, his LV function normalized after a 33% improvement in BPEF (BPEF from 37% to 56%). Despite the improvement in function, the left ventricle remained dilated with an end-diastolic diameter of 4.5 cm (z-score +4.1). The atenolol was discontinued at this time, and his pacemaker settings were kept the same. Within 1 year, the LV function was preserved with a BPEF of 56% and the LV end-diastolic diameter had normalized with a diameter of 3.7 cm (z-score +0.4). Despite the significant changes in the patient's LV function and dimensions over time, he remained asymptomatic throughout this period of follow-up.

Discussion

We describe a patient with acquired CAVB in whom a rapid, but physiologic, pacing rate caused ventricular dysfunction. This was reversed by limiting the upper tracking rate, suggesting that pacemaker-mediated dysfunction in the immature myocardium is affected by heart rate. Tachycardia-induced cardiomyopathy is a well-known complication of incessant arrhythmia, but sinus node–derived rates do not cause this complication. However, the combination of sinus tachycardia and paced activation of the heart that is described by our case can lead to dysfunction and dilation. This is the first report describing improvement in pacemaker-induced DCM in a patient with congenital heart disease following reduction in the upper tracking rate while maintaining a dual-chamber pacing mode. Janoušek and colleagues[2] described a similar case where reverse remodeling of the left ventricle was observed following both the reduction in the paced rate and a change in the pacing mode from dual chamber to single chamber. This report removed both the mechanical dyssynchrony and high paced rates associated with RV pacing, implicating these changes as potential sources of ventricular dysfunction and dilation. Our case provides an example of reverse remodeling with a decrease in the pacing rate while preserving dual-chamber pacing with a single pacing site in the right ventricle. This suggests that ventricular function can be preserved while maintaining the hemodynamic benefit of AV synchrony in a dual-chamber pacing mode as long as a low upper rate is programmed.

Although a beta-blocker was prescribed at the onset of ventricular dysfunction, we attribute the LV remodeling to the change in pacemaker settings. The beta-blocker may have improved the ejection fraction but was unlikely to have contributed to remodeling. This is illustrated by the

timeline for changes in ventricular dimensions with respect to the use of the beta-blocker. This shows that LV remodeling continued well after discontinuation of the medication and, instead, the change in ventricular dimensions correlates well with the adjustment to the pacemaker settings (Figure 1).

Unlike in other similar cases where remodeling was observed over a period of weeks following a change to CRT or VVI with a low back-up rate,[2] the duration for remodeling in our patient was prolonged over a period of 1 year. This may be attributed to the ongoing electromechanical dyssynchrony with single-site RV pacing, making this approach more appropriate for prevention of pacemaker-mediated LV dysfunction or an intervention for asymptomatic patients with evolving LV dysfunction or dilation. This approach was appropriate for our patient, since he was hemodynamically stable and asymptomatic at the time when LV dysfunction was first recognized.

Conclusion

The progression to DCM in patients that require ventricular pacing for CAVB is a well-described complication in infants and children. Understanding this process is especially important in consideration of pacing in neonates, since the incidence of pacemaker-mediated DCM is higher than in older children with a more mature myocardium.[3,9] The mechanism for the development of DCM remains unclear but is believed to be related to 1 or a combination of electromechanical dyssynchrony from single-site RV pacing and high-rate ventricular pacing. CRT and low-rate single-chamber pacing have previously been shown to allow for reverse-remodeling of the left ventricle. We have described a unique case that shows paced activation at high physiologic rates can lead to DCM, and that this process can be reversed with low-rate dual-chamber pacing.

References

1. McLeod KA. Congenital heart disease: Cardiac pacing in infants and children. Heart 2010;96:1502–1508.
2. Janoušek J, Tomek V, Chaloupecký V, Gebauer RA. Dilated cardiomyopathy associated with dual-chamber pacing in infants: Improvement through either left ventricular cardiac resynchronization or programming the pacemaker off allowing intrinsic normal conduction. J Cardiovasc Electrophysiol 2004;15:470–474.
3. Silvetti MS, Drago F, Rav L. Determinants of early dilated cardiomyopathy in neonates with congenital complete atrioventricular block. Europace 2010; 12:1316–1321.
4. Moak JP, Hasbani K, Ramwell C, et al. Dilated cardiomyopathy following right ventricular pacing for AV block in young patients: Resolution after upgrading to biventricular pacing systems. J Cardiovasc Electrophysiol 2006; 17:1068–1071.
5. Tantengco MVT, Thomas RL, Karpawich PP. Left ventricular dysfunction after long-term right ventricular apical pacing in the young. J Am Coll Cardiol 2001; 37:2093–2100.
6. Garg S, Balaji S. Pacing induced ventricular dysfunction in a child: improvement with reduction in paced rate. Pediatr Cardiol 2017;38:1309–1310.
7. Horigome H. Dilated cardiomyopathy in children with isolated congenital complete atrioventricular block. Circ J 2016;80:1110–1112.
8. Karpawich PP, Rabah R, Haas JE. Altered cardiac histology following apical right ventricular pacing in patients with congenital atrioventricular block. Pacing Clin Electrophysiol 2014;1–2.
9. Kim JJ, Friedman RA, Eidem BW, et al. Ventricular function and long-term pacing in children with congenital complete atrioventricular block. J Cardiovasc Electrophysiol 2007;18:373–377.