To date, there has not been direct visualization of the anatomic location of direct His bundle pacing (DHBP) leads in the human heart. The absence of such data has contributed to disagreement about the location of DHBP leads with respect to the plane of the tricuspid valve.\(^1,2\) We present an autopsy study of a patient who had previously had a DHBP lead implanted, showing unequivocally that the lead is implanted on the atrial side of the tricuspid annulus.

An 81-year-old man with diabetes died of sepsis secondary to a lower-extremity infection. Two years prior, the patient presented with symptoms of congestive heart failure and presyncope. He had a history of coronary artery bypass graft and myocardial infarction with mild to moderate left ventricular dysfunction (ejection fraction, 40%–45%). β-blockade therapy was limited by sinus bradycardia and frequent Wenckebach block. The patient was noninducible for ventricular arrhythmias, and a pacemaker was recommended for chronotropic incompetence and AV block. To prevent pacemaker-induced electric dyssynchrony, we implanted a DHBP lead.

DHBP lead implantation was performed as previously described.\(^3\) Briefly, an octapolar mapping catheter was

![Figure 1. Electrograms obtained at the time of lead implant. Shown from top to bottom are the surface ECG leads, the DHBP pacing lead bipolar electrogram, and the octapolar mapping catheter (HBD—distal electrode bipole to HB4—proximal electrode bipole), respectively. Left panel: Sinus rhythm. A distinct His deflection is evident on the DHBP lead and distal octapolar bipolar electrograms (HV interval, 55 ms; QRS duration, 95 ms). The low-amplitude, but discrete His potential, on the DHBP lead is indicated by the arrow. This was the fifth site tested. It is not unusual to see the bipolar His potential diminish in stature on the DHBP lead, presumably because of tissue edema following multiple serial lead fixations. Right panel: Selective direct His bundle pacing. The stimulus-to-QRS interval is isoelectric in all surface leads and equals the HV interval (55 ms). The QRS duration is identical to the conducted QRS. The arrow indicates late septal activation following His Purkinje spread.](image)
used to map the His bundle. A pacing lead was actively fixed adjacent to bipolar electrodes recording a His potential (SelectSecure lead, model 3830, delivered through a deflectable SelectSite sheath, model c304; Medtronic, Minneapolis, MN). A site demonstrating selective direct His bundle capture (criteria previously defined by Deshmukh et al1) and adequate pacing threshold was obtained. The sensed ventricular signal from the pacing lead was of low amplitude (0.8 mV); therefore, to ensure adequate ventricular sensing, a backup lead (CapSure Fix Novus, model 5076; Medtronic) was implanted in the mid-right ventricular septum. Pacing at the middle interventricular septum was programmed to be offset by 40 ms with respect to His bundle pacing. As such, if capture occurred with the His bundle lead, pacing from the interventricular septum would encounter refractory tissue. Selective His bundle pacing resulted in a narrow QRS identical to the conducted QRS (Figure 1). The procedure was uncomplicated, and for the ensuing 2 years, the patient maintained excellent functional status with no further hospitalizations for heart failure. Selective capture with a stable pacing threshold persisted throughout the 2-year follow-up period. After the patient’s death, his family graciously agreed to a limited autopsy of his heart.

Macroscopic examination clearly demonstrated that the lead tip was located on the atrial side of the tricuspid valve adjacent to the supravalvular portion of the membranous septum (Figure 2). The relationship between the tract created by the lead tip and the His bundle is shown grossly and microscopically in Figure 3.

To our knowledge, this is the first anatomic description of a permanent, selectively capturing DHBP lead in a human, confirming that selective capture can occur with the pacing lead on the atrial side of the tricuspid annulus. Pacing at His potential sites closer to the tricuspid valve would be expected to result in nonselective capture because of the proximity of the ventricular septum (Figure 3). Using intracardiac ultrasound imaging in other patients, we have observed output-dependent selective and nonselective capture with the lead at a level above the tricuspid valve (online-only Data Supplement Movie I and Figures I and II).

DHBP maintains physiological ventricular activation, eliminating the risk of pacing-induced myopathy associated with traditional right ventricular apical pacing. In the present case, a backup ventricular lead was required to provide adequate ventricular sensing; however, this is not

Figure 2. Gross examination. A, All 3 leads are visualized with exposure of the free wall of the right atrium. The forceps is gripping the posterior TV leaflet. The DHBP lead is implanted on the atrial side of the valve leaflet. B, Following formalin fixation, the membranous septum was transilluminated from the left ventricle, showing the insertion of the DHBP lead at the superior-most extent of the membranous septum. CS indicates coronary sinus; DHBP, direct His bundle pacing lead; RA, right atrial pacing lead; RV, right ventricular pacing lead; TV, tricuspid valve.

Figure 3. Microscopic examination. A, The formalin-fixed tissue block containing the conduction system shows the direct His bundle pacing (DHBP) lead having been unscrewed, leaving behind a fibrous sheath where the lead tip had been actively fixed (arrow). The lead insertion site is 9 mm above the TV leaflet. B, Masson trichrome (x1) staining demonstrates the proximity of the DHBP lead to the His bundle. The His bundle stains red and is indicated by the asterisk. The arrow points to the TV leaflet. The MS and scar tissue are stained blue. C, Masson trichrome (x100). Screw puncture sites are seen surrounding the His bundle (arrows). There is evidence of a fibrous response within the bundle (blue staining) adjacent to the screw holes. Metallic specks shed by the screw are seen adjacent to the screw hole (inset hematoxylin and eosin stain, ×400). MS indicates membranous septum; TV, tricuspid valve; V, ventricular septum.
typically required because the average ventricular sensing on DHBP leads has been found to be $\approx 2 \text{ mV}$.\textsuperscript{4} It is therefore possible to ensure physiological ventricular activation with DHBP without breaching the integrity of the tricuspid valve.

**Disclosures**

Dr Crespo has served as a consultant to Medtronic. Dr Lustgarten is a consultant and advisor for and receives research support from Medtronic and is a consultant for Biosense Webster.

**References**


**Key Words:** Bundle of His pacing, anatomy, pacemakers, cardiac resynchronization therapy
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Supplemental Material

Supplemental Figures and Movie Legends:

**Figure 1:** One frame of intracardiac US demonstrating the position of a DHBP lead which can be seen superior to the tricuspid valve inserting into the superior aspect of the membranous septum. The right panel shows the DHBP implantation site with a discrete His electrogram (arrow) preceding QRS onset by 68 msec.

**Figure 2:** DHBP site above the tricuspid valve demonstrating output dependent selective and nonselective DHBP capture. The left panel shows the natively conducted QRS during atrial pacing. The middle panel demonstrates selective capture with all 12 leads being isoelectric from stimulus artifact to QRS onset. The right panel demonstrates the response to increasing the pacer output, now with evidence of ventricular capture immediately following the stimulus artifact, albeit with no change in the stimulus to QRS terminus, consistent with nonselective capture of the His bundle.

**Movie 1:** Intracardiac US demonstrating the position of a DHBP lead which can be seen superior to the tricuspid valve inserting into the superior aspect of the membranous septum. The right panel shows the DHBP implantation site with a discrete His electrogram (arrow) preceding QRS onset by 68 msec.
Supplemental Figures:

Figure 1
Figure 2