Introduction and objectives. Permanent His-bundle pacing is effective in patients with supra-Hisian atrioventricular block. We report our experience in patients with infra-Hisian atrioventricular block.

Methods. The study involved selected patients referred for syncope and intraventricular conduction disturbance, infra-Hisian atrioventricular block, with left ventricular dysynchrony and no coronary sinus access. All patients underwent electrophysiological study to evaluate infra-Hisian atrioventricular conduction, both at baseline and after flecainide administration. We selected patients with an indication for permanent pacing in whom His-bundle pacing produced a narrow QRS complex. Leads were implanted in the right atrium, in the bundle of His, and at the apex of the right ventricle, and connected to the atrial, left ventricular, and right ventricular terminals, respectively, of a biventricular pacemaker generator. All pacemakers were programmed in DDD mode with a left ventricle-right ventricle interval of 80 ms.

Results. Between February and December 2004, 7 patients met the study’s inclusion criteria. The His-bundle lead was implanted successfully in 5. The His-bundle pacing threshold remained stable in 2 patients, whereas it increased in 3. During follow-up, at between 2 and 12 months, no lead dislodgement or failure to capture was observed. Ecocardiographically, no deterioration in ventricular function, or any worsening of or new valvular incompetence, was observed. Ventricular dyssynchrony had disappeared in previously affected patients.

Conclusions. His-bundle pacing is the only pacing mode capable of inducing a physiologically normal ventricular contraction. It can be used in some patients with infra-Hisian atrioventricular block.

Key words: Bundle branch block. His bundle pacing. Atrioventricular block. Cardiac pacing.

Estimulación hisiana definitiva en pacientes con bloqueos infrahisianos

Introducción y objetivos. La estimulación permanente del haz de His es eficaz en los bloqueos auriculoventriculares suprahisianos. Mostramos nuestra experiencia en bloqueos infrahisianos.

Métodos. Seleccionamos a pacientes derivados por síntomas y trastornos de la conducción intraventricular, bloqueo auriculoventricular completo con asincronía intraventricular izquierda con seno coronario no accesible. En todos se practicó un estudio electrofisiológico en el que se evaluó la conducción infrahisiana basal y tras la administración de flecainida. Entre los pacientes con indicación de marcapasos permanente se seleccionó a aquellos en los que la estimulación del haz de His provocaba un complejo QRS estrecho. Se programaron en modo DDD con un intervalo ventrículo izquierdo-ventrículo derecho de 80 ms.

Resultados. Desde febrero hasta diciembre de 2004 se estudió a 10 pacientes, de los que 7 cumplieron criterios de inclusión. En 5 pacientes se implantó de forma exitosa el electrodo hisiano. En 2 pacientes, el umbral de estimulación permaneció estable, mientras que en 3 pacientes se produjo una elevación. Durante el seguimiento, entre 2 y 12 meses, no se ha observado desplazamiento o pérdida de captura. Ecocardiográfica y no se ha observado deterioro de la función ventricular ni nueva incompetencia valvular. La asincronía intraventricular disminuyó en los pacientes con asincronía previa.

Conclusiones. La estimulación hisiana constituye el único modo de provocar una contracción ventricular más fisiológica y su utilización es posible en algunos casos de bloqueo infrahisiano.

Palabras clave: Bloqueo de rama. Estimulación en el haz de His. Bloqueo auriculoventricular. Estimulación cardíaca.
INTRODUCTION

Permanent His-bundle pacing is both effective and safe in patients with supra-Hisian atrioventricular block and can improve ventricular functioning.\(^1\,^2\) It is logical to believe, however, that the technique is only appropriate in patients with supra-Hisian atrioventricular block, and that it would be contraindicated in patients with infra-Hisian atrioventricular block.

However, in electrophysiologic studies (EPS) we found that His-bundle pacing with a temporary lead led to the disappearance of complete bundle-branch block (CBBB) in some cases (Figure 1). We therefore decided to attempt definitive His-bundle pacing in selected patients with infra-Hisian conduction disturbances.

METHODS

Patient Selection

Between February and December 2004, we included 7 patients with electrocardiographic (ECG) evidence of intraventricular conduction disturbance and EPS results indicating disturbed infra-Hisian conduction. His-bundle stimulation during EPS in these patients had produced a normal or “fused” QRS complex (Figure 2). Six of the patients proposed for the intervention had been referred for EPS because of syncope. The seventh patient had heart failure due to dilated cardiomyopathy as well as complete left bundle-branch block (CLBBB) and an indication for resynchronization, which was not possible via the coronary sinus. In this patient, the EPS had shown His-bundle block (H \(54\) ms) which was corrected by His-bundle pacing (Figure 3).

Patients ranged from 63 to 82 years of age. There were 4 women and 3 men. The table shows the type of electrocardiographic disturbances presented by the patients.

Pacemaker Implantation

The 7 patients, 4 of whom had CRBBB (1 with added first grade supra-Hisian atrioventricular block), 2 with CLBBB, and 1 with complete infra-Hisian AVB were proposed for definitive His-bundle pacing using a

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**ABBREVIATIONS**

AVB: atrioventricular block.
CRBBB: complete bundle-branch block.
CLBBB: complete left bundle-branch block.
EPS: electrophysiology study.
H: His-bundle electrogram.

**TABLE. Conduction Disturbances in Patients Selected for His-Bundle Pacing**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRBBB</td>
<td>3</td>
</tr>
<tr>
<td>CRBBB with first-grade AV block</td>
<td>1</td>
</tr>
<tr>
<td>CLBBB</td>
<td>2</td>
</tr>
<tr>
<td>Complete infra-Hisian AVB</td>
<td>1</td>
</tr>
</tbody>
</table>

*AV indicates atrioventricular, AV: atrioventricular block; CRBBB, complete right bundle-branch block; CLBBB, complete left bundle-branch block.

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**Figure 1.** Stimulation via a lead located in the His-bundle (HIS DIST) in a patient with complete left bundle-branch block (CLBBB). In the first 8 complexes, various morphologies of the stimulated QRS are produced, but those marked 1 and 2 show complete disappearance of the bundle-branch block, with spike-QRS latency, due to pure Hisian capture. From 3 onwards, His-bundle pacing is stopped and the baseline CLBBB reappears.
biventricular DDD pacemaker. Previous His-bundle pacing had led to the disappearance of the conduction disturbance in all of the patients.

The technique used for pacemaker implantation has been described elsewhere, and consists of introducing a tetrapolar lead using fluoroscopy via the femoral vein until activity is registered in the His-bundle (the reference zone). The lead is advanced and the reference zone “mapped” while attempts are made to register activity in the His-bundle; when this is achieved, contact is maintained between the lead and the septum and the fixation helix is removed. Stability and thresholds are then tested (maximum accepted 2.5 V for 0.4 ms). We used 52 cm, active fixation Tendril SDX, St Jude leads (St Jude, Minneapolis). With this lead, the mechanism used to extract the fixation helix prior to implant leaves several centimeters of guide wire uncovered, which are useful for manipulating and stabilizing the lead.

Leads were implanted in the right atrium, in the bundle of His, and, for safety, at the apex of the right ventricle (Figure 4), and connected to the atrial, left ventricular, and right ventricular terminals, respectively, of a biventricular pacemaker generator.
By programming an appropriate advance in the left ventricular pacing, it is possible to stimulate the “Hisian zone” exclusively and the right ventricular spike locates on the refractory QRS complex with no opportunity for originating local capture (Figure 5). When the Guidant Contak Renewal TR2CRT-P pacemaker was used (on 3 occasions), the sensitivity of the left ventricular channel was adjusted to be as “blind” as possible to avoid inhibiting stimulation of the His-bundle because of possible A wave sensing. In another 2 cases, and again to avoid this effect, we used devices in which left ventricular channel sensing was not possible, such as the Medtronic InSync III.

RESULTS
Effects of His-Bundle Pacing

Selective His-bundle pacing using high output voltages (over 2.5 V) in the 2 patients with CRBBB led to the disappearance of the bundle-block and reduced the duration of the QRS complex (Figure 6), which acquired a “pre-excited” aspect. Using low output voltages led to a reappearance of CRBBB with spike-QRS latency and a failure to normalize QRS morphology and duration.

In 2 patients with CLBBB, His-bundle pacing led to the disappearance of the bundle-block and practically normalized QRS duration and morphology. This was the case of the patient with dilated cardiomyopathy (Figure 7).

In the patient with complete infra-Hisian AVB, His-bundle pacing corrected the disturbance and normalized the QRS (Figure 2).

The His-bundle lead was successfully implanted in 5 (71%) of the 7 patients initially selected for the procedure (2 with CRBBB, 1 of whom had first-grade AVB, 2 with CLBBB, and 1 with complete infra-Hisian AVB). Acute His-bundle pacing thresholds were between 1.2 and 2.3 V with a duration of 0.4 ms.
Fixation of the His-bundle lead required between 12 and 47 mins.

Follow-Up

Between 2 and 12 months follow-up, no lead dislodgement was observed, though the His-bundle pacing threshold increased in three patients to 4, 4.5 and 4.5 V for 0.4 ms at 7, 8 and 10 months, respectively. No problems arose because of oversensing.

The echo-Doppler readings did not deviate significantly from pre-implant values, except in the patient with dilated cardiomyopathy and CLBBB, in which pre-implant left ventricular dyssynchrony was normalized. There was no evidence of AV valvular incompetence.

**DISCUSSION**

It has been known for some time that selective His-bundle pacing can lead to the disappearance of CBBB. This can be explained by longitudinal dissociation in the His-bundle, a theory based on the anatomical and histological studies of James and Sherf which sustains that the fibers going to for the right and left branches...
of the conduction system are organized longitudinally and separated in the His trunk. This makes cross- 
excitation between the right and left bundles (anisotropy) difficult. A lesion which only affects part 
of the His trunk can therefore cause electrocardiographic disturbances typical of CBBBs. This 
has been confirmed by other authors and explains why His-bundle pacing in a zone distal to the 
site of the block and a Hisian extrastimole originating in that region can lead to the disappearance of 
CBBB. The fact that His-bundle pacing does not always lead to an absolutely normalized QRS complex with 
clear latency between the spike and the start of the QRS (His-Purkinje conduction time), can be explained by 
the simultaneous capture of myocardium next to the His-bundle, so that 2 depolarizing fronts are 
produced. One of these captures the His-bundle and activates the left ventricle via the left branch, while the 
other captures myocardium in the Hisian region and depolarizes and resynchronizes the right ventricle 
(Figure 6). The QRS complex obtained is therefore a fusion of the 2 activation fronts, and is similar to that 
seen in anteroseptal pre-excitation syndromes. 

The fact that this did not disappear in any of the 
CRBBB patients in which the QRS complex was 
completely normalized, together with the spike-QRS 
to His-bundle pacing latency, can be explained by 
the location of the block in a peripheral region of the right 
branch, distal from the His-bundle. In patients with CLBBB, His-bundle pacing produces an almost normal QRS complex, although the short spike-QRS latency indicates some degree of 
adjacent myocardial capture (fusion). The disappearance of the CRBBB indicates that it is 
located in the His-bundle (it is impossible to “eliminate” a CLBBB by stimulating sites in the right 
ventricle) and that stimulation is distal to the site of the 
blockage (Figure 3), which remains refractory. 

In patients with complete infra-Hisian 
atrioventricular block, the fact that His-bundle pacing 
produces an almost normal QRS, with minimal 
latency, can be explained by the mechanism described 
above. It also shows that the His-bundle block is 
proximal, and that capture occurs distally to that zone, 
which is free of refractoriness (Figure 2). 

In the patient with dilated cardiomyopathy 
and CLBBB, evidence for intraventricular 
resynchronization produced by His-bundle pacing is 
provided by a return to normal echo-Doppler 
electromechanical patterns. We do not know whether the increase in His- 
bundle pacing threshold over time is due to 
microdislodgement, fibrosis, or some other mechanism.

CONCLUSIONS

Permanent His-bundle pacing is possible in the majority (71%) of cases with infra-Hisian 
atrioventricular block and can be attempted when prior 
stimulation of the His-bundle leads to disappearance of the conduction disturbance (63% of the present 
series). We believe that it is worth persevering this pacing 
site, despite the potential drawbacks, if it means this 
will pursue myocardial contraction which mimics a 
physiological contraction. A lack of knowledge 
regarding the progression of the conduction 
disturbance, lead stability, and the evolution of pacing 
thresholds means that, for the time being, it is 
necessary to ensure ventricular capture using a back- 
up lead in the right ventricle. 

The theory of longitudinal dissociation in the His- 
bundle is confirmed and explains the findings that we 
describe.

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