Atrial Pacing from the Coronary Vein
Ten-year Experience in 50 Patients with Implanted Pervenous Pacemakers

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SUMMARY During the past ten years, pervenous atrial pacemakers have been implanted in 50 patients (mean age 68 years, 60% males) using an electrode positioned in the coronary vein. The indications for atrial pacing were symptomatic sinus bradycardia (72%), atrial brady-tachy syndrome (20%), and recurrent tachyarrhythmias (8%). Atrial pacemakers have been implanted for a total of 1531 pacing months, average 31 months per patient, median 26 months, and range 3–97 months. Effective atrial pacing has been achieved with Medtronic model 5818 and 6904 electrodes. Unipolar or bipolar atrial pacing has been equally effective, and commercially available Medtronic 5950, Cordis 162 and CPI 602 pulse generators have been utilized without difficulty. A total of 11 electrode related malpacing events occurred in the ten-year period with a malpacing event rate of 10% in the first pacing month, 1.1% per paced month during the next six months, and 0.25% per paced month thereafter. Life table analysis reveals that effective atrial pacing was achieved in 76% of the patients during a follow-up of more than five years. This experience substantiates the long-term safety and effectiveness of atrial pacing from the coronary vein using standard pacemaker electrodes and generators.

IN 1968 we first reported on a pervenous atrial pacing technique using an electrode positioned in the coronary vein. Subsequent reports during the period from 1970 to 1974 documented the safety of this procedure in a relatively small number of patients.\(^1\) We have also reported on the usefulness of the coronary vein atrial pacing technique in the termination and inhibition of recurrent supraventricular tachycardia.\(^8\) Since the original article in 1968, we have implanted pervenous atrial pacemakers in the coronary vein in 50 patients. This report details the effectiveness of this pervenous atrial pacing technique during the past ten years.

Methods
Details of the method of implanting a permanent coronary venous atrial pacemaker have been described previously from this laboratory.\(^1\) Presently, the most effective technique for introducing the catheter into the coronary vein utilizes a left cephalic vein approach. With rare exceptions, Medtronic model 5818 and 6904 bipolar catheters have been utilized. A gentle 60° bend from the tip of the electrode and an additional J bend at the electrode tip are made with the styles of the catheter before insertion of the electrode into the vein. The catheter is advanced under fluoroscopic visualization into the right atrium, and with the aforementioned bends in the electrode the catheter is directed away from the tricuspid valve and into the coronary sinus. The characteristic superior direction of the electrode in the coronary vein is well described in previous reports.\(^5,\)\(^6\) The fluoroscopic time for positioning the catheter in the coronary vein is generally less than five minutes. After the catheter is in the mid portion of the coronary vein, the styles are withdrawn and the threshold for pacing is determined for the unipolar proximal (ring) and distal (tip) electrodes and for the bipolar configuration. The lowest atrial pacing thresholds have generally been obtained from the unipolar ring electrode. A threshold of less than 3 milliamps for atrial pacing is optimal, and if higher thresholds are evident the catheter is either advanced further into the coronary vein or withdrawn slightly from its prior position to obtain a lower threshold. Unipolar and bipolar pulse generators have been utilized, and satisfactory atrial pacing has been achieved with Medtronic, Cordis, and Cardiac Pacemaker pulse generators.

Results
The clinical characteristics of the 50 patients with implanted atrial pacemakers are presented in table 1. The mean age of the patients was 68 years; 60% were males. The major indication for atrial pacing was symptomatic sinus bradycardia (72%); 20% had the atrial brady-tachy syndrome, and 8% required atrial pacing for inhibition or termination of intractable or recurrent tachyarrhythmias (ventricular fibrillation in three and paroxysmal supraventricular
tachycardia in one). During the ten years, 50 patients had atrial pacemakers implanted for a total of 1531 pacing months (average 31 months per patient, median 26 months, range 3–97 months).

Many different pacemaker generators have been used effectively in this population (table 2). The Medtronic model 5841/5842 series generators (bipolar) were the most frequently used pacemakers during the initial implantation procedure (58%). More recently an increasing number of Cordis unipolar model 162 series (OmniStimCor) generators have been implanted because of their adjustable output and rate. Currently, 34 patients are being actively paced, and 47% have Cordis model 162 generators. It should be emphasized that each of the pacemaker models listed in table 2 has provided effective atrial pacing. Medtronic model 5841/5842 generators required special modification by the manufacturer to prolong the refractory period of the generator to 350 msec or longer. The commercially available generators of the Medtronic 5950 series, the Cordis 142, 162 and 190 series and the Cardiac Pacemaker 601 and 602 series have refractory period durations which are suitable for atrial pacing, and these units have been used without modification.

Standard Medtronic bipolar electrodes were used in all but one patient (table 2). The Medtronic 5816 electrode was used in three patients during our early 1967 and 1968 experience, model 5818 was used in 27 patients from 1969 to 1974, and the tapered small-tip electrode model 6904 has been used exclusively in 19 patients since September 1974. The threshold for atrial pacing averaged 2.3 ± 1.6 ma (± SD) (range 0.8–10.0 ma) at the time of initial implantation in 50 patients and increased to 3.6 ± 1.1 ma (range 1.8–5.6 ma) at the time of the most recent elective battery replacement in 14 patients. In the last nine atrial pacemakers which were implanted between January 1976 and February 1977, a hybrid system was utilized by connecting a unipolar Cordis model 162 or 190 generator to the ring electrode of a Medtronic 6904 catheter. The threshold for unipolar atrial pacing via the ring electrode averaged 2.4 ± 1.3 ma, a value very similar to that of our earlier bipolar experience.

The total electrode-related malpacing events, i.e., those unrelated to primary generator dysfunction, are presented in table 3. The malpacing events are not uniformly distributed over time, but rather are concentrated in the early post-implantation period. Of 11 malpacing events, five occurred within the first postimplantation month, three occurred in the next six months, and the remaining three occurred between 9 and 33 months after insertion. Electrode dislodgement out of the coronary vein occurred in four patients, a high early threshold in three, and the remaining four events included one temporary malsensing problem, one electrode wire break, and two paced PR interval prolongations of greater than 0.24 sec. The rate of malpacing events averaged 10% during the first implantation month, 1.1% per paced month during the next six months, and 0.25% per paced month thereafter. An actuarial analysis of the effectiveness of atrial pacing over time is presented graphically in figure 1.

Eleven patients died in this series during the 10 year experience, and pacemaker malfunction could not be implicated as the cause of death in any patient. Six patients died with chronic end-stage congestive heart failure, two with documented acute myocardial infarction, and three with problems unrelated to their chronic cardiac disease. Five of the eleven patients died during hospitalizations remote from the initial implantation procedure from problems unrelated to the pacemaker. In each case effective atrial pacing was documented during the terminal episode.
Autopsy examinations on four patients revealed patent coronary veins without blood clot or perforation. In three of the four patients an endothelial sheath had formed over the electrode and the catheter had become adherent to the wall of the vein.

Discussion

This report extends our earlier experience and further substantiates the effectiveness of this atrial pacing technique in the long-term management of patients with sinus node dysfunction and selected types of intractable tachyarrhythmias. For the most part standard generator and electrode pacemaker systems routinely available for ventricular pacing were used, and special modifications were not required. The pacemaker generator should have a refractory period of 325 msec or longer after discharge of the pacing impulse to prevent inappropriate sensing of the QRS complex which follows the paced atrial P wave. In a prior publication we illustrated the electrophysiologic phenomena responsible for inappropriate sensing of the QRS complex.

Since the PR interval is often 200 msec and the QRS duration 100 msec, the refractory period of the generator should be longer than the sum of these two intervals to avoid sensing the terminal portion of the generated QRS complex. In the selection of a pacemaker for atrial pacing, the electrical characteristics of the generator must be known. In the rate adjustable units such as the Cordis Omnistanicor series, the duration of the pacemaker refractory period is inversely related to the demand rate. For example, at a demand pacing rate of 60 beats/min the refractory period is about 375 msec whereas at a rate of 100 beats/min the refractory period diminishes to 225 msec. Thus, with rapid atrial pacing there is an increased likelihood of inappropriate QRS sensing.

A variety of different atrial pacing techniques have been reported in the literature, but none has achieved as favorable long-term results as are presented in this study. The suprasternal approach of Carlen's and Lagergren with direct suturing of electrodes onto the epicardial surface of the atrial wall through a mediastinoscope has not gained wide acceptance. Kastor et al., Smyth and associates, and Castillo and co-workers have used pervenous electrodes positioned in the right atrial appendage for atrial sensing and pacing. Electrode dislodgement has been a troublesome problem, but ongoing modification of the electrode configuration and further clinical experience have substantiated the potential usefulness of these right atrial approaches.

Other pervenous methods using atioventricular electrodes and electrodes with barbs and hooks for atrial fixation have had only limited trials.

Eleven malpractice events were observed in the 50 reported patients during 1531 atrial pacing months for an average event rate of 0.72% per paced month. In the seven patients with either electrode dislocation out of the coronary vein or the development of a high threshold, the initial atrial pacing threshold averaged 4.4 ± 2.8 ma, a value almost twice that of our entire series. As indicated in the Methods section, our current procedure is to strive for an atrial pacing threshold of less than 3.0 ma at the time of implantation. With higher thresholds, inconstant pacing is likely to develop. It should be noted that the average threshold for atrial pacing increased by only 1.3 ma between initial implantation and subsequent battery replacement two to four years later. This small increment is similar to that observed with ventricular pacing.

The life table graph (fig. 1) clearly indicates the higher problem rate during the first few months after implantation with a subsequent performance which is excellent. Over 75% of the patients had effective atrial pacing five years after implantation of the coronary vein electrode.

Atrial pacemakers have special usefulness in selected clinical problems. Although many patients with symptomatic sinus bradycardia can be paced effectively with ventricular electrodes, atrial pacing often improves the hemodynamic state by enhancing atrial contribution to ventricular performance.

The preservation of the normal sequential relationship between atrial and ventricular contraction is especially important in patients with atrial bradycardia and associated myocardial disease. Atrial pacing is most helpful in improving the quality of life in this group. Three patients in this series with symptomatic sinus bradycardia originally had ventricular pacemakers implanted, but subsequently required conversion to atrial pacing because of hypotension and low cardiac output. The clinical situation significantly improved after the atrial pacing.

In some patients with the atrial brady-tachy syndrome with normal atioventricular conduction, ventricular pacing has inadvertently induced recurrent re-entrant tachycardia. Atrial pacing is especially indicated in this clinical situation for not only are the ventricular pacemaker-induced tachycardias avoided, but also atrial pacing may inhibit the expression of the atrial tachycardia.

Although our experience is limited, atrial pacing has controlled intractable supraventricular and ventricular tachyarrhythmias in four patients. With clearer understanding of the re-entrant mechanism in many tachyarrhythmias, the authors suspect that atrial pacemakers will have increasing applicability in the management of troublesome reciprocating supraventricular tachycardias. Furthermore, newer atrial pacing techniques using paired pacing and rapid pacing with rates up to 400/min in conjunction with radiofrequency controlled generators may have wider applicability with the use of the stable coronary vein electrode.
References

Effects of Sublingual Nitroglycerin on Resting Pulmonary Gas Exchange and Hemodynamics in Man

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SUMMARY Simultaneous hemodynamic, ventilation and blood gas measurements were performed in 19 males during cardiac catheterization for evaluation of chest pain syndrome before and 3 to 5 min after 0.4 mg sublingual nitroglycerin. Pulmonary arterial pressures and total pulmonary vascular resistance fell (P < 0.001 for both), and mean systemic arterial pressure decreased (P < 0.05). However, peripheral vascular resistance, cardiac output, and mixed venous PO2 did not change. Total and tidal ventilation, PCO2, pH, and base excess remained unchanged. However, the arterial PO2 decreased from a mean of 80 ± 3 (SEM) to 72 ± 2 mm Hg (P < 0.001) and mean venous admixture increased from 8.8 ± 1% to 12.6 ± 1.5% (P < 0.001). The alveolararterial PO2 difference increased (P < 0.001) and the dead space tidal volume ratio rose (P < 0.05).

We conclude that the decrease in arterial PO2 following sublingual nitroglycerin is caused by redistribution of pulmonary blood flow with imbalance in ventilation-perfusion relationships or shunting.

The purpose of the present study was to investigate the possible effects of an even more widely used vasodilator, sublingual nitroglycerin, on the resting pulmonary gas exchange and simultaneous hemodynamics in man.

Patients and Methods

Nineteen male patients aged 26 to 70, admitted for evaluation of chest pain syndromes, were the subjects of this study. Five patients were normal, 11 had coronary artery disease (including four with abnormal left ventriculograms), two had primary myocardial disease, and one had rheumatic mitral regurgitation.

The studies were performed in the postabsorptive state in the cardiac catheterization laboratory during the course of right and left heart catheterization and coronary arteriography. Prior informed consent was obtained appropriately. Patients were in the supine position and were breathing room air during the entire procedure. All hemodynamic and blood gas data were obtained before the
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