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Right Bundle Branch Block Morphology After Right Ventricular Endocardial Pacing – When Should a Cardiologist Begin to Worry ?

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Abstract

Even though the left bundle branch block (LBBB) morphology in the surface electrocardiogram (ECG) is expected after right ventricular endocardial pacing, the right bundle branch block (RBBB) morphology may be paradoxically seen in around 8 to 10% of patients. The paced RBBB morphology should be given special attention in terms of safe RV pacing or septal and free wall perforation. Simple techniques such as moving the leads V1-2 to one interspace lower than standard (Klein maneuver) and combining frontal QRS axis between -30◦ to -90◦, precordial transition point at or within V3, and absence of S wave in lead I as an algorithmic approach may correctly identify the pacemaker lead in right ventricle with high sensitivity, specificity, and positive predictive value.

Keywords: Right Bundle Branch Block Morphology; Right Ventricular Endocardial Pacing.

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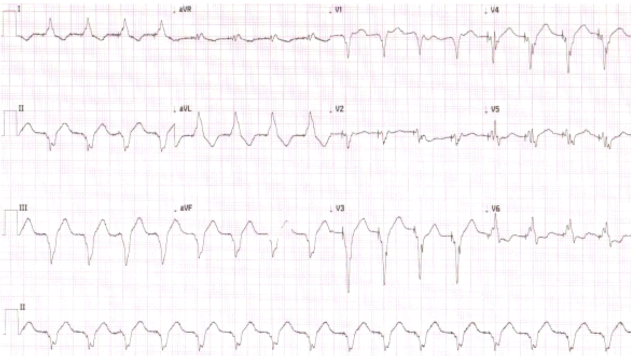
Introduction

The Left Bundle Branch Block (LBBB) pattern in the surface electrocardiogram (ECG) is the usual expected morphology after transvenous right ventricular (RV) pacing with pacemaker capture. Owing to the fact that the tip of the RV pacing lead lies close to the right bundle branch of the native conduction system, the left bundle branch gets activated later and hence produces a LBBB pattern. In contrast, the Right Bundle Branch Block (RBBB) pattern is an unexpected finding.[1] Paced RBBB pattern can represent left ventricular (LV) pacing due to either perforation of the RV septal or free wall or inadvertent positioning of the ventricular lead in the coronary sinus.[2,3] In addition to it, pacing lead in the LV through a retrograde transarterial route or intracardiac defects such as a patent foramen ovale (PFO) or ventricular septal defect (VSD) are also the causes of paced RBBB.[4,5] However, RBBB patterns in RV pacing can occur rarely despite correct placement of the ventricular lead.[6] A study conducted by Coman et al[7] found out that the incidence of paced RBBB in RV apical pacing was 8 percent. Therefore, the evaluation becomes crucial to find out whether the paced RBBB pattern is the result of an uncomplicated transvenous RV pacing or due to lead malposition or perforation.

The Normal QRS Patterns During Right Ventricle Pacing

Regardless of the site in RV, RV pacing produces LBBB morphology in the precordial leads defined as the absence of a positive complex in lead V1 recorded in the fourth or fifth intercostal space.[8] During RV apical pacing, the depolarization begins in the inferior part of the heart and travels superiorly away from the inferior leads. Hence, the paced QRS complexes in the inferior leads (II, III, aVF) are inscribed negative. The frontal plane axis of the paced QRS complex is always superior, usually in the left (Figure 1), or less commonly in the right superior quadrant.[9]

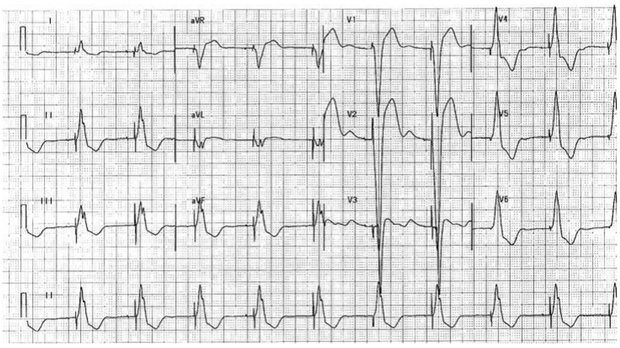
Figure 1.[10] A 12-lead ECG showing RV apical pacing with negative QRS complexes in leads II, III, and aVF.



The Normal QRS Patterns During the Right Ventricle Outflow Tract (RVOT) Pacing

The RVOT pacing shifts the frontal plane paced QRS axis towards the left inferior quadrant and the inferior leads show positive paced QRS complexes (Figure 2). In addition to it, RVOT pacing may also generate qR, QR, or Qr complexes in leads I and aVL.[8] These patterns in lead I and aVL must not be interpreted as a sign of myocardial infarction.[11]

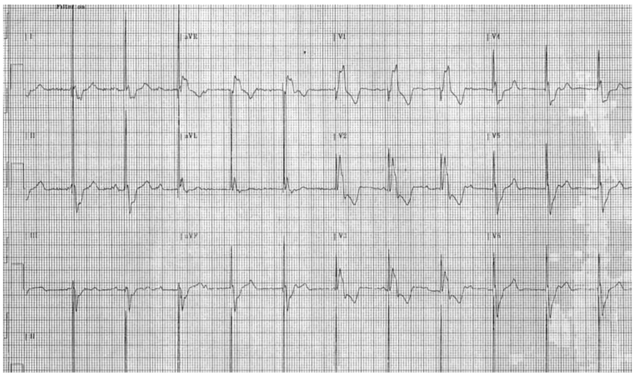
Figure 2.[9] A 12-lead ECG showing RVOT pacing with positive QRS complexes in II, III, and aVF.



The Normal QRS Patterns During Left Ventricular (LV) Pacing

A paced RBBB pattern is seen in the right precordial leads (Figure 3) which are not eliminated when leads V1 and V2 are recorded one intercostal space lower. The RBBB morphology and frontal plane axis cannot differentiate whether the pacing lead is in LV endocardium or in the coronary venous system.[12] In such an instance, an endocardial LV lead is easily diagnosed with transesophageal echocardiography.[13] An endocardial LV lead is a potential source of cerebral emboli. In symptomatic patients, removal of lead after a period of anticoagulation should be considered. However, in asymptomatic or frail elderly patients, long-term anticoagulation is the best therapy.[14]

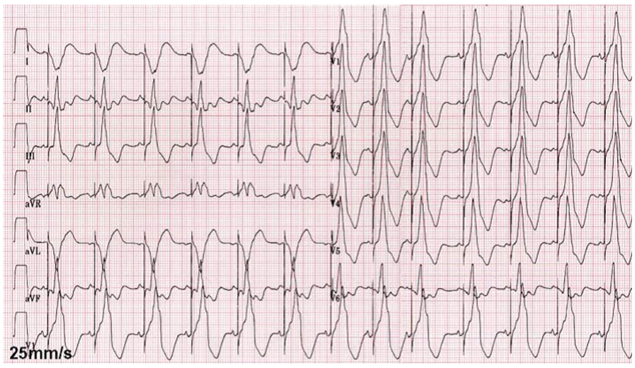
Figure 3.[15] A 12-lead ECG showing LV pacing.



The Normal QRS Patterns During LV Pacing from the Coronary Venous System

The coronary sinus pacing produces paced RBBB morphology in V1 but the QRS complex may or may not be positive in V2 and V3. The apical LV pacing produces negative QRS complexes in leads V4 to V6 while the basal LV pacing (Figure 4) produces positive QRS complexes in the same leads.[16] What is of interest is that a paced LBBB morphology can be appreciated with LV pacing when the pacing is from the middle and the great cardiac veins.[17] The paced frontal plane often shows a right axis deviation.[9]

Figure 4.[9] A 12-lead ECG showing RBBB with right axis deviation and positive precordial concordance consistent with LV pacing from the coronary sinus with basal LV pacing.



Paced RBBB in an Uncomplicated RV Pacing

A dominant R wave in lead V1 and V2 recorded in fourth intercostal space during RV pacing is known as RBBB pattern of depolarization. Although rare, uncomplicated RV apical pacing may paradoxically show RBBB morphology.[6] This pattern is present in approximately 8% to 10% of patients with uncomplicated RV pacing.[9]

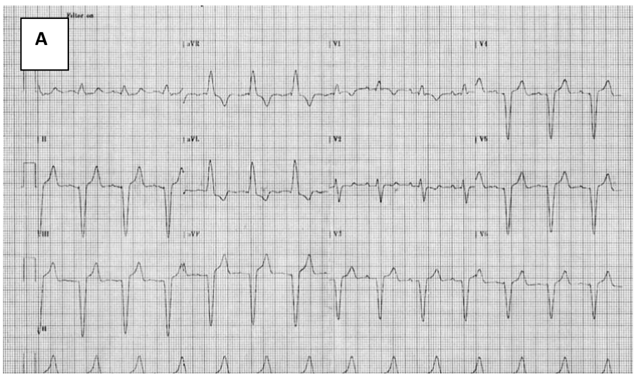
Several hypotheses have been proposed to explain RBBB morphology in cases of uncomplicated RV pacing. One plausible mechanism is that the portions of the interventricular septum which are anatomically right ventricle may behave functionally and electrically as left ventricle thereby depolarizing the left ventricle first. This would impart RBBB morphology in the surface ECG.[3] Another hypothesis suggests that the pacemaker stimulus may enter the right bundle branch and then travel in a retrograde direction to the AV junction and down the left bundle branch.[18] An alternative explanation for the RBBB pattern could be the result of a combination of RV activation delay due to severe disease of the RV conduction system and early penetration of the electrical impulse into the LV conduction system.[2] Similarly, higher placement of precordial lead (i.e. in 2nd or 3rd intercostal spaces) or development of ventricular fusion beat too produces RBBB morphology.

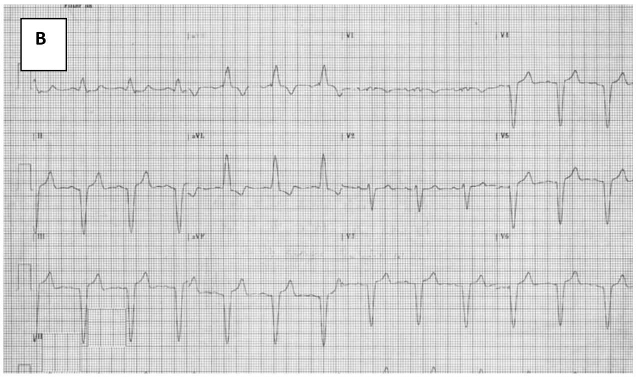
Discussion

Although a left bundle branch block (LBBB) is an expected morphology on the surface ECG after RV endocardial pacing, a right bundle branch block (RBBB) morphology can also be seen in around 8 to 10% of patients.[9] The RBBB configuration on the surface ECG may signify both complicated (septal and free wall perforation with subsequent LV pacing) and uncomplicated clinical situations. Positioning the ventricular lead inadvertently in the left ventricle may create serious clinical problems and require life-long anticoagulation or lead extraction. Fortunately, not all RBBB morphology is associated with LV pacing. Rather, most of the patients have RV leads in the correct position inside the heart.

There are a number of ECG features that have been reported to predict an uncomplicated RV apical pacing when the paced QRS has a RBBB configuration. A study conducted by Klein et al.[19] reported eight patients with RBBB pattern in leads V1-2, LBBB pattern in lead I, and pacing lead located in the RV apex. It was named as a "pseudo-RBBB" pattern which indicated that RV depolarization had preceded LV activation, and therefore perforation or malposition of the pacing lead had not taken place. They also recognized that the placement of leads V1 and V2 one interspace lower than the standard location could eliminate RBBB pattern with inscription of deep QS or rS complexes in V1-V2; as a consequence there of, it is now also known as the Klein maneuver (Figure 5). With this maneuver, the ventricular activation is superiorly and anteriorly oriented which forms the basis for disappearance of RBBB morphology.[20] In yet another study it was shown that 48% of patients with RBBB pattern in V1-2 had the contour eliminated with the Klein maneuver.[15] In sharp contradistinction to it, Yang et al. have reported on one patient whose RBBB pattern did not change with this technique despite the fact that the lead was in the RV apex.[6]

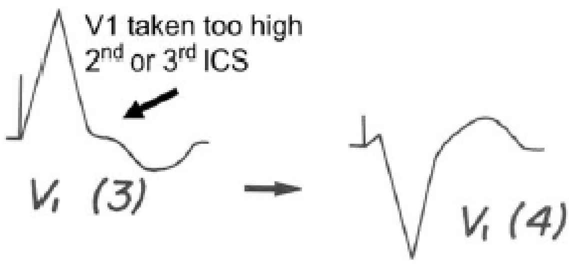
Figure 5.[15] Klein Maneuver. A. RBBB pattern in V1. B. elimination of RBBB pattern after placement of leads V1-2 one interspace lower than standard.





On the other hand, placing the leads one space higher than the usual space will further enhance the height of the R wave which would normalize after placing them in the correct position (i.e. in 4th interspace),[19] as shown in Figure 6 below.

Figure 6. Tall R wave in V1 in higher interspace which normalized by placing in the 4th interspace.



A somewhat similar study conducted by Coman et al.[7] reported seven cases of RBBB pattern during permanent RV pacing. Similar to the previous study, there was disappearance of RBBB morphology and inscription of QS or rS complexes in V1-2 when the leads were placed one interspace lower than the standard position. The pacemaker lead in them was found to be located in the distal RV septum or apex. However, it was noticed that RBBB pattern was not eliminated by placing the leads one interspace lower in four patients in whom the pacemaker lead was found to be located in the mid-septum. Hence, it was also concluded that the Klein maneuver reliably distinguished patients with mid-septal leads from those with leads in the distal septum and apex.

Similarly, the other ECG feature of an uncomplicated RV pacing is the QRS axis between -30° and -90° in the frontal plane, i.e. left axis deviation. In other words, the maximal QRS vector should be oriented to left, superior, and anterior. However, with a paced RBBB pattern and the maximal QRS vector oriented to the right, inferior, and posterior may be a warning sign of perforation of right ventricle.[21]

In addition to it, Coman et al.[7] also found out that the frontal plane axis of 0° to -90° along with precordial transition lead (where R wave amplitude is equal to S wave amplitude) by V3 may be able to differentiate uncomplicated RV septal or apical pacing from all other forms of LV pacing (including coronary veins) with a sensitivity of 86%, specificity of 99%, and positive predictive value of 95%. The same frontal axis of 0° to -90°, but precordial transition after V4, indicated pacing in the middle cardiac vein or posterior and posterolateral wall of LV (sensitivity 72%, specificity 100%, and positive predictive value 100%). A frontal axis between -90◦ and -180◦ or between 90◦ and 180◦ indicated other locations of LV pacing.

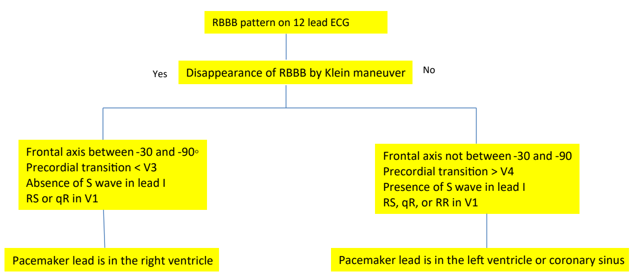
In yet another study conducted by Okmen et al.[15] reported that the location of pacemaker lead could be detected correctly by surface ECG in patients with RBBB pattern during pacemaker capture. The useful parameters for differentiation of RBBB morphology with RV stimulation from LV stimulation were: a) Frontal axis, b) QRS morphology in leads V1 and I, and c) Precordial transition point. The study revealed that of all the patients with RBBB pattern with pacemaker lead in the RV, a frontal axis between -30◦ to -90◦ was found in 96%, the precordial transition point at V3 in 96%, RS configuration in V1 in 64%, and absence of S wave in lead I in 96%. The sensitivity, specificity, and positive predictive value (PPV) of these parameters are shown below in Table 1.

Table 1.[15] The Sensitivity, Specificity, and PPV of the criteria used to identify RV placement of the electrode in the presence of RBBB pattern.

	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)
Frontal axis -30◦ to -90◦	97	100	100
Precordial Transition V3	97	100	100
Absence of S Wave in I	94	100	100
RS in V1	54	25	67
qR in V1	20	83	77

Finally, an electrocardiographic algorithm was developed in order to locate the pacemaker lead in patients with paced RBBB pattern with RV pacing. It is shown in the figure 7 below.

Figure 7.[15] An ECG algorithm to locate the pacemaker leads in patients with paced RBBB pattern.



When the lead position can hardly be determined by the above ECG parameters, the chest x- ray, echocardiography, and fluroscopy can correctly aid to locate the pacemaker lead (Figure 8-10).

Figure 8.[22] A. Postero-Anterior View and B. Lateral View of CXR showing the RV lead oriented antero-inferiorly, consistent with RV apical location. Black arrow indicates the tip of the ventricular lead.

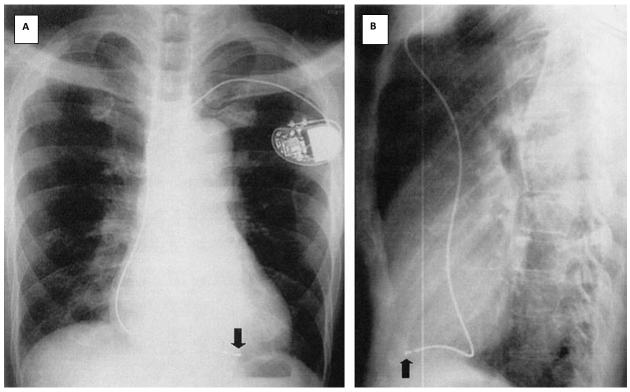


Figure 9. [23] 2D Transthoracic echo: Subcostal view (a) and apical 4 chamber view (b) demonstrating and confirming the ventricular pacing lead going from right atrium to right ventricle with its tip located in the apical position.

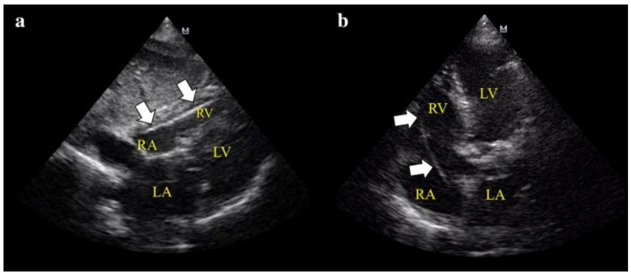
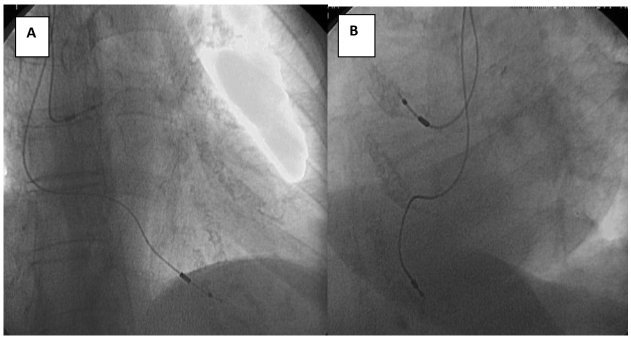


Figure 10.[24] Fluroscopic Views: A. RAO 30◦ shows the ventricular lead oriented anteriorly and inferiorly in the RV apex. B. LAO 45◦ shows the ventricular lead in infero-apical position consistent with placement in RV apex.



Conclusion

A paced RBBB contour after RV apical pacing does not always signify left ventricular pacing due to malpositioned ventricular lead. However, a red flag is often raised to rule out a septal or free wall perforation. The location of pacemaker lead can be accurately predicted by following the electrocardiographic algorithm and performing the Klein maneuver that might reduce unnecessary radiation exposure from chest x-ray or fluoroscopy and help eliminate inappropriate anticoagulation or lead extraction. However, when in doubt, chest x-ray, echocardiography, and fluoroscopy should be done to correctly localize the site of pacemaker lead. To conclude, the answer to the question raised in the title of the paper lies in the fact that disappearance of RBBB with Klein maneuver, a frontal plane axis of -30◦ to -90◦, precordial transition point by V3, and absence of S wave in lead I need not be a cause of concern and worry to a cardiologist.

Conflict of Interest: None
Acknowledgement: None

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