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Review

Anatomical approach to permanent His bundle pacing: Optimizing His bundle capture☆,☆☆,★

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Abstract Permanent His bundle pacing is a physiological alternative to right ventricular pacing. In this article we describe our approach to His bundle pacing in patients with AV nodal and intra-Hisian conduction disease. It is essential for the implanters to understand the anatomic variations of the His bundle course and its effect on the type of His bundle pacing achieved. We describe several case examples to illustrate our anatomical approach to permanent His bundle pacing in this article.

Keywords: His bundle pacing; Selective His bundle pacing; Nonselective His bundle pacing; Intra-Hisian AV block

Introduction

Permanent His bundle pacing (HBP) is the most physiological form of ventricular pacing. Right ventricular pacing is known to cause ventricular dyssynchrony, heart failure and increased mortality [1–4]. By maintaining conduction through the normal His-Purkinje system, HBP prevents ventricular dyssynchrony and may reduce heart failure. Deshmukh et al., demonstrated the feasibility of permanent HBP in patients undergoing AV node ablation in the year 2000 [5]. Since then, several investigators have reported successful HBP in a significant number of patients [6–10]. Nonetheless, widespread adoption of this technique has remained elusive.

Anatomy of the His bundle

The His bundle begins from the AV nodal tissue and courses along the membranous septum on the right side before penetrating to the left side on the crest of the muscular portion of the inter-ventricular septum. It is essential for the implanters to understand that a significant length of the proximal His bundle rests on the right atrial-left ventricular part of the membranous septum, which is above the tricuspid valve plane. Several anatomical variations of the distal His bundle course have been described. Our experience of permanent His bundle pacing in more than 400 consecutive patients has enabled us to understand these variations and their impact on achieving selective or non-selective His bundle pacing. Kawashima and Sasaki investigated the locational variation of the His bundle in 105 elderly human hearts and described three distinct patterns [11]. In type I (46.7% of 105 cases), the His bundle consistently coursed along the lower border of the membranous part of the interventricular septum but was covered with a thin layer of myocardial fibers spanning from the muscular part of the septum. In type II (32.4%) the His bundle was apart from the lower border of the membranous part of the interventricular septum and ran within the interventricular muscle. In type III (21%), the His bundle was immediately beneath the endocardium and coursed onto the membranous part of the interventricular septum (naked His bundle). These variations in the course of the His bundle help explain the different patterns of His bundle capture.

Definitions

There have been several different descriptions of His bundle capture. In order to provide uniformity, we recommend the following definitions based on the original descriptions published by Williams et al. [12], and Deshmukh et al. [5].

Selective His bundle pacing (S-HBP) is defined by ventricular activation occurring solely over the His-Purkinje system. S-HBP can be recognized by the

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following criteria: [1] His-Purkinje mediated cardiac activation and repolarization, as evidenced by electrocardiographic (ECG) concordance of QRS and T wave complexes similar to baseline; [2] the paced-ventricular interval is almost identical to the His-ventricular interval (Fig. 1). S-HBP has been variously described in literature as direct HBP, pure-His pacing and selective-direct HBP. It is important to note that S-HBP may result in normalization of pre-existing right or left bundle branch block with T wave memory changes [13,14].

Non-selective His bundle pacing (NS-HBP) is defined based on capture of basal ventricular septum in addition to His bundle capture as: [1] no isoelectric interval between pacing stimulus and QRS; [2] recording His bundle electrogram on the pacing lead; [3] electrical axis of the paced QRS concordant with the electrical axis of the spontaneous QRS (if known); [4] narrowing of QRS at higher output due to fusion between RV and His bundle capture and widening of QRS at lower output due to loss of His bundle capture or vice-versa (Fig. 2). Paced QRS complexes may be narrower than the baseline rhythm in the setting of pre-existing BBB or infra-nodal AV block [10,15]. NS-HBP has variously been described in literature as paraHisian pacing [5], pure-paraHisian pacing [16], nonselective-direct HBP [17]. Significant confusion still exists regarding paraHisian pacing as several authors do not report actual His bundle capture thresholds (the lowest pacing output at which QRS narrowing occurs) which may or may not be higher than the RV capture threshold [18]. In order to avoid confusion, when His bundle capture is present with fusion, it should be referred to as nonselective HBP (NS-HBP) and both HB and RV capture thresholds should be specified.

Anatomical approach to His bundle pacing

We have previously described our His bundle pacing technique utilizing unipolar mapping from the pacing electrode without using an electrophysiology mapping catheter [8,9]. In patients with normal His-Purkinje conduction, our approach is to achieve selective His bundle pacing. In our experience, we are able to achieve S-HBP in about 50% of these patients. Our ability to achieve S-HBP is limited by atrial capture, atrial oversensing and/or ventricular undersensing in the proximal His bundle region. If any of the above issues are noted at the time of implant, the lead is positioned slightly more distally. Often the distal His bundle is covered by a thin layer of myocardial fibers spanning from the muscular part of the interventricular septum (Kawashima Type I His bundle) [11]. In these patients we see minimal ventricular fusion and the paced QRS duration is usually less than 120 ms. In a third of patients, the His bundle lies within the muscular interventricular septum (type II), where selective HBP is not feasible. In this situation, NS-HBP is achieved with RV capture threshold lower than the His capture threshold. In patients with the naked His bundle (type III), significant His bundle injury current can be observed with S-HBP and very low His capture thresholds (<0.5 V). In patients with His-Purkinje conduction disease (bundle branch blocks or intra-Hisian AV block) our preference is to achieve NS-HBP. We do not routinely use a RV backup pacing lead in most of our pacemaker implants. By achieving NS-HBP, the right ventricular basal myocardial capture can provide a safety back-up pacing should there be progression of distal Purkinje conduction disease [10].

The following case examples illustrate our anatomic approach to permanent HBP in specific scenarios.

Case 1: A 74-year-old man with recurrent persistent atrial fibrillation, nonischemic cardiomyopathy, severe LV systolic dysfunction, EF <20% and class III NYHA symptoms was referred for AV node ablation and biventricular ICD implantation. He had previously failed multiple antiarrhythmic drugs and atrial fibrillation ablation. EKG at baseline showed normal PR interval

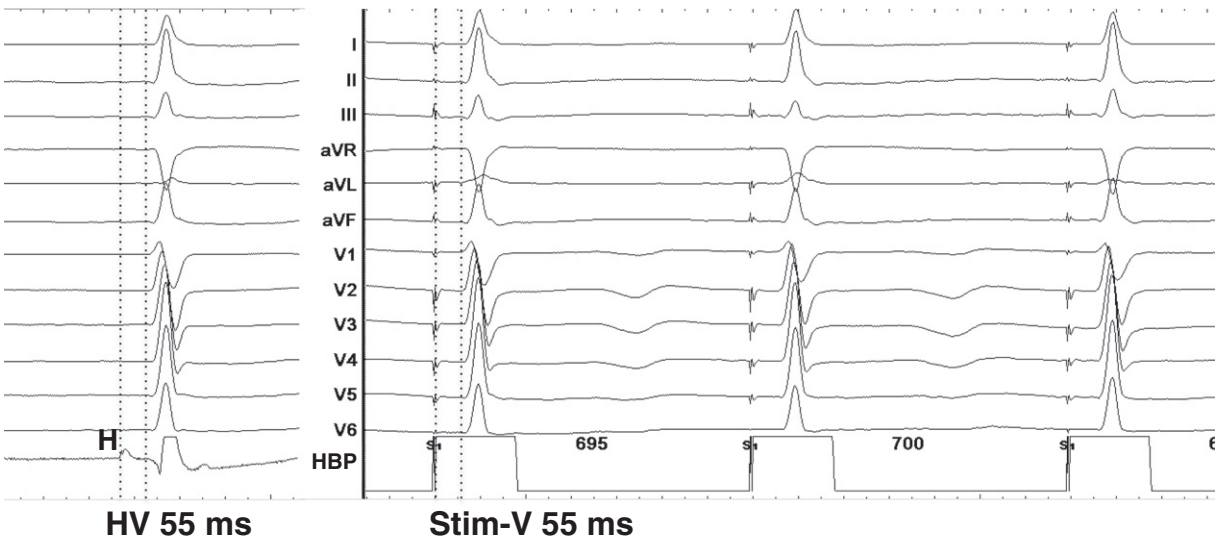

Fig. 1. Selective His bundle pacing (S-HBP). The left panel shows simultaneous 12-lead electrocardiogram with intracardiac electrogram from the His bundle pacing lead at a sweep speed of 100 mm/s. The HV interval is 55 ms. The right panel demonstrates selective HBP with QRS morphology identical to the baseline with an isoelectric stimulus-QRS interval of 55 ms.