The third decade of cardiac pacing *Multiprogrammable pulse generators*

S SERGE BAROLD, MICHAEL D FALKOFF, LING S ONG,
ROBERT A HEINLE

From the Division of Cardiology, Department of Medicine, The Genesee Hospital and The University of Rochester School of Medicine and Dentistry, Rochester, New York, USA

Cardiac pacing as a clinical discipline is now over 20 years old. The end of the first decade saw the development of the demand pacemaker, the first "intelligent" implantable prosthetic device. Further progress took place mostly in the latter half of the second decade, with the introduction of lithium power sources with greater longevity, miniaturisation of electronic circuits, overall improvement in design with the widespread use of hermetic encapsulation of power sources and components for greater protection, and the development of non-invasive programmability. As we begin the third decade of cardiac pacing, the inexorable and accelerated growth of pacemaker technology has already fostered a large array of sophisticated multiprogrammable pulse generators, with a variety of functions. The complexity of pulse generators will inevitably continue to increase with the promise that devices will be far more specific in their clinical applicability.

In 1978, about 36 per cent of all pacemaker implants in the United States used programmable pulse generators¹ and it appears almost certain that these units will largely or indeed completely replace non-programmable systems in the next few years as confidence and reliability improve and the benefits of non-invasive programming become more widely appreciated. Indeed, the greater longevity of lithium powered pulse generators can in itself be considered an important reason for programmability. It is impossible to predict in advance who will require modification of pacemaker variables and the likelihood of a change in a patient's requirements will undoubtedly increase the longer the same generator remains implanted.

Received for publication 11 November 1980

Advantages of programmable pulse generators

We believe that all pulse generators should be multiprogrammable for the following reasons.

(1) OPTIMUM PACING SYSTEM FOR SPECIFIC CLINICAL SITUATIONS

The large variety of pulse generators now permits the selection of an optimum pacing system tailored to the need of the patient. The "fine tuning" provided by multiprogrammable pulse generators represents an improvement in the quality rather than the quantity of life. In addition, the functional versatility of multiprogrammable pulse generators has contributed significantly to the development and clinical use of a variety of pacing systems. Atrial, atrioventricular sequential, and automatic antitachycardia pacing are beginning to realise their full potential, mostly because of the availability of multiprogrammability.

(2) DIAGNOSIS AND TREATMENT OF PACEMAKER COMPLICATIONS

Multiprogrammable pulse generators have greatly simplified the solution of many pacemaker problems. Mounting evidence suggests that the capability of altering pacemaker characteristics by programmability may make operative revision unnecessary in many patients with pacing problems.²⁻⁵

At present it appears that at least four variables should be programmable^{6,7}: rate, output, sensitivity, and refractory period, the latter being the least important. The clinical advantages of these programmable variables are well known and do not need reiteration here. Programmable hysteresis may be

considered as a new technological bonus in search of a clinical application⁸; the concept was introduced several years ago but never became popular because certain clinical disadvantages outweighed its theoretical benefits.⁹ Its resurrection as a programmable characteristic may lead to an increase in its clinical application and greater understanding of its potential advantages.

Programmability of pacing mode

Programmability of pacing mode has not received sufficient emphasis though it represents one of the major recent advances in pacemaker technology.

(1) ASYNCHRONOUS PACING

This may be achieved by decreasing sensitivity or by infinite prolongation of the refractory period and may be useful in certain clinical circumstances. For instance, asynchronous atrial pacing in a patient with the bradycardia-tachycardia (sick sinus) syndrome may terminate re-entry supraventricular tachycardia without patient awareness by the delivery of an appropriately timed stimulus into the re-entry circuit. Occasionally "noisy leads" with the development of oversensing from relatively small electrical transients (for example artefacts from Irnich grasping electrodes¹⁰) may be rendered serviceable by converting to asynchronous pacing thereby avoiding another intervention.

(2) SYNCHRONOUS PACING (VVT OR AAT)*

Some contemporary programmable pulse generators may be converted from the inhibited to the synchronous mode, a manoeuvre potentially useful in the following circumstances: (a) high noise environment; (b) in the presence of obscure extraneous sources of oversensing because the triggered pacemaker impulse represents a marker for the diagnosis and timing of sensed signals; (c) correction of oversensing caused by noisy leads or myopotential inhibition with the avoidance of bradycardia. This provides an attractive alternative to the problem of myopotential oversensing without altering the input sensitivity. (d) Investigation and treatment of obscure dizziness or symptoms that may be pacemaker-related. Programming from the VVI to VVT mode may eliminate elusive undiagnosed periods of pulse generator inhibition sug-

gesting a problem with oversensing. (e) Temporary or permanent programming to the synchronous mode may be useful diagnostically by using programmed external chest wall stimulation to obtain non-invasive electrophysiological data or therapeutically in the termination of re-entry tachycardia by the delivery of burst stimulation activated by rapid chest wall stimulation.¹¹

(3) DUAL CHAMBER PACEMAKERS

We shall confine our discussion to the atrioventricular sequential demand (DVI) pulse generator because it represents the progenitor of a new generation of complex dual chamber pulse generators.

(a) Programmability from the DVI to VVI function may be useful in the diagnosis of pacemaker arrhythmias,¹² to avoid self-inhibition from displacement of the atrial electrode with a conventional bipolar DVI pulse generator,¹³ to save energy whenever permanent atrial fibrillation supervenes or to eliminate asynchronous atrial pacing if it aggravates or even induces various atrial tachyarrhythmias. (b) The atrioventricular sequential interval like other programmable indices requires fine tuning, and further experience with non-invasive studies may help to determine its optimum duration in any given circumstance. A relatively short atrioventricular sequential interval, especially when associated with an intra-atrial conduction delay, may not necessarily produce the maximal haemodynamic benefit attainable with longer atrioventricular sequential intervals. (c) All DVI pulse generators should be programmable to the AAI mode. The percutaneous subclavian technique for venous access¹⁴ has greatly simplified the insertion of two small polyurethane leads¹⁵ via the same introducer. If the durability of the new polyurethane leads lives up to expectations, all patients requiring permanent pacing should be considered for a dual chamber system. A DVI generator programmable either to the VVI or AAI function comes close to the concept of a simple universal pulse generator and represents an acceptable present alternative to more complex dual chamber pacemakers capable of pacing and sensing from both chambers. These latter devices are still under development or undergoing early clinical trials and a great deal of experience will be needed to work out the optimum electronic characteristics suitable for the majority of patients. A simple, easily-implantable DVI pacing system programmable to either the VVI or the AAI mode provides an attractive system for patients currently candidates for atrial pacing with a single lead so as to protect them from the small but definite risk of developing atrioventricular block.

*In this three-letter code the first letter indicates the chamber paced; the second, the chamber sensed; and the third, the mode of response (I=inhibited; T=triggered; A=atrium; V=ventricle; D=both chambers; O=neither chamber) (Parsonnet V, Furman S, Smyth NPD. Report of the intersociety Commission for Heart Disease Resources: implantable cardiac pacemakers—status report and resource guideline. *Am J Cardiol* 1974; 34: 487–500).

Programmable automatic antitachycardia pulse generators

This is a new and already crowded field comprising a wide variety of automatic antitachycardia pacemakers with underdriving, overdriving, scanning, and orthorhythmic functions for the prevention or termination of tachycardia, with the additional capability of rate support for bradycardia. These antitachycardia devices are now undergoing extensive clinical trials all over the world. This type of treatment requires fine adjustment of pacemaker indices by programmability because the complexity and variability of the electrophysiological *milieu* may necessitate frequent revision of pacemaker settings.

Programmable pulse generators may be useful in the treatment of tachyarrhythmias in the following circumstances.¹⁶

- (1) Overdrive suppression.
- (2) Prevention of atrioventricular junctional reciprocating tachycardias by atrioventricular sequential pacing with either a zero or very short atrioventricular sequential time.^{17 18} This is another reason why the atrioventricular sequential time should be programmable and its optimum value should be determined electrophysiologically before implantation. More complex programmable pulse generators such as double-triggered systems (DDT) or P-synchronous pacemakers may also be useful in the prevention of tachycardia.¹⁸
- (3) Automatic termination of tachycardia. Pacing techniques needing the active participation of the patient (or close relative) when the tachycardia develops outside hospital require an alert, intelligent patient with a positive attitude, who understands his condition and symptoms.^{19 20} The need for active patient intervention is a distinct disadvantage if the tachycardia occurs after or during sleep, or is associated with syncope, dizziness, chest pain, or unawareness before haemodynamic deterioration. The various autonomic and compensatory reflex mechanisms triggered at the onset of the tachycardia may make its termination more difficult if allowed to continue for more than a few seconds.²¹ For this reason many investigators consider that the ideal antitachycardia pacemaker should automatically turn itself on when the tachycardia starts and switch itself off automatically when the tachycardia ends.²² Precise electrophysiological characterisation of re-entry tachycardia is essential before using these complex and potentially dangerous devices. We believe that such sophisticated pacemakers should be restricted to centres capable of performing detailed electrophysiological investigations to determine, by repeated measurements, the required

number of stimuli and cycle length to terminate re-entry tachycardia safely, reliably, and consistently. Automatic antitachycardia pacemakers should possess the capability of programming rate, output, pacing mode, and sensitivity, the latter being vital for the optimum detection of atrial depolarisation during supraventricular tachycardia.

Conventional multiprogrammable pulse generators (VVI, AAI, DVI) with back-up underdrive antitachycardia characteristics are beginning to appear and will most probably become commonplace in the future. One recent device functions as a dual demand (antitachycardia) underdrive pacemaker merely by reprogramming the refractory period to its longest duration²³ while simple modification of a conventional DVI bipolar pulse generator provides a programmable underdrive dual (or double as labelled by the manufacturers) demand atrioventricular sequential pulse generator for the automatic termination of supraventricular tachycardia by pacing both the atrium and the ventricle.²⁴

The automatic burst antitachycardia (overdrive) pacemaker is at present the most popular device for the termination of re-entry tachycardia.²⁵⁻²⁸ Such a pacemaker delivers a given number of stimuli in quick succession at a preselected rate upon sensing the tachycardia. The lowest limit of the tachycardia rate to be sensed must be programmable in several steps to minimise the possibility of sensing sinus tachycardia or atrial fibrillation with a rapid ventricular rate, a crucial consideration in the case of implanted ventricular burst pacemakers for the treatment of refractory ventricular tachycardia.²⁷ The lowest rate capable of activating the tachycardia detecting circuit of the pacemaker should be selectable over a wide range of rates perhaps from 120 to 200 per minute with increments of five to 10 beats a minute. The rate and duration of rapid burst stimulation must be programmable in several steps to accommodate the complex and changing electrophysiological circumstances responsible for the perpetuation of re-entry tachycardia. Telemetry and interrogation capabilities are essential because such devices are potentially dangerous especially when used for ventricular tachycardia. These devices should all contain a form of memory to record the occurrence of tachycardia and the appropriate response of the pulse generator.

Automatic burst pacemakers appear quite promising for the treatment of supraventricular tachycardia. In selected cases automatic pacing may indeed be more efficacious and convenient than pharmacological treatment for life. The role of automatic pacemakers for the treatment of ventricular tachycardia will most probably remain

small because of their inherent risk²⁹ but such devices may be useful in patients with drug refractory tachycardia who are unsuitable candidates for cardiac surgery and electrophysiological procedures such as encircling ventriculotomy,³⁰ or endocardial resection,³¹ to ablate the re-entry pathway. When used for ventricular tachycardia, demonstration of safety and efficacy of these pacemakers requires extensive electrophysiological observations before implantation, with at least 100 successful trials without acceleration or degeneration into ventricular fibrillation.²⁷ In this respect all special function programmable pulse generators should have the capability of disarming any of their characteristics with simple, readily available equipment, a concept particularly important in the potentially dangerous automatic burst antitachycardia pulse generator.

New problems with programmable pacemakers

(1) INVOLUNTARY OR INCORRECT PROGRAMMING

Programmable pulse generators carry the small but definite hazard of inadvertent reprogramming by external influences^{32 33} (magnets, electromagnetic interference, cross-programming, etc.) that improved circuitry will almost completely eliminate. There are anecdotal reports of spontaneous reprogramming of pacemakers but it should be remembered that the physician himself may be the phantom who has reprogrammed the pacemaker without recording it. The programming technique must be precise in order to avoid the delivery of only part of the coded message that may lead to inappropriate programming. Inability to reprogram and abnormal programming are often results of incorrect use or positioning of the programmer rather than a true defect in the pulse generator or programmer itself. Some contemporary programmers are so complicated that they require digital gymnastics and invite programming errors. The physician must become familiar with the programming technique and must understand the code of the programming sequence and its theoretical complications.

(2) CONFIRMATION OF PROGRAMMING AND INTERROGATION

There must be a feedback mechanism from the pulse generator to confirm that it has carried out the intended program. Manufacturers have incorporated various markers to confirm receipt of the coded message. These include a temporary change in rate (automatic interval) or function, additional im-

pulses, activation of a small light on the programmer, or telemetric (bidirectional) transmission of data out of the pulse generator. All multiprogrammable pulse generators will soon possess the capability of sophisticated interrogation. We believe that telemetry is not a luxury but a necessity in the present technological development of programmable pulse generators and that it is particularly important in cases where the patient history is in doubt or unknown. Indeed the telemetric determination of lead impedance (reflecting integrity) has already added a new dimension to the follow-up of pacemaker patients, and other transmitted variables may become quite important as we learn more about their significance. Present technology only gives access to data stored in the pulse generator and returns what has actually been programmed and received. This constitutes no guarantee that the pacemaker itself has been reprogrammed to the selected variable so that the physician should know how to determine whether the pulse generator has carried out the programmed command. In other words, there exists as yet no "searching or monitoring circuit" to ensure that the pulse generator has executed the intended program.

(3) CREATION OF NEW ARRHYTHMIAS AND WRONG DIAGNOSIS OF POWER SOURCE DEPLETION

The injudicious use of sensitivity and refractory period programmability may cause new arrhythmias with undersensing and oversensing and the indiscriminate use of hysteresis may lead to widespread confusion. Slowing of the pacemaker rate is the universal indicator of battery depletion. A slow pacemaker rate could be misinterpreted as true pacemaker failure by physicians unfamiliar with programmability. For this reason, some manufacturers have designed their pulse generators to slow only the magnetic rate upon battery depletion. In some pulse generators it is impossible to know the true programmed rate if the patient's spontaneous rate is faster than the programmed rate because application of the magnet yields the magnetic rate only. Adding to the confusion, the magnetic rate of some generators is actually slower than the free-running programmed rate.

(4) ENCOURAGEMENT OF OVERSIMPLIFIED SOLUTIONS TO COMPLEX PROBLEMS

Many years ago when the DC defibrillator came into clinical use, it was felt that the precise diagnosis of cardiac arrhythmias was no longer essential because most cardiac arrhythmias could be effectively treated by electrical cardioversion. This,

of course, has proved to be quite false, but the same trend may occur with programmable pacemakers. Thus, when faced with recurrent muscle twitching at the anodal site of a unipolar pulse generator it may be tempting to simply reprogram the pulse generator to a low voltage (or pulse width) rather than make the correct diagnosis of a "flipped" pacemaker that may require pocket revision to avoid uncoiling of the electrode, the ultimate consequence of a pacemaker twiddler's syndrome.³⁴

(5) BEWILDERING ELECTRONIC GADGETRY AND LACK OF STANDARDISATION. IS IT ALL WORTH IT?

Some physicians fear that the increasing complexity of electronic circuits may create additional risks of electronic failure and others feel that the impact of programmable pulse generators will probably be small in the overall care of patients with implanted pulse generators.³⁵⁻³⁷ These fears are probably unjustified with modern, sophisticated, and reliable electronic circuitry. The large variety of programmable pulse generators, however, and their corresponding programmers from a multitude of manufacturers will undoubtedly lead to confusion, particularly for patients who are evaluated in centres unfamiliar with a particular programmable device. Lack of standardisation will require pacemaker centres to carry a complete panoply of programmers. Though universal standardisation will probably never be achieved, there is need for some degree of order before the situation becomes totally uncontrollable and incomprehensible as each new generation of programmable pulse generators from an ever-increasing number of manufacturers spawns new generations of programmers specific for a particular device or manufacturer.

(6) SHOULD THE USE OF PROGRAMMABLE PULSE GENERATORS BE RESTRICTED TO MAJOR MEDICAL CENTRES?

Some authorities argue that the vast majority of programmable characteristics are never used and therefore multiprogrammable pacemakers should be restricted to major medical centres. We do not agree with this contention because it is often the very lack of expertise that requires the advantages of programmability. The programmable pulse generator with its forgiving characteristics may be of great value in the treatment of various pacemaker complications (avoidable or unavoidable), but such devices should not be a substitute for poor technique. The use of complex devices carries, however, a great responsibility on the part of the implanting physician to keep himself abreast of this rapidly changing technological field. In contrast, automatic

antitachycardia pacemakers should be restricted to medical centres with the facilities for detailed electrophysiological investigations as these devices may be extremely dangerous without proper surveillance.

(7) COST OF COMPLEX TECHNOLOGY

We feel that selection of a pacemaker based on economic reasons does not serve the patient justly and believe that the advantages of programmability, if needed, should not be denied because of cost only. Programmable pulse generators may continue to increase in cost substantially with greater complexity of function and some discretion in their use may eventually become necessary. Injudicious use of complex devices will inevitably increase costs, and it is incumbent upon the leaders of the medical community to provide appropriate education in this rapidly evolving discipline to avoid runaway costs from technology often of marginal clinical benefit. On the other hand, a retrospective study of cost effectiveness (some of it doubtless biased because it originated from manufacturers³⁸) suggests that multiprogrammable pulse generators at this stage of their development are probably cost effective because they may avoid operative intervention in about 20 per cent of patients.²⁻⁵ Further prospective studies are obviously required to determine the clinical and economic impact of multiprogrammable pulse generators and such investigations should include the additional cost of technical personnel, training, equipment, and surveillance techniques for these new devices.

Future directions of programmable pacemakers (Table)

The exponential growth of pacemaker technology requires a constant struggle to maintain a proper clinical perspective of new developments, and the physician must maintain a healthy degree of scepticism to avoid becoming a total slave to technology. The engineer can program virtually everything with the inevitability that the physician will ultimately be overwhelmed so that a reasonable compromise must be reached somewhere along the line. In this context the development of "smart" or "intelligent" pacemakers is fraught with certain inherent limitations that are not technological but physiological, and the design of these devices will require proper algorithms to optimise function and obviate counterproductive complex arrhythmias.

Soon multiprogrammable pacemakers with telemetry and interrogation capabilities will be commonplace.³⁹ Engineers should strive to incorporate the capability of transtelephone programmability

Table *Multiprogrammable pulse generator of the future*

Modality	
Ventricular demand or synchronous (VVI, VVT)	
Atrial demand or synchronous (AAI, AAT)	
P-synchronous with and without ventricular sensing (VAT VD (T/I))	
AV sequential pacing (DVI)	
Optimised sequential pacing (double demand) DDI, DD (TI/I), DDD, etc	
Automatic tachycardia function	
Detection of tachycardia	
Termination of tachycardia by single, double, or train of stimuli; number and timing of stimuli will be fully programmable, relatively simple programming of dual demand mode will be commonplace	
Demand function when slowing of the spontaneous rate occurs	
Programmable variables	
Rate, voltage (increase above conventional 5 V for high threshold situations and decrease in several steps), pulse width, sensitivity, refractory period, escape interval (positive and negative hysteresis), PR or AV sequential time, unipolar or bipolar modes	
Variable interrogation	
Rate, voltage, pulse width, sensitivity, refractory period, threshold, lead impedance, battery impedance, and voltage (or current), R wave amplitude (with actual telemetric transmission of the electrogram for oscilloscopic display)	
Automatic function	
(a) Automatic adjustment of output according to threshold, sensitivity according to signal	
(b) Fully automatic physiological pacer with sensor for feedback loop: P wave, pH, PO_2 , PCO_2 , respiration, temperature, intracardiac volume, pressure, etc.	
Memory	
Microprocessors with Holter capabilities	
Detection of pacemaker malfunction	
Self-correction	
Flag alert	
? Automatic defibrillator	

because many patients will be seen in places where an appropriate programmer may not be available. The next generation of pulse generators will incorporate decision-making capabilities and memory by means of microprocessors with the equivalence of several hundred thousand components. Auto-programmable pulse generators with automatic adjustment of variables according to need may help some patients who may not have the time or may be too far away for reprogramming in case of need. For example a threshold tracking system will automatically adjust the output according to the energy required for pacing, or the sensitivity will change automatically according to the nature of the sensed signal. There will be automatic physiological pacemakers with biological sensors capable of adapting pacer mode and performance automatically according to changing physiological circumstances by means of a feedback loop concept. Indeed a pH responsive pulse generator has already been used clinically⁴⁰ and the feasibility of a pulse generator

responsive to the respiratory rate has already been shown.⁴¹ Perhaps more than one biological signal (electrophysiological, mechanical, or metabolic) will modulate the response of such futuristic pacemakers. Conceivably the pacemaker of the future will incorporate an electronic brain capable of detecting, diagnosing, and treating electrically all known cardiac arrhythmias, and such devices will probably contain implantable defibrillator systems perhaps in the next five to 10 years.⁴² Devices with monitor capabilities⁴³ should become commonplace with the widespread flexibility attainable with microprocessors that will allow the recording and playback of cardiac arrhythmias memorised by the pulse generator. The future of programmable pacemakers has been aptly described in a recent editorial⁴⁴: "the proliferation of technology will be bewildering but the accomplishments will be brilliant. In the next few years new techniques will be available and in widespread use making today's seem simple. We should all in the profession and industry prepare for the coming revolution".

References

- 1 Goldman BS, Parsonnet V. World survey on cardiac pacing. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 41-4.
- 2 Furman S, Escher D, Fisher J. Seven year experience with programmable pulse generators. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 19-1.
- 3 Griffin JC, Quitman JA. Pacemaker programmability: the role of non-invasive pacing system revision. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 19-3.
- 4 Furman S, Pannizo F. Operative revision reduction with output programmable pulse generators (abstract). *PACE* 1980; **3**: 371.
- 5 Lathrop T, Jonak L. Multiparameter pacemaker programmability: a cost-effective atraumatic solution for many pulse generator and patient related complications (abstract). *PACE* 1980; **3**: 377.
- 6 MacGregor DC, Furman S, Dreifus LS, Cuddy TE. The utility of the programmable pacemaker. *PACE* 1978; **1**: 254-9.
- 7 Vera Z, Klein RC, Mason DT. Recent advances in programmable pacemakers. Consideration of advantages, longevity and future expectations. *Am J Med* 1979; **66**: 473-83.
- 8 Azulay A, Vagnini FJ, Saha CK, Frantz SL. Permanent prophylactic ventricular demand pacing with VVI extended negative rate/hysteresis. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 16-5.

- 9 Thompson ME, Shaver JA. Undesirable cardiac arrhythmias associated with rate hysteresis pacemakers. *Am J Cardiol* 1976; **38**: 685-8.
- 10 Furman S, DeCaprio V. Electrode causation of pacemaker inhibition. *Chest* 1977; **72**: 117-9.
- 11 Naumann d'Alnoncourt C, Lüderitz B. Diagnostic and therapeutic pacing in tachycardias by implantable pulse generators. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 9-7.
- 12 Barold SS, Falkoff MD, Ong LS, Heinle RA. Characterization of pacemaker arrhythmias due to normally functioning AV demand (DVI) pulse generators. *PACE* 1980; **3**: 712-23.
- 13 Furman S, Reicher-Reiss H, Escher DJW. Atrioventricular sequential pacing and pacemakers. *Chest* 1973; **63**: 783-9.
- 14 Littleford PO, Parsonnet V, Spector SD. Method for the rapid and atraumatic insertion of permanent endocardial pacemaker electrodes through the subclavian vein. *Am J Cardiol* 1979; **43**: 980-2.
- 15 Stokes K, Cobian K, Lathrop T. Polyurethane insulators, a design approach to small pacing leads. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979; Chapter 28-2.
- 16 Wiener I. Pacing techniques in the treatment of tachycardias. *Ann Intern Med* 1980; **93**: 326-9.
- 17 Coumel P, Cabrol C, Fabiato A, Gourgon R, Slama R. Tachycardie permanente by rythme réciproque. I. Preuves du diagnostic par stimulation auriculaire et ventriculaire. II. Traitement par l'implantation intracorporelle d'un stimulateur cardiaque avec entraînement simultané de l'oreillette et du ventricule. *Arch Mal Coeur* 1967; **60**: 1830-64.
- 18 Castellanos A, Waxman HL, Berkovits BV, Myerburg RJ. Implantable pacemakers for cardiac tachyarrhythmias. *Cardiovasc Clin* 1980; **11** (1): 159-73.
- 19 Ryan GF, Easley RM Jr, Zaroff LI, Goldstein S. Paradoxical use of a demand pacemaker in treatment of supraventricular tachycardia due to the Wolff-Parkinson-White syndrome: observation on termination of reciprocal rhythm. *Circulation* 1968; **38**: 1037-43.
- 20 Peters RW, Shafon E, Frank S, Thomas AN, Scheinman MM. Radiofrequency triggered pacemakers. Uses and limitations. A long-term study. *Ann Intern Med* 1978; **88**: 17-22.
- 21 Curry PVL, Rowland E, Fox KM, Krikler DM. The relationship between posture, blood pressure and electrophysiological properties in patients with paroxysmal tachycardia. *Arch Mal Coeur* 1978; **71**: 293-9.
- 22 Krikler D, Curry P, Buffet J. Dual demand pacing for reciprocating atrioventricular tachycardia. *Br Med J* 1976; **i**: 1114-6.
- 23 Sowton E, O'Keefe DB, Curry PVL. Use of a multiprogrammable pacemaker in the dual demand mode: influence of pacing rate on termination of tachycardias. *Eur Heart J* 1980; **1**: 165-70.
- 24 Berkovits BV, Castellanos A, Dreifus LS, et al. Double demand sequential pacing for the termination of paroxysmal reentry tachyarrhythmias. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 6-21.
- 25 Neuman G. Symposium on supraventricular tachycardia: pacemaker management. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979, Chapter 10-4.
- 26 Van Hemel NM, Bakema H. Treatment of supraventricular tachycardia by chronic demand atrial rapid burst pacing. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 9-8.
- 27 Fisher JD. Implanted automatic burst pacemakers for termination of ventricular tachycardia (abstract). *Am J Cardiol* 1980; **45**: 458.
- 28 Griffin JC, Mason JW. Clinical use of an implantable automatic tachycardia terminating pacemaker. *Clin Res* 1980; **28** (2): 177A.
- 29 Ruskin JN, Garan H, Poulin F, Harthorne JW. Permanent radiofrequency ventricular pacing for management of drug-resistant ventricular tachycardia. *Am J Cardiol* 1980; **46**: 317-27.
- 30 Guiraudon G, Fontaine G, Frank R, Escande G, Etievent P, Cabrol C. Encircling endocardial ventriculotomy: a new surgical treatment for life-threatening ventricular tachycardias resistant to medical treatment following myocardial infarction. *Ann Thorac Surg* 1978; **26**: 438-44.
- 31 Josephson ME, Harken AH, Horowitz LN. Endocardial excision. A new surgical technique for the treatment of recurrent ventricular tachycardia. *Circulation* 1979; **60**: 1430-9.
- 32 Fieldman A, Dobrow RJ. Phantom pacemaker programming. *PACE* 1978; **1**: 166-71.
- 33 Furman S. Spurious pacemaker programming. *PACE* 1980; **3**: 517-8.
- 34 Meyer JA, Fruehan CT, Delmonico JE Jr. Pacemaker twiddler's syndrome: a further note. *J Thorac Cardiovasc Surg* 1974; **67**: 903-7.
- 35 Berman ND, Lipton IH, Dickson SE. The role of programmable pacemakers. An assessment based on 264 implants. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 19-2.
- 36 Copperman IJ, Laniado S. Non-programmable ventricular pacing in the sick sinus syndrome (abstract). *PACE* 1980; **3**: 366.
- 37 Del Marco CJ, Tyers GFO, Brownlee RR, et al. The unfulfilled promise of programmable pacemakers (abstract). *PACE* 1980; **3**: 368.
- 38 Lathrop TJ. Multiparameter pacemaker programmability: a cost-effective, atraumatic solution for many pulse generator and patient-related complications. *Medtronic News* **10**: June 1980, 2-3.
- 39 Mugica J. Passé, présent et futur de la stimulation cardiaque. *Arch Mal Coeur* 1980; **73**: 325-6.
- 40 Cammilli L, Ricci D, Risani R, et al. pH-triggered pacemaker: design and clinical results. In: Meere C, ed. *Cardiac pacing, proceedings of the 6th world*

- symposium on cardiac pacing*. Montreal: Pacesymp, 1979: Chapter 19-8.
- 41 Ionescu VL. An "on demand pacemaker" responsive to respiration rate (abstract). *PACE* 1980; **3**: 375.
 - 42 Mirowski M, Reid PR, Mower MM, *et al*. Termination of malignant ventricular arrhythmias with an implanted automatic defibrillator in human beings. *N Engl J Med* 1980; **303**: 322-4.
 - 43 Ozemek HS, Bissett JK. Analysis of ventricular

arrhythmias by limited microprocessor systems: the pacemaker of the future (abstract). *Circulation* **62**, suppl III: 288.

- 44 Furman S. Pacemaker programmability. *PACE* 1978; **1**: 161-2.

Requests for reprints to Dr S Serge Barold, The Genesee Hospital, 224 Alexander Street, Rochester, New York 14607, USA.