

**THE SYSTEM CONCEPT OF PHYSIOLOGIC PACING:
RIGHT PARASTERNAL APPROACH TO ATRIAL
AND VENTRICULAR PACING, ATRIAL MAPPING,
EEG, AND STAGING**

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THE SYSTEM CONCEPT OF PHYSIOLOGIC PACING :
 RIGHT PARASTERNAL APPROACH TO ATRIAL AND VENTRICULAR PACING,
 ATRIAL MAPPING, EEG, AND STAGING

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TABLE I Physiologic Pacing - Patients

Sept 1976 - July 1979 - 34 months			
Patients		25	
Sex	M/F	12/13	
Age	Average	69.25	
	Median	63.5	
	Range	44-83	
Follow-Up (Months)			
		Range	Average
Atrial Synchronous		31-33	32.5
Atrial		0.5-8	4.2
A-V Sequential		1-16	9.6

INTRODUCTION

The relief of syncope with pacing may be associated with disabling vertebral basilar symptoms due to the reduced stroke output of RV pacing and, in part, to vertebral artery obstruction. Rate programming is not effective in relieving these symptoms. Vertebral artery surgery was most beneficial when combined with physiologic pacing [Carney 1,2]. Attempts at physiologic pacing, exclusive of open heart surgery, had met with frustration until the advent of a new A-V sequential pacemaker, a new atrial electrode and a new surgical approach.

Our experience with 25 patients since September 1976 suggests that the right sided approach to pacing the right atrium and ventricle is practical [Carney 3], that atrial mapping is useful in the selection of the optimal pacing site, that both mapping and fixing the electrode position requires surgical intervention, that in many patients physiologic pacing is best accomplished in stages, and finally, that implantable pacing devices should be compatible with expansion into a physiologic pacing system with minimal device replacement.

TABLE II Physiologic Pacing - Techniques

Atrial Synchronous	4
Atrial Pacing	2
AV Sequential	14
Primary 9	
Secondary 5	
First Stage to AV Pacing	8

IMPLANTED DEVICES

This experience is limited to the use of the Elema-Schonander atrial synchronous pacemaker EM 156-50, the Medtronic programmable atrial, 5994AP and AV sequential pacemaker, 5992, the atrial sensing electrode (EM 567), the atrial stimulating electrode (Medtronic 6995) and the bipolar endocardial electrode (Medtronic 6902).

TABLE III Surgical Approach to the Atrium

LEFT - 9	RIGHT - 14
Parasternal 8	Parasternal 12
Thoracotomy 1	Thoracotomy 2
RA 8 LA 1	RA 14
RV 9	RV* 10
	T-A 7
	SVC 3

* Sub-xiphoid 2, transvenous 2

RIGHT PARASTERNAL APPROACH

The preferred approach to the right atrium is through the bed of the third costal cartilage rather than the fourth as suggested by Calvin [2] because of the improved access to the superior vena cava and the superior aspect of the atrium. A curvilinear incision, convexity toward the sternum, is carried down to the bony thorax. The single cartilage is separated from the perichondrium and removed. The internal mammary artery and vein are ligated and

divided. Dissection proceeds beneath the sternum to the pericardium. The thin walled pleura may be entered at this point. The pericardium is opened longitudinally and stay sutures are positioned. Pericardial adhesions are divided as required. A retractor is placed in the pericardium for lateral traction. Anterior thoracotomy may be easily achieved by lateral extension of the incision.

THE RIGHT ATRIUM

The size, shape and tension of the atrium is variable. Distension may be extreme in heart failure. There is also marked variation of pacing threshold, action potential, waveform, and wall thickness, friability and motion. The conduction system of the atrium differs from that of the ventricle by its pathways. The distribution of sites for optimal atrial pacing is primarily in the superior and medial portions of the right atrium [FIGURE 1].

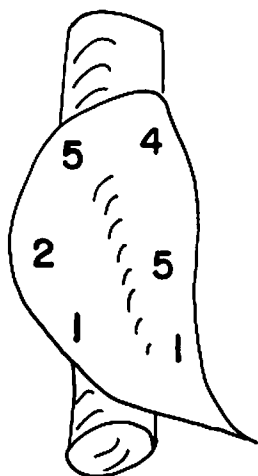


FIGURE 1 Optimal Right Atrial Pacing Site Location in 18 Patients

SITE SELECTION PRIOR TO APPLYING ELECTRODE

Application of the pacing electrode (6995) is facilitated by creating a ridge of atrium with a horizontal mattress suture. Repeated application of the pacing electrode causes fragmentation of the sleeve on the electrode jaw. The friability of the atrium and the problems of securing the electrode make paramount the selection of the optimal pacing site PRIOR to electrode fixation.

The desired features for an atrial pacing site include low threshold, ease of electrode application, minimal motion of electrode at point of contact and long term performance. Usually suitable pacing thresholds could be achieved [TABLE IV], but sensing the atrium is more difficult because of the range of potential, the slow rate and the varying waveforms [Figure 2].

TABLE IV Initial Atrial Implant Data with the 6995 Electrode (PSA 5300, Tektronix 214)

	Threshold		P Wave	Duration Mode
1.JV	1.4 V 1.7 V	7.9 mA 9.3 mA	nmo nmo	22 months RV
2.LR	0.7 V 1.0 V	1.3 mA 1.9 mA	2.6 mV 2.3 mV	19 months RV
3.MD	0.8 V 0.5 V	1.2 mA 0.8 mA	6.0 mV 3.0 mV	24 months RV
4.JC	1.5 V 0.7 V	3.6 mA 1.4 mA	nmo nmo	Failed RA->A-V
5.MT	10.0+V	21.0+mA	*	A-V -> RV
6.LB	0.9 V 0.5 V	1.9 mA 0.8 mA	1.0 mV 3.0 mV	7 months RV->A-V
7.ES	0.8 V 1.7 V	2.0 mA 4.4 mA	nmo nmo	10 months A-V
8.RP	0.8 V 1.0 V	1.7 mA 1.8 mA	2.5 mV 2.5 mV	12 months A-V
9.VA	1.2 V 0.8 V	2.8 mA 1.6 mA	nmo nmo	10 months A-V
10.JZ	0.9 V 3.0 V	2.2 mA 7.9 mA	nmo nmo	5 months A-V
11.RK	0.8 V 0.7 V	2.3 mA 0.9 mA	3.5 mV 3.5 mV	1 months A-V
12.BB	0.7 V 1.2 V	2.1 mA 2.2 mA	nmo nmo	1 months A-V
13.RB	0.5 V 0.6 V	1.0 mA 1.1 mA	nmo nmo	16 months A-V
14.CW	0.8 V 0.9 V	1.7 mA 2.1 mA	nmo nmo	13 months A-V
15.LP	0.6 V 0.8 V	1.0 mA 0.9 mA	— 18.0 mV	15 months A-V

* Atrial fibrillation. Unable to convert to Sinus Rhythm.

TABLE V Variation of Pacing Threshold with Atrial Site and Electrode

RK	6902 Exploring		6995 Pacing	
Site 1.	2.0 V	5.1 mA	Site #2	
#2.	0.8 V	1.6 mA	(+) 0.8 V	2.3 mA
3.	3.5 V	6.5 mA	(-) 0.7 V	0.9 mA
4.	0.7 V	1.6 mA	(+/-) 1.0 V	2.3 mA
5.	3.0 V	6.2 mA		

TABLE VI Inactive Atrial Electrode (6995)
Threshold 7 Months after Implant

11-78 First Stage	6-79 Second Stage
(-) 0.9 V 1.9 mA	(-) 0.8 V 3.1 mA
(+) 1.4 V 3.2 mA	(+) 1.3 V 4.7 mA
	(+/-) 1.3 V 3.1 mA

LB

THE ATRIAL EXPLORING ELECTRODE

The tip of the endocardial electrode (6902) is applied to the lateral and medial aspects of the atrium in a high, mid and low position. Atrial electrograms are recorded and pacing thresholds are determined. The site with the most desirable values and features is selected and the permanent atrial electrodes are applied. The threshold values obtained with the exploring electrode approximates that of the permanent pacing electrode [TABLE V].

INSTRUMENTATION FOR MAPPING THE ATRIUM

The pacing threshold and high voltage atrial signals could be measured with the Pacemaker System Analyzer (Medtronic 5300), but low voltage potentials, waveforms and slew rates require a storage oscilloscope (Tektronix 214) for analysis.

EEG - MONITOR AND POLYGRAPH

EEG monitoring of patients with cerebral vascular insufficiency has been extended to pacemaker implants after experiencing shock and slow wave activity when determining right ventricular pacing thresholds [Anderson 5]. Acute deterioration may escape detection at this time because all attention is focused on threshold determination.

The Grass Model 89 is electrically isolated and can be used for recording unipolar atrial electrograms (AEG) and a reference ECG lead without modification. The EEG records both waveform and voltage from the atrial wall [FIGURE 2]. An EEG with a two channel polygraph could be modified to perform electrophysiological studies in the community hospital adequate for lead placement [Anderson 5].

PROBLEM: ATRIAL ARRHYTHMIA

Atrial fibrillation and flutter is associated with a high threshold and failure of the physiologic pacing system. Failure of sensing with the atrial synchronous pacemaker may result in competing rhythm and require emergency removal.

Cardioversion may not succeed. Defibrillation cannot be accomplished through the right parasternal incision with internal paddles, so that sterile external paddles should always be available in the operating room. Trauma to the atrium may aggravate post-operative arrhythmia.

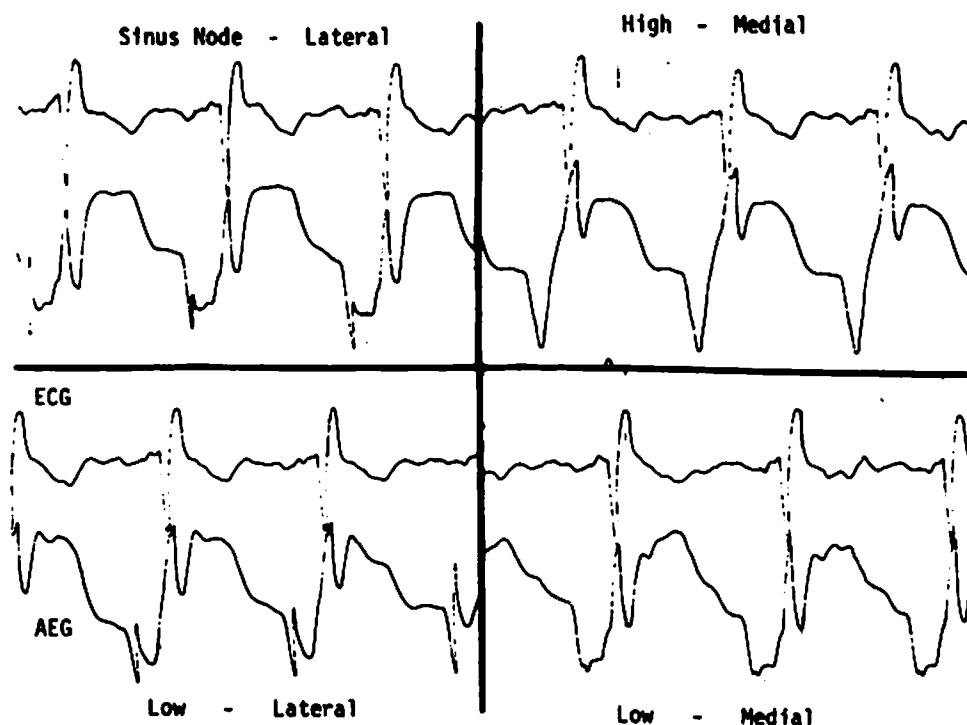


FIGURE 2 Unipolar Atrial Electrogram Recorded on the EEG
Surface ECG lead is helpful reference to atrial waveforms which vary with site.

PROBLEM: ATRIAL ELECTRODE FUNCTION

Long term maintenance of atrial electrode function is a primary concern. Though mediastinal SENSING electrodes appear to function well [Carlens 6], all the atrial sensing electrodes attached directly to the mobile atrium failed or were associated with death within sixteen months. STIMULATING electrodes may be different. The longest functioning A-V sequential system is 16 months old with no problem in sight. Careful selection of a stable site with low threshold, two point fixation of the electrode tip with attention to the lay of the line have been employed.

PACING THE VENTRICLE FROM THE RIGHT SIDE

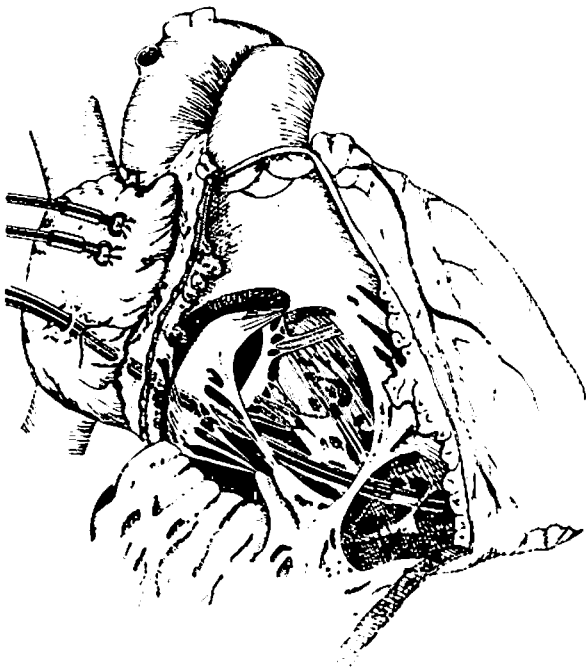


FIGURE 3 Trans-Atrial RV Endocardial Electrode Atrial Pinch On Electrodes

THE TRANS-ATRIAL TECHNIQUE OF RV PACING

Pacing the right ventricle through the right parasternal approach is accomplished by passing the endocardial electrode, used for mapping the atrium, through the wall of the atrium into the RV. Under image amplifier control, this electrode is guided into the right ventricle and secured with the purse string suture. A friable atrial wall with a high CVP can result in rapid and profound blood loss with minimal manipulation. The superior vena cava is more substantial and if the purse string can be placed, the RV electrode can be introduced by this route without the hazard of atrial bleeding. Post-operative dislodgment of this electrode has not occurred. On the other hand, if a transvenous route is utilized, manual guidance of the electrode may facilitate passage.

STAGING PHYSIOLOGIC CARDIAC PACING

Primary implantation of a physiologic pacing system is rare [Citron 7]. A major deterrent to physiologic pacing is pre-existing pacing hardware that cannot be used in a physiologic pacing system. For this reason, STAGING of physiologic pacing has merit because later conversion need not be associated with abandoning incompatible but functioning electrode or pacemaker and the cost of the replacement is saved.

For a poor risk patient, transvenous RV pacing is the least traumatic. In the FIRST STAGE, if only a RV electrode and an A-V sequential pacemaker is implanted and if the atrial function is inactivated, the A-V PACE-MAKER FUNCTIONS AS A PROGRAMMABLE RV DEMAND PACE-MAKER. When the patient's condition has improved and the RV electrode has become secure, the atrial electrodes can be added by the right parasternal or transvenous route as the SECOND STAGE to physiologic pacing.

On the other hand, a good risk patient may tolerate the application of both the atrial and the ventricular electrodes as a FIRST STAGE, and either the atrium or the ventricle need be paced. This permits time to DEMONSTRATE THE NEED FOR PHYSIOLOGIC PACING. Conversion is simplified by merely replacing the pacemaker under local as the SECOND STAGE.

TABLE VI First Stage to AV Pacing

RV Electrode	?
RV pacemaker, RV pacing	
RA & RV Electrodes	5
RV pacemaker, RV pacing	
RA & RV Electrodes	
RA pacemaker, RA pacing	1
RV Electrode	**** 2
A-V pacemaker, RV Pacing	

POST OPERATIVE COMPLICATIONS

Post-operative atrial arrhythmia is common, and prophylactic medication (quinidine, lidocaine) is probably of value. Atrial fibrillation, if not controlled, results in failure of the physiologic pacing system. In the atrial synchronous pacemaker, atrial fibrillation or failure of sensing results in dangerous competing rhythm and emergency pacemaker replacement may be required; in the A-V sequential pacemaker, RV pacing continues uninterrupted. Delayed pericardial drainage was required in one patient. Pleural and pericardial drainage are employed as indicated but the pericardium was usually left open without drainage.

TABLE VII Complications

Death	1
Atrial Synchronous. Shock & Slow Wave Activity with RV pacing. Expired in atrial flutter, po ii.	
Atrial Arrhythmia	16
Refractory Atrial Fib. 2	
Failure of Atrial Sensing	2 (3?)
Pleural Effusion	2
Pericardial Effusion	1
Hypotension	2
RV Pacing	
Adrenal Insufficiency	
Slow Wave Activity (EEG)	2
RV pacing	
Substernal Tunneling	
Pacemaker Size (A-V)	3
Inability to Program	1
Retro-rectus pouch	

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SUMMARY

Physiologic pacing is now attainable with the advent of newly designed atrial electrodes and a programmable A-V sequential pacemaker. The right parasternal approach gives good access to the right atrium directly and to the right ventricle by the trans-atrial route. Mapping of the atrium for waveform and pacing threshold appears to be of value. Only in the operating room, can an electrode be precisely fixed to a chosen atrial site. Staged physiologic pacing requires that the initial pacemaker and electrode be capable of expansion into a physiologic pacing system.

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