How to Perform Permanent His Bundle Pacing: Tips and Tricks

PUGAZHENDHI VIJAYARAMAN, M.D.* and GOPI DANDAMUDI, M.D.†

From the *Division of Cardiac Electrophysiology, Cardiac Electrophysiology, Geisinger Heart Institute, Wilkes-Barre, Pennsylvania; and †Division of Cardiac Electrophysiology, Indiana University School of Medicine, Indianapolis, Indiana

Right ventricular pacing can cause ventricular dyssynchrony and result in reduced left ventricular systolic function and heart failure. Permanent His bundle pacing is a more physiologic form of pacing, but can be technically challenging. In this article, we describe our technique for permanent His bundle pacing including special considerations and limitations associated with His bundle pacing. (PACE 2016; 39:1298–1304)

pacing, new technology

Introduction

Right ventricular apical pacing has been the cornerstone of bradycardia pacing for many decades. In attempts to simulate physiologic conduction, atrioventricular (AV) sequential and rate-responsive pacing was developed. Clinical observations and large clinical trials demonstrated that right ventricular pacing lead to ventricular dyssynchrony, reduced left ventricular function, and heart failure.[1–3] Permanent His bundle pacing is promising as a more physiologic form of pacing. Early investigators found this to be feasible but technically challenging.[4,5] Recent development of a specially designed pacing lead and delivery tools has made permanent His bundle pacing feasible and safe in routine clinical practice.[6,7] To date, we have successfully performed His bundle pacing in more than 500 patients.

Implantation Technique

Early attempts at permanent His bundle pacing (HBP) involved the use of a standard active fixation pacing lead with a reshaped or deflectable stylet. However, this procedure was technically difficult and time consuming. The advent of a 4-Fr, lumenless active fixation lead with an exposed screw (3830 SelectSecure™, Medtronic Inc., Minneapolis, MN, USA) and a dedicated delivery sheath (SelectSite™-C304, or C315 His, Medtronic) has made routine permanent His bundle pacing feasible (Fig. 1). Historically, an electrophysiology-mapping catheter was routinely used to locate the His bundle. The bipolar electrode demonstrating the largest His bundle electrogram amplitude was targeted for fixing the pacing lead. Early in our experience, we assessed the utility of a mapping catheter to locate the His bundle in an institutional review board-approved protocol; we determined that a mapping catheter was not necessary for successful His bundle pacing.[8] Alternatively, we employ a unipolar mapping technique using the tip of the pacing lead to locate the His bundle. While the deflectable C304 sheath is very helpful to locate this His bundle, it can be challenging to secure the lead in the His location. The pacing thresholds tend to be higher unless the lead is directly fixed to the His bundle. The fixed-curve C315 sheath has a proximal curve directing the sheath to the tricuspid annulus while the secondary septal curve points the sheath perpendicular to the myocardial surface allowing the lead to be fixed securely. We have been able to achieve much better His bundle capture thresholds in the range of 1–1.5 V @ 1 ms using this sheath.

Once venous access is obtained (cephalic, subclavian, or axillary vein), a 7-Fr sheath is placed over a short guidewire. The C315 sheath is then advanced over a long guidewire such that the sheath tip is near the tricuspid annulus (Video S1). When the guidewire is withdrawn, the sheath tends to settle toward the anterior/superior tricuspid annulus near the His bundle region. The 3830 pacing lead is then advanced toward the tip of the sheath with a unipolar configuration. We use the atrial channel of the Medtronic Pacing System Analyzer at a gain setting of 0.05 mV/mm

Disclosures: Pugazhendhi Vijayaraman (Medtronic-Speaker, Boston Scientific-Advisory board); Gopi Dandamudi (Medtronic-Speaker, Bohringer-Ingelheim-Speaker).

Address for reprints: Pugazhendhi Vijayaraman, M.D., Cardiac Electrophysiology, Geisinger Heart Institute, Geisinger Wyoming Valley Medical Center, MC 36-10, 1000 E. Mountain Blvd., Wilkes-Barre, PA 18711. Fax: 570-808-2306; e-mail: pvijayaraman1@geisinger.edu; pvijayaraman@gmail.com

Received March 30, 2016; revised May 8, 2016; accepted May 23, 2016.

doi: 10.1111/pace.12904

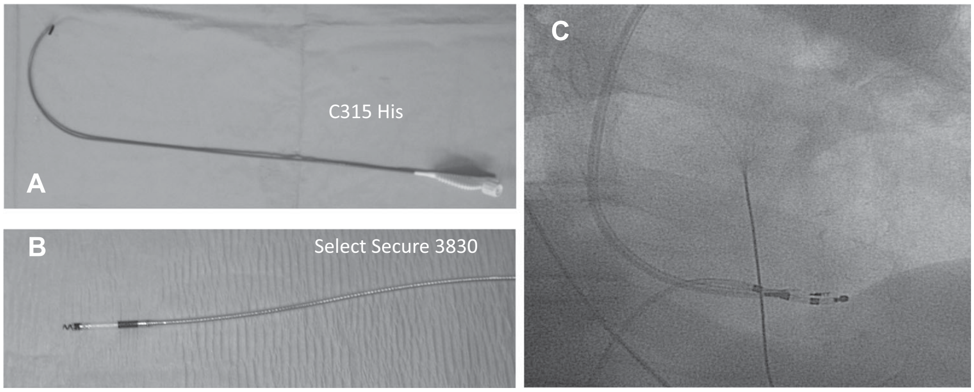

Figure 1. *(A) Fixed curve C315 His (Medtronic) delivery sheath has a 5.5-Fr inner diameter and a 7-Fr outer diameter. (B) SelectSecure 3830 (Medtronic) pacing lead is a 4.1-Fr, lumenless, solid core lead with an exposed active-fixation screw. (C) An electrophysiology catheter is used to guide the placement of permanent His bundle pacing lead.*

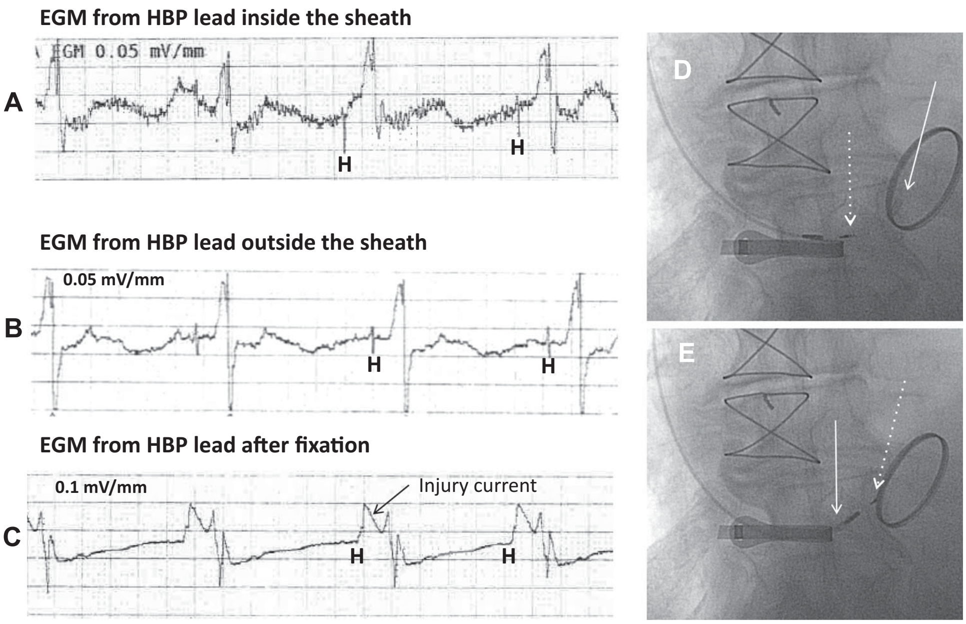

Figure 2. *(A) Unipolar electrogram obtained from the HBP lead while still inside the C315 His delivery sheath. (B) Electrogram from the HBP lead just outside the delivery sheath. (C) His bundle injury current recorded from the HBP lead after the lead is actively fixed to the His bundle region. There is slight prolongation of the HV interval, likely due to edema. (D) Fluoroscopic image of the HBP lead inside the C315His sheath. (E) Fluoroscopic image of the HBP lead just outside the sheath. Note the location of prosthetic mitral valve in relation to the His bundle, which can be used as a marker during implantation of the HBP lead. Solid white arrow points to the tip of the C315 His sheath, dashed arrow points to the tip of the HBP lead. EGM = electrogram; H = His; HBP = His bundle pacing; HV = His-ventricular.*

and sweep speed of 50 mm/s. In more than one-third of our cases, His bundle electrogram can be identified while the lead is still within the sheath (Fig. 2). The tip of the sheath is in direct contact with the septal tissue, allowing the intervening blood column inside the sheath to act as a conductor. The lead tip is gently advanced to the tip of the sheath. If the displayed electrogram shows large atrial signals then the sheath needs to be advanced toward the ventricle. Alternatively, if the electrogram is predominantly ventricular, the sheath is pulled back toward

Table I.

His Bundle Pacing Implant Checklist

Medtronic SelectSecure 3830 pacing lead (4.1 Fr)
Medtronic C315 His delivery sheath (C304 deflectable sheath—optional)
Electrophysiology mapping catheter (optional)
Twelve-lead ECG monitoring
Pacing system analyzer:
electrogram (EGM) gain 0.05 mV/mm
EGM sweep speed 50 mm/s
Unipolar mapping
Pace mapping
Pacing thresholds: His bundle capture/RV capture
Check for atrial capture if significant atrial signals present
Adjust sensitivity settings based on R-wave amplitude
Shorten AV delays by 40–50 ms to accommodate for HV interval
Back-up RV pacing lead (optional)

AV = atrioventricular; ECG = electrocardiogram; EGM = electrogram; HV = His-ventricular; RV = right ventricular.

Table II.

HBP Limitations

Failure to implant (10–15%)
High thresholds
Infra-Hisian (distal) block
Tricuspid valve replacement
Inability to fix the HBP lead
Subacute increase in pacing thresholds (10%)
Ventricular undersensing
Far-field atrial oversensing
Atrial capture
Injury to His bundle (7.8%)
Transient HV block (1%)
Transient right bundle branch block (RBBB) (3.5%)
Permanent RBBB (2.8%)

HBP = His bundle pacing; HV = His-ventricular; RBBB = right bundle branch block.

the tricuspid annulus. Once atrial to ventricular electrogram ratio of 1:2 is noted, the sheath is pointed toward the superior-anterior septum or mid-posterior septum by minimal clockwise or counterclockwise rotation, respectively. It is important to note that the sheath has excellent torque. Once the His electrogram is identified, pacing is performed at 5 V @ 1 ms to ensure capture. If no His electrogram is identified, pace mapping can be performed to assess His capture. It is important to display 12-lead electrocardiogram (ECG) during His bundle mapping and pacing. Once the His location is identified, the fluoroscopic image is saved as a reference. The sheath is held steady by the left hand and the pacing lead is slowly rotated clockwise approximately five times, without releasing the lead between rotations, to transmit the torque. Due to the fibrous nature of the His region, if the lead is anchored well, it will rotate back counterclockwise. If the lead is not anchored well, it will not torque back, even if the His capture threshold is acceptable. In this situation, the threshold will invariably increase before the end of the procedure. The sheath is pulled back while the lead is gently held forward until a loop is formed in the atrium. The pacing threshold is tested with particular attention to the 12-lead ECG morphology. We preferably test at a pulse width of 1 ms to allow for a lower voltage. In most patients, we accept a His bundle capture threshold of 2.0 V @ 1 ms. In patients with His-Purkinje disease, higher His bundle capture threshold may be accepted provided the right ventricular capture threshold is significantly lower (nonselective HBP). We can demonstrate His bundle injury current in approximately 40% of patients undergoing successful HBP lead implantation (Fig. 2). It is essential not to miss the His injury current following lead fixation, as the His electrogram and the injury current may merge with the ventricular electrogram. The acute His capture threshold may be higher but will invariably decrease before the end of the procedure. We have previously shown that the presence of His bundle injury current at implant is associated with lower His capture thresholds compared to those without demonstrable injury current.[9] Once acceptable threshold is obtained, the sheath may be slit and removed. It is important to maintain adequate loop in the right atrium prior to and during sheath removal, as it would be extremely difficult to advance the lead once the sheath is removed. If the lead is pulled back into the superior vena cava, we have occasionally employed a snare to advance the lead (via the cephalic vein or the outer sheath).

Capture Threshold

His bundle capture threshold is generally tested in bipolar configuration. Unipolar thresholds tend to be slightly lower than bipolar measurements. Selective HBP can be achieved in approximately 50% of patients with a narrow QRS. In this situation, paced QRS is identical to native QRS and His-ventricular (HV) interval is equal to stimulus to ventricular interval (Fig. 3). Right ventricular myocardial capture can occur at higher pacing outputs. We tend to place the HBP lead slightly more ventricular so as to

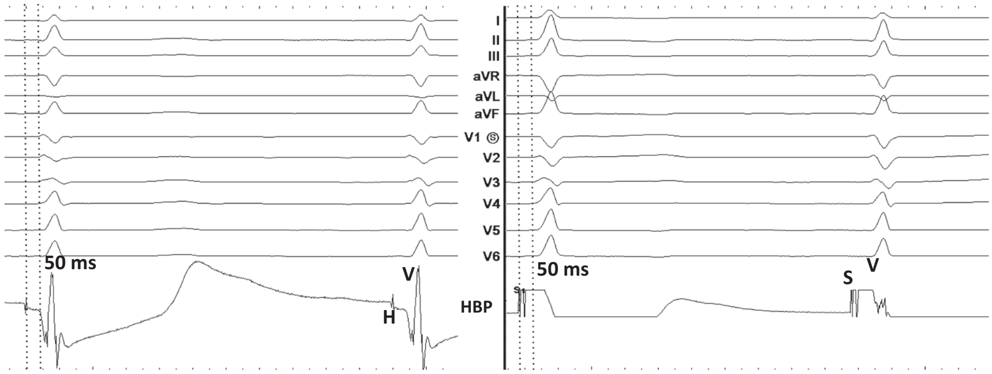

Figure 3. *Selective His bundle pacing. The left panel shows the 12-lead ECG and the electrogram from the HBP lead. The right panel shows selective His bundle pacing with a stimulus to QRS interval equal to the HV interval of 50 ms. The QRS morphology and duration is identical to the native QRS. ECG = electrocardiogram; HBP = His bundle pacing; HV = His-ventricular.*

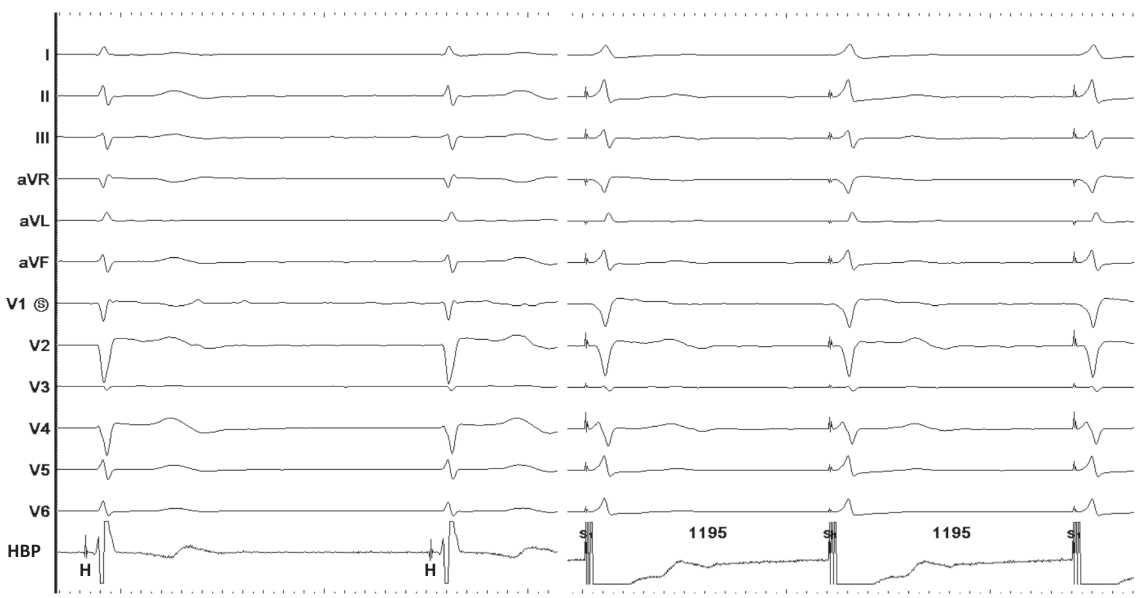

Figure 4. *Nonselective His bundle pacing. The left panel shows the 12-lead ECG and the electrogram from the HBP lead in a patient with atrial fibrillation and slow ventricular rate. The right panel shows nonselective His bundle pacing with a stimulus to QRS interval shorter than the baseline HV. The paced QRS axis is similar to baseline QRS in addition to a delta wave due to right ventricular septal preexcitation in addition to conduction through His-Purkinje system. ECG = electrocardiogram; HBP = His bundle pacing; HV = His-ventricular.*

obtain nonselective HBP (NS-HBP) in patients with His-Purkinje disease (HV block). In NS-HBP, there is evidence for fusion from right ventricular myocardial capture in addition to His capture (Fig. 4). The stimulus to ventricular interval is shorter than the HV interval and the paced QRS axis is similar to baseline QRS with a delta wave due to right ventricular septal preexcitation. In this situation, we report and monitor both right ventricular and His bundle capture threshold. The final pacing output is programmed at least 1 V above His capture threshold. We do not routinely implant a back-up right ventricular (RV) pacing lead. In patients with pacemaker dependency and His/RV capture thresholds greater than 2 V, or in some patients with indications for cardiac resynchronization therapy-pacemaker (heart failure, left ventricular ejection fraction <50%, AV node ablation), we have implanted a back-up RV or left ventricular

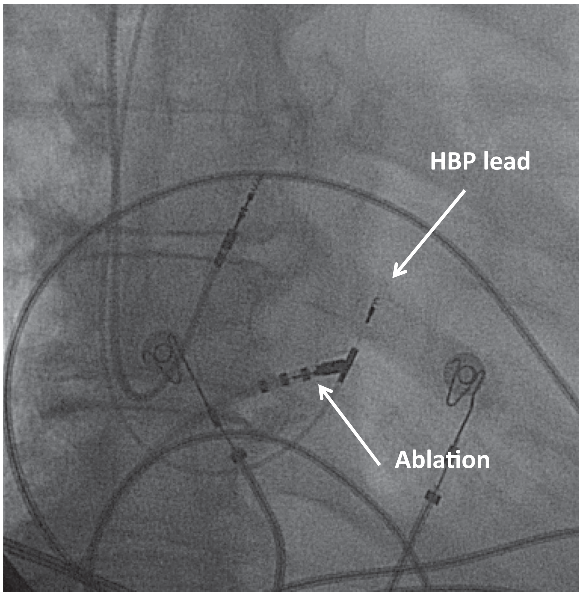

Figure 5. *AV node ablation: Fluoroscopic view in AP projection is shown. The ablation catheter is positioned inferior and posterior (atrial) to the distal electrode of the HBP lead. AP = anteroposterior; AV = atrioventricular; HBP = His bundle pacing.*

(LV) pacing lead. In these situations, the His pacing is timed to be 80 ms earlier than the RV output to achieve physiological His bundle pacing.

Sensing

The electrogram obtained from the HBP lead may demonstrate atrial, His, and ventricular signals. The ventricular amplitude may occasionally be lower than 1 mV. Prior to fixing the lead, we try additional mapping to obtain electrograms larger than 1–2 mV. Far-field atrial electrograms can occasionally be larger than the ventricular electrogram creating a challenge for programming sensitivity settings. We have rarely encountered His electrograms to be as large as 2 mV and associated with oversensing. Once the lead is fixed and sheath pulled back, it is essential to check bipolar signals. The sensed ventricular amplitude may be lower than the far-field atrial amplitude in bipolar configuration compared to unipolar amplitude obtained during mapping (Fig. 5). It is critical to program the ventricular sensing parameters appropriately compared to traditional RV parameters and to know the maximal sensitivity settings available in various models of pacemakers. See Table I for implant checklist.

Follow-Up

Pacemaker function is routinely checked on the day following implantation, at 2 weeks, and at 3 months to assess His bundle capture thresholds and ventricular sensing. In a small percentage of patients, the pacing threshold may increase by 0.5–1 V within 24 hours. If pacemaker dependent, patients should be followed more frequently to ensure safe chronic pacing thresholds. In about 10% of the patients, the His pacing threshold may continue to increase for up to 3 months and lead revision may be considered. In our experience, 3–5% of patients required lead revision secondary to high thresholds or noncapture.[7,10] Beyond 3 months, further worsening of His capture threshold is uncommon. The acute or subacute increase in HBP threshold is often due to microdislodgement of the pacing lead resulting from tricuspid valve motion or local fibrosis. While histopathological evidence is not available, we have not observed development of intra-Hisian conduction block during follow-up or at the time of generator change (3–9 years).[11] Frank dislodgement of the HBP lead was not observed in follow-up of more than 500 implants.

During follow-up, assessment of His bundle capture using multilead ECG is recommended. At 3-month follow-up, the pacing output is programmed to at least 1 V above the His capture threshold as confirmed with multilead ECG. His bundle pacing can correct underlying bundle branch block, which is often due to disease in the main His bundle. In patients with bundle branch block, three different capture thresholds may occasionally be noted (RV, right bundle or left bundle, and complete His bundle capture). Longitudinal dissociation of the fibers destined to become right or left bundle in the main His bundle explains the above phenomenon. Twelve-lead ECG may sometimes be necessary to establish the pacing output that fully corrects underlying bundle branch block.

Special Considerations

Right-Sided Implant

The delivery sheaths for His bundle pacing are designed for left pectoral implantation. However, His bundle pacing can successfully be performed from the right pectoral region. We prefer to use the C315 His sheath for our right-sided implants. It is more difficult to manipulate the deflectable C304 sheath from the right side. It is necessary to advance the sheath over the guidewire to the tricuspid annular region. The sheath needs to be rotated counterclockwise and this position maintained carefully during lead positioning. Because of the significant torque required to

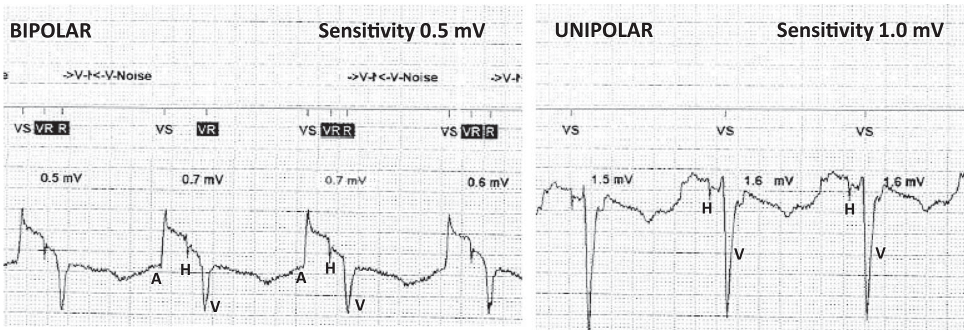

Figure 6. *Oversensing: The left panel shows electrograms from HBP lead in bipolar configuration. At a sensitivity setting of 0.5 mV, there is significant oversensing of the far-field atrial electrogram and occasionally even the His electrogram. The right panel demonstrates a larger R wave (1.6 mV) in unipolar configuration. HBP = His bundle pacing.*

maintain this position, it is very common for the sheath to rotate back to the right atrial free wall. While advancing the sheath, adequate care should be taken to avoid atrial perforation.

Be Prepared for Asystole

In patients with preexisting left bundle branch block or second-degree AV block, development of complete heart block and asystole during manipulation of the sheath and the lead should be anticipated. In the absence of a temporary transvenous pacing lead, we routinely place the atrial lead in the right ventricle to provide back-up pacing during His bundle mapping.

Atrial Fibrillation

In patients with chronic atrial fibrillation and AV block (AV node ablation), a back-up RV pacing lead may be placed in addition to the His bundle pacing lead. In these patients, a dual-chamber pacemaker may be used with the His bundle pacing lead connected to the atrial port and programmed to nonatrial sensing DVI mode. If a single-chamber pacemaker was used in patients with chronic atrial fibrillation, AAI mode would allow for higher sensitivity than VVI mode (0.15 mV vs 1 mV).

AV Node Ablation

While some centers may wait 2–4 weeks after the initial device implant to perform AV node ablation, it is our practice to perform AV node ablation during the initial pacemaker implant. The ablation catheter is initially placed at the His bundle location via femoral venous access. We typically obtain a slightly distal His location for the HBP lead (very small atrial and a larger ventricular signal). AV node ablation is performed after successful implantation of the HBP lead. The ablation catheter is positioned inferior and posterior to the distal electrode of the HBP lead (Fig. 5). Care is taken to avoid any location closer to the distal electrode. As soon as AV block is achieved during the ablation, we pace from the HBP lead at 0.5–1 V above the His capture threshold. Any loss of His capture should serve as a warning to stop the ablation. If AV node ablation cannot be achieved from the right heart, ablation from the left heart can theoretically be attempted from the septal mitral annulus. However, any ablation in the LV outflow septum would result in AV block at the distal His bundle and loss of capture from the HBP lead and therefore should not be attempted.

Automatic Threshold Testing

Utility of automatic threshold testing features (capture management or autocapture) is limited in HBP. In patients with selective HBP, due to lack of evoked potentials, this feature may fail to detect the true His capture threshold. In patients with nonselective HBP, this feature will detect myocardial capture threshold and not His bundle capture. We generally do not activate this feature in patients with HBP.

Limitations

Permanent HBP may be unsuccessful in 10–15% of patients due to infra-Hisian conduction block, unacceptably high pacing thresholds, poor sensing, large right atrium, mechanical tricuspid valve, or inability to locate the His bundle or fix the lead (Table II). Subacute increase in His bundle capture threshold can occur during follow-up in approximately 10% of the patients. Ventricular undersensing, atrial oversensing (Fig. 6), and occasionally atrial capture may pose a challenge. Gentle manipulation of the sheath and the pacing lead is required during the implant procedure to prevent acute injury to the His/right bundle. We have observed development of transient, complete intra-Hisian AV block during implantation of permanent HBP lead in 1% of patients. More importantly, new persistent right bundle branch block can occur in up to 3%. In our experience, HBP generally corrects the right bundle branch block induced during the implantation.[12] While permanent HBP may not be feasible in patients with tricuspid valve replacement (mechanical or bioprosthetic), we have successfully performed HBP in several patients with tricuspid valve annuloplasty.

The authors experienced a significant learning curve to achieve successful and reliable His bundle pacing. Early in our experience, we allowed an additional 30 minutes for His bundle pacing compared to conventional RV pacing. Currently, we routinely perform His bundle pacing in all of our patients without need for additional procedural time. New implanters will require additional procedural time during their learning phase.

Conclusions

Permanent HBP can be routinely and safely performed in most patients undergoing pacemaker implantation. HBP, by virtue of utilizing the native conduction pathways, can prevent the development of ventricular dyssynchrony and LV dysfunction. By investing in the development of newer delivery systems and leads, routine HBP can become a reality. We believe that a large randomized controlled trial to compare the clinical outcomes between HBP and RV pacing is feasible and should be pursued. Widespread use of HBP by most electrophysiologists would be a necessary initial step in achieving this goal.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Video S1. How to perform His bundle pacing.