Introduction

Bundle branch re-entry ventricular tachycardia (BBRVT) is a unique type of ventricular tachycardia (VT) that employs both bundles and the ventricular septum as integral components of a re-entrant circuit. Tchou and Mehdirad\(^1\) described three categories of BBRVT (Figure 1). The most commonly reported VT morphology is that of left bundle branch block (LBBB)-like pattern (type A), which activates the right bundle branch (RBB) in an antegrade direction and the left bundle branch (LBB) in a retrograde fashion. Type C employs the LBB for antegrade activation and the RBB for retrograde activation, thus giving a right bundle branch block (RBBB)-like VT morphology. BBRVT has been reported to occur in patients with varying degrees and types of structural heart disease in whom the His–Purkinje system (HPS) is affected.\(^2\)\(^-\)\(^5\) The electrocardiographic expression of HPS disease is quite variable, with most patients expressing some degree of intraventricular conduction delay in the form of LBBB or RBBB with or without PR prolongation and rarely in a patient with persistent complete heart block.\(^6\) We report a patient in whom BBRVT storm developed during the recovery phase of unexplained, transient complete heart block. Patient exhibited both type A and type C VT morphologies and was successfully treated by radiofrequency ablation (RFA) of RBB.

Clinical case

A 22-year-old obese gentleman with no significant past cardiac history was admitted with recurrent syncope while playing video games. Upon presentation to the emergency room his underlying rhythm was sinus with LBBB. In the emergency room, the patient again experienced recurrent syncope associated with episodes of complete heart block (Figure 2). Some of these events were associated with protracted episodes of ventricular asystole requiring cardiac resuscitation and placement of a temporary transvenous pacemaker. Hospital work-up failed to reveal a cause for the patient’s heart block (normal chemistries, TSH, negative Lyme disease serologies including Western blot, negative blood cultures, and normal chest X-ray). The patient exhibited no symptoms of systemic sarcoid, and cardiac magnetic resonance imaging (MRI) was not performed because of ongoing pacing needs. Coronary angiography was normal and transthoracic echocardiogram was significant for a heavily calcified, mildly stenotic bicuspid aortic valve. On hospital day 2, atroventricular (AV)
conduction recovered with residual RBBB. An attempt at removal of the temporary pacemaker was met by recurrence of cardiac arrest due to intermittent complete heart block. On hospital day 3, the patient underwent an uneventful dual-chamber pacemaker implant. The following day, the patient began to experience frequent episodes of sustained VT with rates between 230 and 270 bpm, which were fairly well tolerated by the patient while in bed (Figure 3). Both RBBB- and LBBB-like VT morphologies were observed. The RBBB morphology VT exhibited a similar QRS morphology to that in sinus rhythm (Figure 4). Most episodes terminated spontaneously or were terminated with manual overdrive pacing via the permanent pacemaker. In spite of intravenous amiodarone administration, a few prolonged episodes required external cardioversion. The patient then underwent an electrophysiology study (EPS) where a PR interval of 190 ms with QRS duration of 135 ms (RBBB) and an HV interval of 78 ms were recorded. Atrial pacing at a cycle length of 360 ms produced AV block. An LBBB morphology VT was readily inducible with programmed right ventricular stimulation using short–long–short sequences. Despite aggressive stimulation, the RBBB morphology VT was not induced. During VT, entrainment pacing was initially performed from the right ventricular (RV) apex and later, due to catheter migration, from the superior mid-RV septum. Entrainment from both of these sites yielded a similar post-pacing interval (PPI) (Figure 5). During transient entrainment, two of the four entrainment criteria were demonstrated with pacing from the superior mid-RV septum (Figure 6). At this catheter location, a RBB potential was able to be recorded during tachycardia with a RBB potential–QRS interval of 35 ms.

**Figure 1:** Categories of bundle branch re-entry ventricular tachycardia. Type A employs the right bundle branch for antegrade conduction thus giving a left bundle branch block-like morphology also described as counterclockwise activation. Type B involves re-entry within the fascicles of the left bundle branch (LBB) (fascicular VT). Type C employs the LBB for antegrade activation, thus giving a right bundle branch block-like morphology also described as clockwise activation.

**Figure 2:** A three-lead rhythm strip recorded in the emergency room during an episode of syncope. From top to bottom leads II, MCL1, and lead I. Sinus tachycardia with left bundle branch block and first-degree AV block precedes an episode of complete heart block.
Figure 3: Spontaneous ventricular tachycardia (VT) noted on telemetry within 24 h after pacemaker implant. (a) A right bundle branch block-like VT and (b) a left bundle branch-like VT. Note baseline right bundle branch block in sinus rhythm.

Figure 4: Twelve-lead electrocardiogram during sinus rhythm, type C and type A bundle branch re-entry ventricular tachycardias (BBRVTs). Note similarity of QRS morphology of type C BBRVT and SR.
Figure 7. Spontaneous perturbations in cycle length during tachycardia were observed with RBB potential–RBB potential changes preceding R-R changes. Information gathered from the EPS was consistent with a re-entrant VT within the HPS with antegrade RBB activation and retrograde activation via LBB (type A bundle branch re-entry). RFA was performed during sinus rhythm targeting the RBB potential, which was difficult to localize due to baseline RBBB. During RFA, no further change in RBBB morphology was noted. Post ablation, VT was not inducible with aggressive stimulation. The following day, the pacemaker was explanted and replaced with an implantable cardioverter-defibrillator (ICD) at the request of the family. Within 24 h following the ICD implant, the patient experienced numerous VT episodes: most episodes were pace terminated and some were treated with ICD shocks. The patient was emergently taken for a second EPS where both type A and type C BBRVTs were induced. Entrainment from the RV apex of both types of VTs yielded a similar PPI (Figure 8). A visible RBB potential preceding the QRS onset was again evident during type A BBRVT. RFA targeted the RBB potential led to a clear increase in QRS duration to 156 ms (Figure 9). Post
A First criterion of entrainment

B Second criterion of entrainment
Ablation, VT was rendered non inducible. No further VT episodes have been documented on device interrogation during a follow up period of 24 months with no antiarrhythmic agents. The patient has also been free of AV block as his ICD follow-up data-documented RV pacing at less than 1% since device implantation.

**Discussion**

BBRVT has been described to occur in patients with a wide spectrum of underlying structural heart disease. The unifying theme in this patient population is the occurrence of HPS conduction delay—usually in the form of bundle branch block (without bidirectional block on either of the bundles or concordant unidirectional block on both bundles) that serves as the milieu for re-entry within the bundles. Recognition and diagnosis of this arrhythmia is crucial as BBRVT is readily amenable to catheter ablation, thus sparing patients from the unnecessary grief of less effective or less desirable therapies such as antiarrhythmic drug therapy or ICD shocks.

Our case study provides an interesting clinical and diagnostic observation in regards to BBRVT. From a clinical standpoint, the observation of BBRVT storm during the recovery phase of heart block raises awareness for BBRVT as a potential cause of VT storm in patients with HPS disease. This is an interesting facet of BBRVT which was not well appreciated previously and
deserves attention. Indeed, Sakata et al.\textsuperscript{9} reported a 12.5\% incidence of BBRVT among patients with VT clusters when compared with other series of recurrent VT referred for VT ablation where the incidence of inducible BBRVT was 6.7–8.5\%. A high incidence of BBRVT has also been reported by Reithmann et al.\textsuperscript{10} on a series of four ICD patients with VT storm in whom all had inducible BBRVT and/or interfascicular re-entrant VT at time of electrophysiology evaluation. Reinitiation of ventricular macro-reentry within the HPS by back-up ventricular pacing appeared to be the mechanism of VT storm in these patients. Other case reports have also emphasized the incessant presentation of BBRVT.\textsuperscript{11} Incomplete recovery of the RBB appeared to have played a key role in creating a substrate favorable for BBRVT in our patient as the repetitive VT episodes were not initiated by back-up ventricular pacing (Figure 3) and creation of complete RBBB with RFA eliminated both

\begin{figure}[h]
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\includegraphics[width=\textwidth]{figure8.png}
\caption{Paper speed 100 mm/s. Last three entrainment beats shown. (a) Pacing cycle length 230 ms, ventricular tachycardia (VT) cycle length 250 ms and post-pacing interval (PPI) of 260 ms. (b) Pacing cycle length 230 ms, VT CL of 250 ms and PPI of 250 ms.}
\end{figure}
types of VT. Thus, bidirectional block along a bundle is protective. From a diagnostic standpoint, an interesting observation was made during entrainment of this arrhythmia. While most criteria for the diagnosis of BBRVT involve assessment of the relationship of the HPS recording to arrhythmia activity or sequence of HPS activation during tachycardia, it is at times difficult to record His or RBB potential during tachycardia. Under such circumstances, entrainment from the RV apex with a PPI minus VT cycle length of $30\text{ ms}$ has been reported to be suggestive of BBRVT. In our case, entrainment of type A VT from the RV apex and mid-superior RV septum yielded a similar PPI which was nearly identical to VT cycle length. This finding of a short PPI from the superior mid-RV septum has not previously been described and is not attributed to direct capture of RBB during entrainment from this site (Figure 10). This is evident from the observations of the timing of the RBB potential preceding the pacing artifact and the timing of the RBB potential on the last entrained beat that arrived at the pacing rate consistent with orthodromic capture of the RBB during

Figure 9: Paper speed 50 mm/s. From top to bottom, leads I, V1, and V3. Note further widening of the terminal part of the QRS during radiofrequency ablation (arrow) creating complete right bundle branch block.

Figure 10: Paper sweep speed 200 mm/s. From top to bottom leads I, II, aVF, aVR, V1, and right ventricular (RV) proximal and distal bipoles. RV catheter at mid-superior RV septum. Last two beats of entrainment of type A bundle branch re-entry ventricular tachycardia shown. During entrainment of ventricular tachycardia, the RBB potential precedes the pacing artifact. The last entrained beat (large arrow) with RB potential arriving at same rate as the paced rate consistent with orthodromic capture of the RB during entrainment. Pacing at CL of 260 ms. Tachycardia CL 271 ms. Post-pacing interval 272 ms.
entainment. These findings suggest that there are other regions along the RV septum from which entrainment maneuvers can yield a similar PPI to that obtained from the RV apex in patients with BBRVT. It is likely that a large portion of the septum lies within the path of activation between the multiple exit points and entrance sites of the bundles and here forms a broad circuit from which entrainment would yield a short PPI. Further studies are needed to validate this finding.

**Conclusion**

BBRVT can manifest as a VT storm during the recovery phase of transient complete heart block and should be carefully assessed during EPS, especially in patients with HPS conduction disease as curative treatment is readily achieved with RFA of the RBB. Entrainment from the mid-RV septum in patients with BBRVT can yield a PPI that is similar to VT cycle length, but further studies are needed to validate this observation.

**References**

5. Matsuoka K, Fuji E, Uchida F. Successful radiofrequency catheter ablation of “clockwise” and “counterclockwise” bundle branch re-entrant ventricular tachycardia in the absence of myocardial or valvular dysfunction without detecting bundle branch potentials. Heart 2003; 89:e12.