

Crossing of strength–duration curves with His bundle pacing and impact of pacing mode on thresholds



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Introduction

His bundle pacing (HBP) is increasingly being adopted as an alternative for right ventricular pacing, as it avoids its deleterious effects by recruiting the intrinsic conduction tissue to activate the ventricles. A prerequisite is capture of conduction tissue, which must be confirmed by careful observation of the 12-lead electrocardiogram during threshold tests.

HBP may capture conduction tissue only (selective His bundle pacing, S-HBP) or also capture myocardial tissue (nonselective His bundle pacing, NS-HBP).¹ The transitions that can be observed with decreasing output before loss of capture are *either* from NS-HBP to S-HBP *or* from NS-HBP to myocardial capture only, depending on the relative thresholds of the tissues.²

We present a patient in whom we report for the first time transitions *both* from NS-HBP to S-HBP and from NS-HBP to myocardial capture only by pacing at different combinations of voltage output and pulse widths. Also, we report for the first time that His bundle and local myocardial thresholds were lower when testing in VVI compared to DDD mode.

Case report

A 52-year-old patient was implanted with HBP (cardiac resynchronization therapy pacemaker device with the His bundle lead connected to the left ventricular port and the atrial and backup right ventricular [RV] leads in their respective ports) for idiopathic third-degree atrioventricular (AV) block (Figure 1). He had junctional escape rhythm with right bundle branch block morphology. During implantation, we obtained NS-HBP with His bundle and myocardial thresholds of 2 V/0.4 ms and 0.8 V/0.4 ms, respectively. Decrementing the

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KEY TEACHING POINTS

- With His bundle pacing, strength–duration curves of the His bundle and the adjoining myocardium may cross, as there is no physiological reason for them to be parallel.
- Crossing of strength–duration curves results in different transitions in QRS morphology with decrementing output of His bundle pacing, depending upon the programmed pulse width.
- His and myocardial thresholds can vary considerably depending upon the pacing mode (DDD or VVI) that is programmed during the test, probably owing to differences in atrioventricular synchrony and contact of the His lead. Until the prevalence of this finding is determined, it is wise to perform threshold tests in the mode that is permanently programmed.

pacing voltage at 0.4 ms resulted in a transition from NS-HBP to myocardial capture only.

During device follow-up, because of the relatively elevated His bundle threshold, we performed threshold tests at different pulse widths and noticed transitions *both* from NS-HBP to S-HBP *and* from NS-HBP to myocardial capture only, with different pulse width and voltage output combinations (Figure 2). Subsequently, we constructed strength–duration curves for the His bundle and local RV myocardium by assessing capture thresholds throughout the whole programmable voltage range and at several pulse widths during unipolar VVI and DDD pacing at 80 beats per minute (Figure 3). Standard 12-lead electrocardiogram criteria were used to differentiate between NS-HBP, S-HBP, and pure myocardial capture.¹

At pulse widths at and above 0.3 ms, the His bundle threshold was *higher* than the myocardial threshold, resulting in QRS transition from NS-HBP to myocardial capture only (Figure 2, upper panel). However, when pacing at a pulse duration below 0.3 ms, the His bundle threshold was *lower* than the myocardial threshold, resulting in transition from

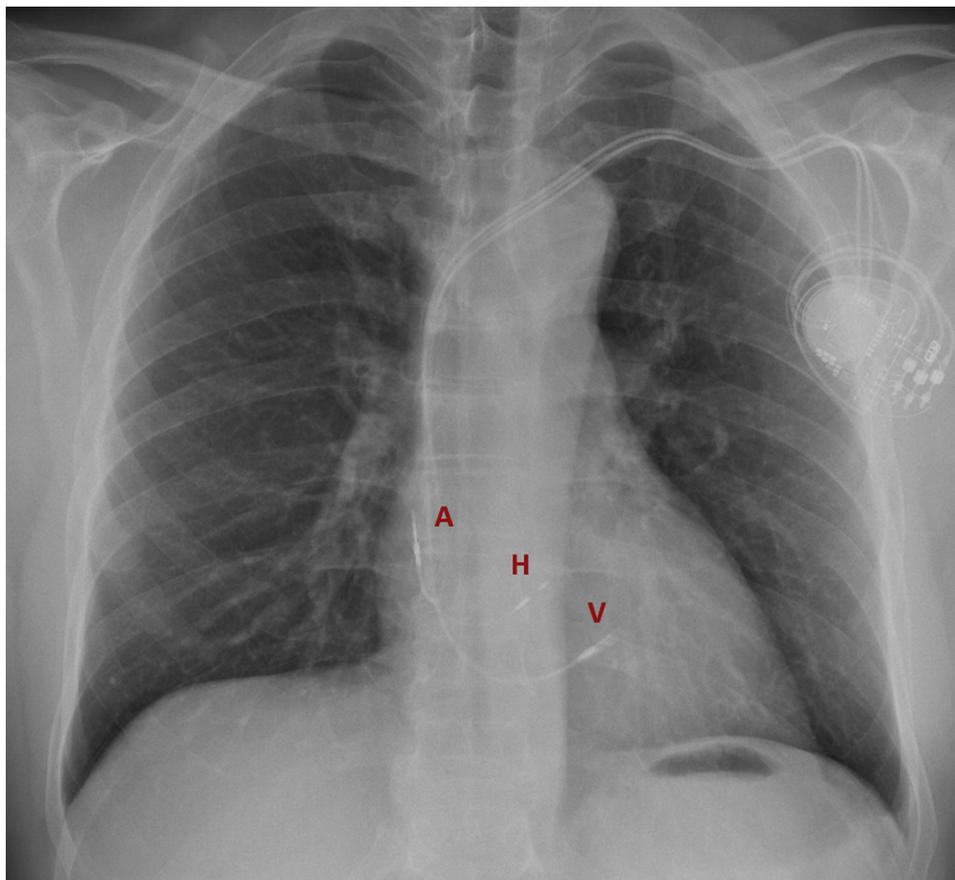


Figure 1 Chest radiograph of the patient after implantation of a cardiac resynchronization therapy pacemaker with the His bundle lead (H) connected to the left ventricular port, and the atrial (A) and backup septal right ventricular (RV) lead connected to their respective ports.

NS-HBP to S-HBP (Figure 2, lower panel). On the strength–duration curve, this translated into a crossover of threshold curves for the His bundle and the local myocardium (Figure 3). The same observation was made when pacing in a DDD configuration. Interestingly, we also found that His bundle and local myocardial thresholds were consistently higher by 0.25–1.75 V when testing in DDD compared to VVI configuration for the whole range of pulse durations (Figure 3). All measurements were performed in the supine position and were repeated 3 times, with similar results.

Discussion

This case demonstrates for the first time that (1) strength–duration curves may cross for His bundle and myocardial thresholds, resulting in different transitions in capture with decrementing voltage, depending upon the programmed pulse width; and (2) pacing thresholds may differ between DDD and VVI pacing modes.

The relation between pulse width and stimulus amplitude threshold is described by rheobase and chronaxie. The rheobase is the lowest voltage amplitude that captures the tissue at an infinitely long pulse duration. The chronaxie is defined as the pulse duration at which the voltage required for capture is twice the rheobase. Differences in chronaxie between the

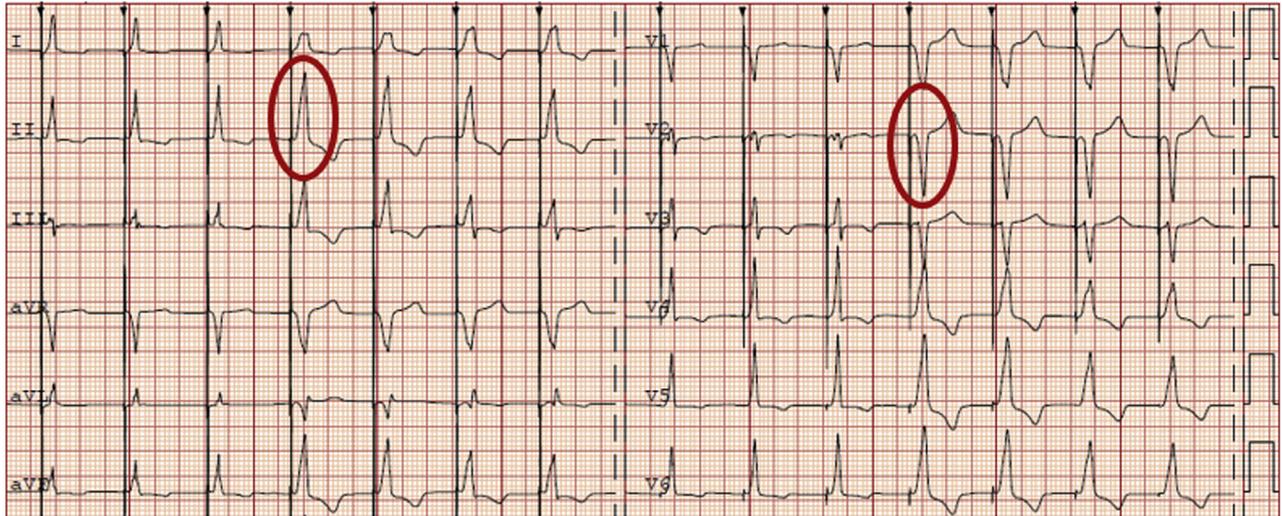
phrenic nerve and ventricular myocardium have been exploited to avoid phrenic nerve capture at longer pulse widths for coronary sinus leads.^{3–5}

Jastrzębski and colleagues⁶ studied strength–duration curves for HBP in 127 patients and found lower chronaxie for the His bundle compared to local RV myocardium in patients with S-HBP (whereas chronaxie did not differ in patients with obligatory NS-HBP). As a result, S-HBP is facilitated with pacing at shorter pulse width. In their study, separate and parallel strength–duration curves were found for the His bundle and local RV myocardium.⁶ Crossing of the curves was not systematically evaluated but was observed in a few patients (unpublished personal communication).

In our patient, we observed a crossover of the curves at a pulse duration between 0.2 and 0.3 ms. Even though the His bundle and ventricular myocardium have strength–duration curves that have a similar form with an exponential rise in capture voltage at lower pulse width, we are not aware of a physiological reason for them to be perfectly parallel. In most instances, however, the curves are sufficiently separated for them never to cross.

Another observation was the consistently higher thresholds for the His bundle and local RV myocardium when tests were performed in the DDD mode compared to the VVI

Threshold test at pulse width 0.4 ms



Threshold test at pulse width 0.2 ms

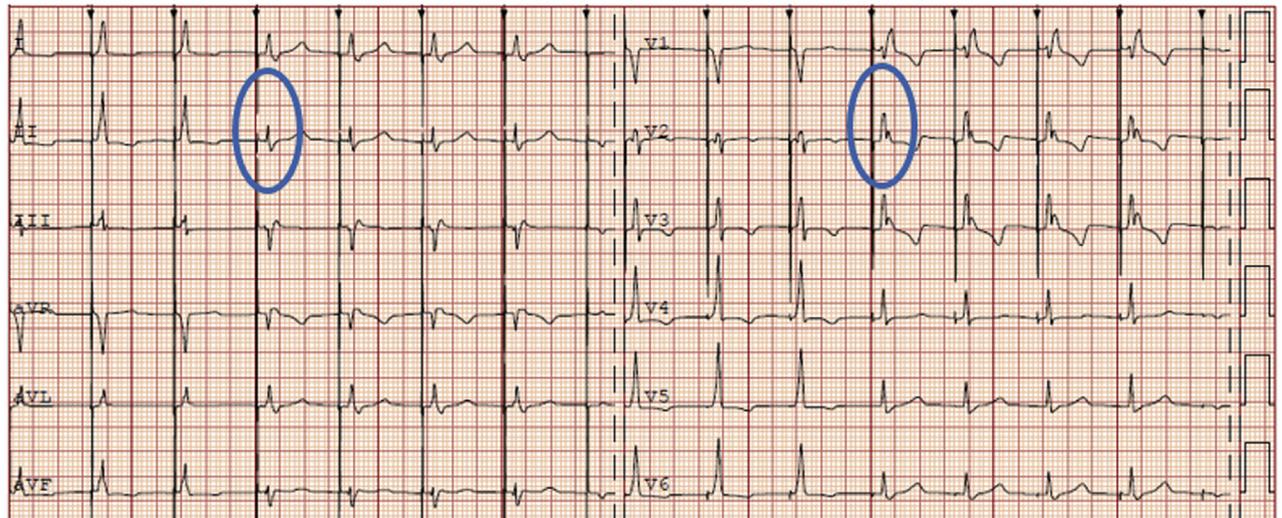


Figure 2 **Upper panel:** When pacing the His bundle at a pulse width of 0.4 ms, a QRS transition from nonselective His bundle pacing (NS-HBP) to myocardial capture only is observed with decreasing voltage output (*red circles*). **Lower panel:** When pacing the His bundle at a pulse width of 0.2 ms, the QRS transitions from NS-HBP to selective HBP without correction of the underlying right bundle branch block (RBBB) with decreasing voltage output (*blue circles*). Note QRS narrowing with NS-HBP owing to fusion pacing (capture of the right ventricular myocardium serves to “resynchronize” the conduction delay of RBBB).

mode. To the best of our knowledge, this has never been studied systematically before. It is known that thresholds for HBP may show greater beat-to-beat variability than for conventional RV lead positions. This may be owing to variations in orientation of the His bundle lead resulting in differences in tissue contact. Atrial and ventricular volumes are likely to be affected by pacing in VVI or DDD modes owing to differences in AV synchrony, thus affecting lead orientation and thereby the thresholds. Possibly, the influence of concealed AV conduction in the AV junction (despite complete AV block) might have also played a role in this observation for

the His bundle threshold (but does not explain differences in myocardial threshold).

Conclusion

We report crossing of strength–duration curves for His bundle and myocardial capture thresholds, which lead to different transitions in QRS morphology at different pulse widths. A second new observation is that we obtained considerably higher thresholds when performing His bundle and myocardial capture tests in the DDD mode compared to the

Strength-duration curves

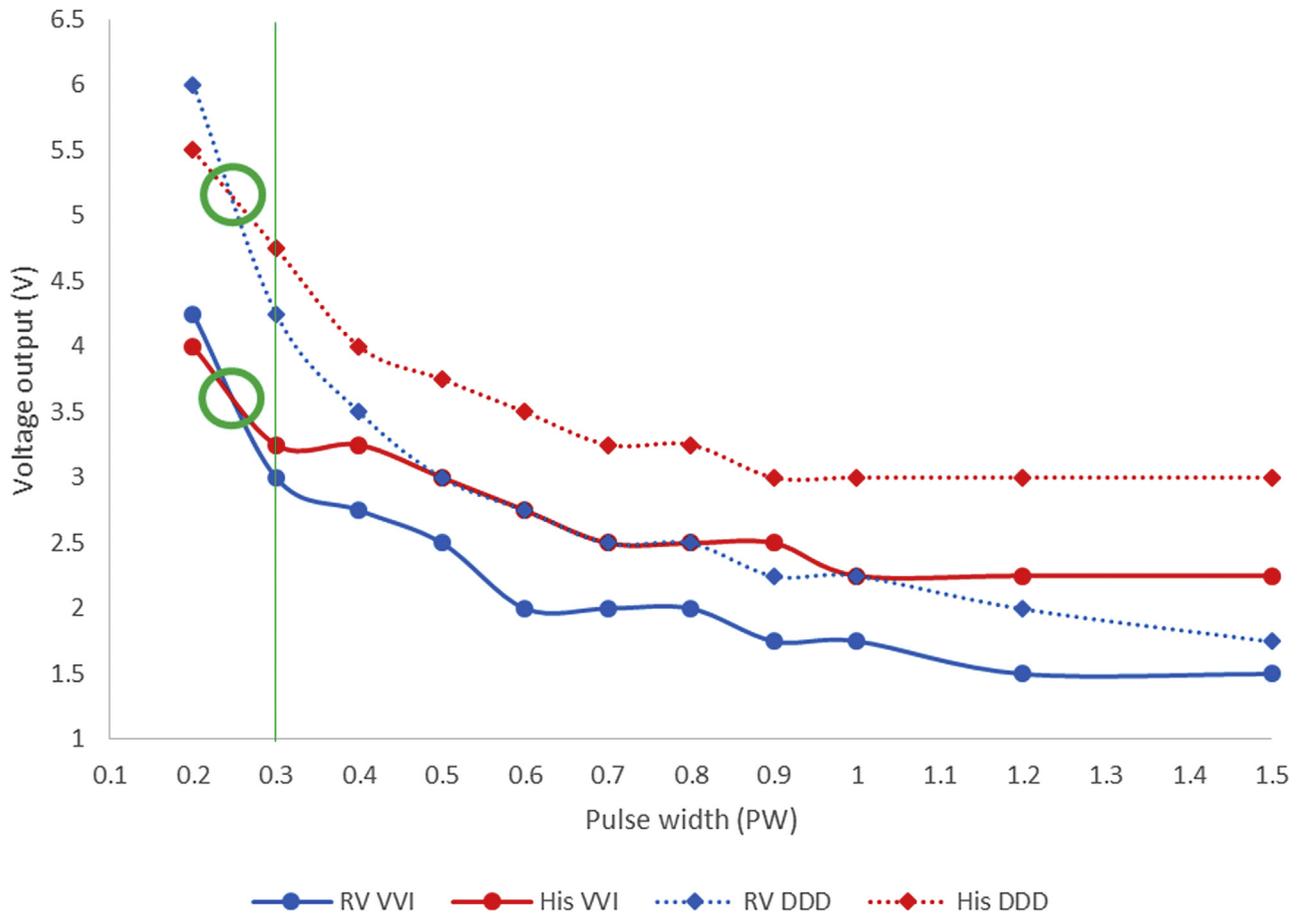


Figure 3 Strength-duration curves for local right ventricular (RV) myocardium and His bundle in VVI (solid lines) and DDD (dotted lines) pacing mode at 80 beats per minute. Pacing at and above a pulse width of 0.3 ms results in a His threshold (blue lines) that is higher than the local RV threshold (red lines). When pacing with a pulse width less than 0.3 ms, the RV threshold is higher than the His threshold, resulting in a crossover of the curves (green circles), in both a VVI and DDD pacing mode. In the DDD pacing mode, the voltage thresholds are higher for the whole range of pulse durations. At 0.1 ms, only His capture was possible at a threshold of 8 V in the VVI mode (not shown); there was no capture in the DDD mode.

VVI mode. The prevalence of these findings needs to be better defined. In the meantime, it would be advisable to perform threshold tests in the mode that is permanently programmed.

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