Upgrade to dual chamber pacing after long-term ventricular stimulation

Feasibility and intermediate term follow-up

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Aims To evaluate the feasibility and follow-up results of atrial lead implantation and a change to dual chamber pacing following long-term treatment with single chamber ventricular stimulation.

Methods and Results During a 30-month period, 70 consecutive patients with ventricular pacemakers were referred for pulse generator exchange or lead reoperation. Using defined criteria, an upgrade procedure was considered indicated in 34 of the cases (49%); these patients had a mean age of 74·8 ± 8·8 years, and had been treated with VVI or VVIR pacing for a mean time of 7·8 ± 3·8 years (range 1·8–17). An atrial lead was successfully implanted via ipsilateral subclavian venipuncture through the existing pectoral pacemaker pocket in 33 of the 34 cases (97% of the attempts). Postoperatively, one atrial lead dislodgement was seen, and another patient required atrial lead adjustment due to P wave undersensing. The mean follow-up period was 14 ± 10 months. During this time, four patients developed permanent atrial fibrillation (annual incidence 11%). In 82% of the patients in whom an upgrade procedure was attempted, dual chamber pacing was maintained at the end of follow-up.

Conclusion Restoration of AV synchrony is possible in a substantial proportion of patients treated with long-term ventricular stimulation. Atrial lead placement through ipsilateral subclavian venipuncture is generally feasible, and the vast majority of cases remain in dual chamber pacing with normal function during intermediate term follow-up.

Key Words: Dual chamber pacing, ventricular pacing, atrial pacemaker leads, atrial fibrillation.

Introduction

The haemodynamic importance of properly timed atrial systole has been recognized since the beginning of this century, and many studies have demonstrated a higher cardiac output with atrial or atrioventricular (AV) synchronous pacing than with ventricular stimulation[1–3]. There is ample evidence of the beneficial effects of maintained AV synchrony in clinical pacing. In sinus node disease, atrial stimulation results in lower risks of permanent atrial fibrillation, heart failure, stroke and mortality when compared with ventricular pacing; these findings have been made in retrospective treatment-comparison studies[4, 5] and in a recent randomized and controlled investigation[6]. In high-grade AV block, quality of life has been demonstrated to be superior with DDD compared with VVIR pacing[7], and there is evidence that AV synchronization may result in a lower mortality during follow-up, at least in patients with congestive heart failure[8,9]. Knowledge of the importance of AV synchrony has had a significant impact on the selection of pacing mode at primary pacemaker implantation, and it is now generally agreed that a pacing system retaining a normal AV activation sequence should be the first choice[10,11]. However, a significant number of patients have previously received ventricular (VVI or VVIR) pacemakers, and the management of these cases poses a clinical problem. If symptoms caused by AV dyssynchrony are present, i.e. the ‘pacemaker syndrome’[12,13], an upgrade to dual chamber pacing is indicated, but a change to dual chamber pacing may have beneficial effects in other patients with ventricular pacing as well[14]. Nevertheless, there are indications that upgrade procedures are performed only in a minority of patients with ventricular pacing at the time of pulse generator exchange. Data from the Swedish Pacemaker Registry (1996) show that 19-9% of patients with single chamber ventricular


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pacemakers had an upgrade to dual chamber pacing when the pulse generator was exchanged; the remaining 80·1% continued with VVI or VVIR pacing (personal communication, Anita Bocray, the Swedish Pacemaker Registry).

An upgrade is impossible in some patients, including cases with permanent atrial fibrillation. Although atrial lead implantation in previously paced patients is performed in many centres, the practicability of this procedure in sizeable numbers has not received great attention. Doubts regarding the reliability of dual chamber stimulation following a long period of ventricular pacing may also result in a decision to maintain VVI or VVIR stimulation.

The aim of this study was to investigate the possibility of performing an upgrade to dual chamber pacing in patients previously treated with ventricular stimulation, and to evaluate the risk of atrial lead and arrhythmia complications following this procedure.

**Methods**

**Patient selection**

From November 1994, all patients with a VVI or VVIR pacemaker, who were referred for a pulse generator exchange or a lead reoperation, were evaluated regarding the possibility of upgrading the pacemaker system to dual chamber pacing. The case records of these patients were reviewed, and all available ECG recordings were studied. An upgrade procedure was not considered indicated if any of the following was present:

1. Permanent atrial fibrillation or flutter (defined as atrial fibrillation or flutter documented both before referral and on the pre-operative ECG, without documented sinus rhythm in between);
2. Recurrent paroxysmal supraventricular tachyarrhythmias, not controlled by antiarrhythmic medication;
3. Normal sinus rhythm and AV conduction, with an indication for cardiac pacing that was apparently transient (e.g. in conjunction with a myocardial infarction);
4. Severe, limiting disability for non-cardiac reasons;
5. The choice of the patient not to have an atrial lead implanted, after having received information about the procedure.

In all other cases, an upgrade to dual chamber pacing was attempted.

**Operative technique**

Patients were prepared as for routine pacemaker implantation, including the administration of prophylactic, single-dose intravenous cloxacillin. A pre-operative chest X-ray or venography was not performed. Conscious sedation was employed if preferred by the patient. The pectoral pulse generator pocket was opened under local anaesthesia, the pulse generator was disconnected from the ventricular lead, and the lead was inspected. An intracardiac electrogram was recorded. The amplitude of the QRS complex, the ventricular pacing threshold (at 0·5 ms impulse duration), and the lead impedance (at 5 V pulse amplitude and 0·5 ms impulse duration) were determined using a Medtronic 5311B pacing systems analyser (Medtronic, Inc., Minneapolis, Minn., U.S.A.).

The course of the ventricular lead was visualized with standard antero-posterior fluoroscopy. The subclavian vein was then punctured through the pulse generator pocket during continuous fluoroscopy, taking care not to touch the ventricular lead with the needle. When backflow of venous blood was seen, a standard J-shaped guide wire was passed through the needle. To confirm free passage into the venous system and to exclude an arterial puncture, the tip of the guide wire was routinely advanced below the right diaphragm. A 10 French introducer set was then bent slightly to form a gentle curve, and advanced over the guide wire during fluoroscopy. The atrial lead was introduced, and the lead tip was placed, preferably in the right atrial appendage, using a J-shaped stylet. Stability of the lead tip was ascertained by advancing the lead body through the tricuspid valve, letting the blood stream exert a ‘pull’ on the lead. An intracardiac electrogram was recorded. The intra-atrial P wave amplitude, pacing threshold, and lead impedance were determined as described above. A P wave amplitude larger than 1·5 mV and an atrial pacing threshold below 1·5 V were considered acceptable. If there was evidence of ventricular lead dysfunction, another introducer set was placed over the retained guide wire to implant a new ventricular lead as well[15]. Removal of the previously implanted ventricular lead was not attempted. The leads were connected to a dual chamber pulse generator (DDD or DDDR), and the pulse generator pocket was closed.

A postoperative chest X-ray was performed on the day of surgery. The pacemaker function was tested and adjusted prior to discharge; this included determination of sensing and pacing thresholds in the atrium and the ventricle, and activation and tailoring of the rate responsive function in cases of chronotropic incompetence.

Routine follow-up consisted of an outpatient visit 1 month after the operation, and at 12 month intervals thereafter. Cardiac symptoms were recorded, an ECG recording was made, and the adequacy of sensing and pacing was determined at these visits. Antiarrhythmic drugs were given only to patients with documented paroxysmal supraventricular tachyarrhythmias. The data analysis was retrospective.

**Statistics**

Data are presented as mean ± SD. The Student’s t-test was used for comparison of means, with a difference of \( P<0.05 \) considered significant. The follow-up time was calculated from the pacemaker implantation to the last
visit. The follow-up data are presented using Kaplan–
Meier survival curves with 95% confidence limits (CL).

Results

Patient data

During the 30-month period from November 1994 to
April 1997, 70 patients with permanent VVI or VVIR
pacemakers were referred for pulse generator exchange
or lead reoperation (Table 1). In 48 of the patients a
pulse generator replacement was indicated due to nor-
mal pulse generator battery depletion. In eight cases
reoperation was necessary because of malfunction of the
pacemaker system, and 14 patients were referred for
consideration of a change of pacing mode (from ven-
tricular to dual chamber pacing, or from VVI to VVIR
stimulation) because the haemodynamics with the
present system were considered suboptimal. A factor
precluding an upgrade to dual chamber pacing, as
defined above, was present in 36 (51%) of these cases
(Fig. 1). An upgrade procedure was thus attempted in

the remaining 34 patients. In these patients, the existing
ventricular lead had been implanted through the right
cephalic vein in 20, the left cephalic vein in one, the right
subclavian vein in one, the right external jugular vein in
10, and through the right internal jugular vein in two
cases.

Perioperative results

In 33 of the 34 patients (97%) atrial lead placement by
an ipsilateral subclavian venipuncture through the pace-
maker pocket was successful. In the 22 cases where the
existing ventricular electrode had been implanted
through a cephalic or subclavian vein, the course of the
new atrial lead was cranial to the ventricular lead in 16,
and caudal in six cases. Intra-operative measurements
are shown in Table 2.

In the only case where the upgrading attempt failed,
puncture of the subclavian vein and introduction of the
guide wire was without problems. However, insertion of
the lead introducer resulted in arterial bleeding, obvi-
ously from a lesion of the subclavian artery. The intro-
ducer and the guide wire were withdrawn, and the
bleeding was controlled by digital pressure and place-
ment of a suture around the puncture channel. The
upgrade procedure was abandoned, and a pulse gener-
ator exchange was performed. The postoperative course
was uneventful.

Thus, a total of 33 patients had an upgrade to dual
chamber pacing, and 37 underwent pulse generator

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**Table 1** Patients referred for pulse generator exchange
or lead reoperation

<table>
<thead>
<tr>
<th>n</th>
<th>Gender</th>
<th>Time in ventricular pacing</th>
<th>Age at referral</th>
<th>Initial indication for pacing</th>
<th>Present pacemaker system</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>35 male, 35 female</td>
<td>69.5 ± 10.1 y (range 41–88)</td>
<td>78.8 ± 9.7 y (range 53–96)</td>
<td>SND: 25 (7 with PSVT) AVB: 40 (3 with PSVT) Atrial fibrillation, slow rate: 5</td>
<td>56 VVI, 14 VVI-R</td>
</tr>
</tbody>
</table>

AVB=high-grade atrioventricular block; PSVT=paroxysmal
supraventricular tachyarrhythmias; SND=sinus node disease; y=years.

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**Table 2** Intraoperative measurements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave amplitude</td>
<td>3.1 ± 1.2 mV (range 1.6–5.8)</td>
</tr>
<tr>
<td>Atrial stimulation threshold</td>
<td>0.5 ± 0.3 V (range 0.1–1.2)</td>
</tr>
<tr>
<td>Impedance</td>
<td>353 ± 62 ohms (range 250–498)</td>
</tr>
</tbody>
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**Figure 1** Schematic representation of considerations and outcome in 70 consecutive patients with ventricular pacing, referred for a pulse generator exchange or lead reoperation.
exchange and continued treatment with ventricular stimulation. The characteristics of these two groups are compared in Table 3. The patients who received an atrial lead and a dual chamber pulse generator were significantly younger and had a shorter period of ventricular pacing than those in whom an upgrade procedure could not be performed. Paroxysmal supraventricular tachyarrhythmias had been documented in six of the patients in whom dual chamber pacing was initiated (in four before the first pacemaker implantation, and in two during the period of ventricular stimulation).

Twenty-eight of the atrial leads used were of the unipolar screw-in type (Biotronik DY 60-UP or YP 60-UP; Biotronik GmbH & Co., Berlin, Germany): one was a bipolar screw-in model (Biotronik Y 60-BP), and four were unipolar, straight tined leads (Biotronik TIR 60-UP). In no case was the indwelling ventricular lead damaged during atrial lead implantation; however, three patients received a new ventricular lead (due to a preoperatively documented insulation defect or a high stimulation threshold). Twenty-one patients received a DDR pulse generator (Biotronik Ergos or Dromos DR, or Intermedics Marathon DR; Intermedics SA, le Locle, Switzerland), and 12 patients, in whom the sinus node function was considered normal, a DDD pulse generator (Biotronik Gemnos or Physios).

In one patient, the atrial lead became dislodged on the day of the operation, and reprogramming to ventricular pacing was chosen. In the remaining 32 patients with an upgrade to dual chamber pacing, the postoperative chest X-ray showed a satisfactory atrial lead position and no pneumothorax, and the postoperative sensing and pacing threshold measurements were adequate. Nine patients (27%) were discharged on the day of surgery, and 20 (61%) on the first postoperative day; two patients left the hospital 2 days after operation, and the remaining two on the fourth postoperative day.

Follow-up

The 32 patients discharged with dual chamber pacing were followed postoperatively for a mean period of 14 ± 11 months (range 0.2–34 months). No patient was lost to follow-up. In one case, P wave undersensing developed postoperatively, requiring reoperation with a change of the lead position. In one further case, transient P wave undersensing was noted. In the remaining 30 cases, no sensing or pacing abnormalities were detected. No infections of the pacemaker system were seen.

In four cases, conversion to atrial flutter or fibrillation was noted during follow-up, requiring reprogramming to VVI or DVI pacing mode. Supraventricular tachyarrhythmias were not documented before conversion in any of these patients, who have remained in atrial fibrillation; the annual incidence of permanent atrial fibrillation was thus 11% (Fig. 2). Cardioversion was not attempted in these cases. None of the six patients with paroxysmal supraventricular tachyarrhythmias documented prior to the upgrade procedure had atrial flutter or fibrillation at the follow-up visits.

Of the 34 patients initially accepted for an upgrade procedure (intention to treat), 28 (82%) remained in normal dual chamber pacing at the end of follow-up. This proportion was 82% (95% CL: 67–97%) at 12 months, and 75% (95% CL: 57–94%) at 24 months postoperatively (Fig. 3). Four patients died during follow-up. In two of these the cause of death was myocardial infarction, with no preceding angina. It is

![Figure 2](https://example.com/fig2.jpg)  
Proportion of patients discharged with dual chamber pacing (n=32) who were free of permanent atrial fibrillation, as a function of time (bold line). The thin lines indicate the 95% confidence limits.
In a literature review, Spittell and Hayes[16] found a high disease. In the two other cases the cause of death was possible that the increase in heart rate following the upgrade to dual chamber pacing was detrimental in these cases of previously undiagnosed ischaemic heart disease. In the two other cases the cause of death was not related to the pacemaker treatment.

**Discussion**

In a literature review, Spittell and Hayes[16] found a high incidence (30–45%) of lead-induced venous thrombosis early or late after transvenous pacemaker implantation. The present results demonstrate that a puncture of the subclavian vein is almost always possible despite the presence of an indwelling lead. Presumably, the thrombotic changes described generally do not extend throughout the length of the vessel. This is consistent with a report of a case of subclavian vein occlusion[17], where the vein was patent on the central side of the obstruction, permitting pacemaker lead implantation through a subclavian venipuncture. A pre- or intra-operative venography before an upgrading attempt therefore appears unnecessary. In favour of subclavian vein patency in our series was probably the high use of jugular veins (12 patients) in the earlier pacing procedure.

Permanent atrial fibrillation develops in a substantial number of patients with ventricular pacing for sinus node disease[4–6], and the incidence of this arrhythmia increases with patient age[18]. As expected, permanent atrial fibrillation was therefore a common contraindication to an upgrade from ventricular to dual chamber pacing. A considerable risk of conversion to atrial fibrillation may persist despite a change to dual chamber pacing, and may cause pacing disturbances. The annual incidence of permanent atrial fibrillation in this population (11%) exceeds that reported in less elderly patients following primary dual chamber pacemaker implantation (1.8%–4.5%)[19,20], but in our opinion this risk of permanent atrial fibrillation should not preclude an upgrade. However, a dual chamber rate adaptive pulse generator, with an automatic mode switch to VVIR pacing in case of an atrial tachyarrhythmia, appears the best choice for these patients.

Holter recordings were not routinely performed prior to the upgrade. It is possible that such recordings, by detecting asymptomatic paroxysmal supraventricular tachyarrhythmias, may identify patients at a high risk of developing permanent atrial fibrillation. The fact that the six patients with documented paroxysmal tachyarrhythmias did not develop permanent atrial fibrillation during follow-up raises doubts about the prognostic relevance of the information to be obtained by long-term ECG recording. However, the incidence and importance of asymptomatic supraventricular tachyarrhythmias following an upgrade from long-term ventricular pacing deserves further investigation.

The alternative treatment in these patients is to change to a VVIR pulse generator, providing rate response but not AV synchrony. Patients treated with long-term ventricular pacing may have a high prevalence of degenerative changes in the atrial myocardium, both as a result of the negative haemodynamic consequences of the ventricular stimulation and because of old age; this may influence the atrial contractile function negatively, and diminish the positive effect of AV synchrony. On the other hand, there is evidence that the atrial contribution to cardiac function becomes more important with advanced age, as the ventricular compliance decreases[21]. In a randomized double-blind crossover comparison, Sulke et al.[14] found that exercise capacity and perceived general well-being were superior with DDD than with VVI pacing following an upgrade procedure in 16 patients. Although their data favour the concept of upgrading from VVI pacing, the relative importance of AV synchrony and of the exercise rate response provided with the DDD mode could not be ascertained.

In a recent series[22], a high incidence of complications of upgrade procedures was reported. We have experienced what we consider to be a low rate of complications of this procedure, but the relatively large usage of the jugular veins in the previous procedure may have been helpful.

To guide the clinical management of pacemaker patients treated with long-term ventricular pacing, it remains to be determined to what extent these patients benefit from the restoration of AV synchrony, in terms of haemodynamics, quality of life, and cardiovascular morbidity.

**References**

Upgrade to dual-chamber pacing


