Electrocardiographic Analysis of Paced Rhythms

Correlation with Intracardiac Electrograms

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KEYWORDS

- QRS morphology • Ventricular pacing • Biventricular pacing
- BiV responders pacemaker-mediated tachycardia • Intracardiac electrograms

KEY POINTS

- Review of the 12-lead electrocardiogram is useful for determining the site of pacing.
- A right bundle branch block pattern may rarely be seen in patients when the right ventricular pacing lead is in the right ventricle.
- The QRS morphology in V_1 is useful for determining the site of left ventricular pacing.
- A variety of device-specific, or company-specific, algorithms may be programmed on to prevent pauses, atrial fibrillation, or minimize ventricular pacing.
- Familiarity with these device-specific algorithms is necessary to avoid the mistaken diagnosis of device failure.

ELECTROGRAMS FROM IMPLANTED DEVICES

Intracardiac electrograms are produced by the movement of electrical current through the myocardium. As a wavefront of depolarization travels toward an endocardial electrode in contact with myocardium, it is manifested as a positive deflection and as the wavefront passes under the electrode, a brisk negative deflection is recorded. The intrinsic deflection recorded in the pacemaker and implantable cardioverter defibrillator (ICD) electrodes are predominantly biphasic in nature. Whereas the surface electrocardiogram (ECG) records the electrical activity from the entire heart (smaller in amplitude), the intracardiac electrogram records only local wavefronts (larger amplitude).

Unipolar and Bipolar Electrograms

A unipolar signal is recorded from 1 electrode in contact with the myocardium (tip electrode) and the other on the pulse generator while the bipolar electrogram is recorded between the 2 electrodes

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within the heart. Because the distance between the electrodes in the unipolar configuration is large, it may detect electrical signals that originate far from the tip electrode inside the heart (far-field R waves in an atrial lead, T waves in the ventricle) or outside the heart (local skeletal myopotentials in the pocket, diaphragmatic myopotentials). Oversensing of far-field signals are not unique to unipolar sensing and may occur in bipolar configuration, leading to altered device function. Current generation pacemakers and ICDs are capable of providing real-time, near-field, bipolar, and unipolar electrograms from the right atrium, right ventricle (RV), and left ventricle (LV), in addition to far-field electrograms from the device and the shocking coils in the RV and SVC (superior vena cava). In addition, some of these are also available as stored electrograms during an arrhythmic event, greatly improving the device's diagnostic accuracy.

In addition to sensing or pacing dysfunction leading to abnormal surface ECGs, several algorithms programmed in a device may result in what seems to be abnormal device function (autocapture, ventricular pacing avoidance algorithms, mode switch, His bundle pacing, biventricular [BiV] pacing, etc) can lead to unusual ECG findings that may confuse a casual interpreter. To correctly interpret paced ECGs, one has to be familiar with various basic functioning of cardiac implantable electronic devices (pacemaker and ICD). The appearance of the ECG in a paced patient depends on the pacing mode used, placement of pacing leads, device pacing thresholds, and the presence of native electrical activity.

EFFECT OF VENTRICULAR PACING SITE ON ECG

Typically, a ventricular pacing lead is placed in the RV apex. RV apical pacing results in left bundle branch block (LBBB) pattern with left axis deviation characterizing the ventricular activation wavefront traveling from apex to base of the heart. In contrast, if the lead is placed in the RV outflow tract, it results in a LBBB pattern with right axis deviation depicting superior to inferior spread of the activation wavefront. A right bundle branch block pattern noted during attempted RV pacing should raise concern for inadvertent LV pacing (**Box 1**). Although a RBBB pattern can occur during conventional RV apical pacing in 10% to 20% of cases,[1,2] this scenario has to be excluded by careful evaluation of ECG, echocardiogram, and radiographic images (**Fig. 1**). This pattern can also be owing to placing lead V_1 too high in the second or third intercostal space. A tall R wave in V_3 and V_4 would invariably signify that the pacing lead is not in the RV.

Box 1
Causes of right bundle branch block pattern on ECG during right ventricular (RV) pacing

1. RV lead placement in the middle cardiac or posterior LV branch of the coronary sinus.
2. Lead placement via the subclavian artery into the left ventricle.
3. Lead placement via patent foramen ovale or atrial septal defect into the left ventricle.
4. Possible lead perforation of the RV apex or interventricular septum.
5. Uncomplicated RV apical pacing.
6. High placement of ECG electrode V1.

Abbreviation: LV, left ventricular.

His Bundle and Para-Hisian Pacing

Selective site pacing is currently feasible with the availability of specifically designed pacing leads and catheter delivery systems. Direct His bundle pacing can result in ventricular pacing spikes followed by isoelectric interval of 30 to 60 ms duration followed by QRS complexes similar to native morphology.[3] Differential diagnosis in this situation should include failure of capture by ventricular pacing followed by native conducted complex. Para-Hisian pacing results from capture of the His bundle with intrinsic conduction along with fusion from basal septal myocardial capture. The ECG demonstrates a slight increase in QRS amplitude with the axis concordant with the native complex and evidence for delta waves suggesting fusion.[4] Usually, no isoelectric interval is noted between pacing spike and QRS onset. In the absence of a visible pacing spike, the ECG can be mistaken for septal preexcitation (**Fig. 2**). By utilizing the His-Purkinje conduction system, pacing results in minimal or no ventricular dyssynchrony.

BiV Pacing

Electrocardiographic analysis of BiV paced rhythm is critical in the evaluation of cardiac resynchronization devices during implant and follow-up, and for troubleshooting. BiV pacing with the RV lead in the apex and LV lead in the posterior or posterolateral veins usually results in right superior axis deviation (-90° to -180°), and the QRS complex is positive or dominant (R or Rs) in V1.[5] A negative paced QRS complex (LBBB pattern) in lead V_1