More on pacemakers

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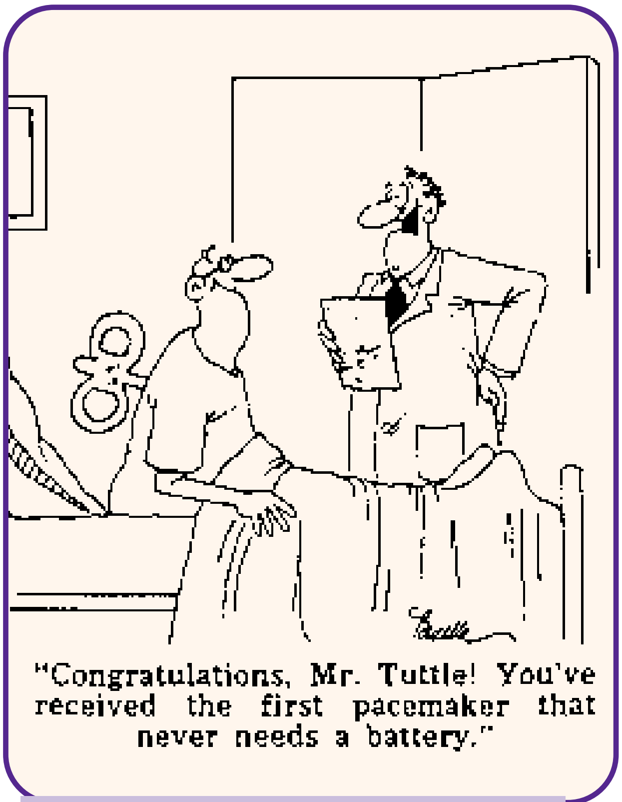
For those of you undeterred by the offering on simple pacing in the last issue and still eager for more information, this brief follow-up article will discuss some further general aspects and a few of the more recent applications of pacemaker technology.



There have been great advances in pacemaker technology over the last 30 years.

Which pacemaker is best?

The continuing development of pacemaker technology means that cardiologists can now choose between a number of different pacing systems and pacing modes. As a result, they must consider several variables when deciding which pacemaker is best for each patient treated.

First comes the patient (see Figure 1). The demands made by an elderly patient with limited mobility will clearly be less than those of a younger patient who is still very active and perhaps even participating in sports. For the former, a simple VVI device will provide an adequate cardiac output, will be easier to implant and will be more cost-effective. For the latter, a more sophisticated device with multiprogrammability may be required to meet the widely varying demands. As an aside in this regard, it is chastening to observe that even the most sophisticated device is still a pale competitor of our own sinus node and conducting system.

Other considerations include the presence of AV block, either intermittent or permanent, or the concomitant use of drugs with AV nodal blocking effects. For patient in normal sinus rhythm, a basic VVI device will maintain an adequate heart rate but without normal AV synchrony. This may predispose to atrial fibrillation and compromise cardiac output in those with borderline or impaired function. For these reasons, a dual chamber system or a system with atrial sensing (VDD for the initiated) is preferable.

It is not always straightforward however as patients who received dual chamber pacemakers and then developed paroxysmal atrial fibrillation, flutter or tachycardia used to present a particular problem. Their devices would continuously pace at the programmed upper rate limit as long as the tachyarrhythmia persisted leading to troublesome palpitations and even heart failure. This can now be avoided by implanting newer systems capable of switching to controlled ventricular pacing if the atrial rate increases above a defined limit. Pacemakers with such mode-switching capability are helpful for this subset of the pacemaker population.

Finally, for those patients with chronotropic incompetence whose heart rates fail to increase appropriately in response to exercise or stress, a rate responsive pacemaker is best (see below).

There are many different algorithms published which help in the decision making process. One such is shown in Figure 2 (adapted from A Practice of Cardiac Pacing by Furman, Hayes and Holmes, Futura Publishing Co). This may serve as a rough guide and I will not elaborate on it further.

"I'm only helping with the dishes 'til you get your pacemaker."

Individual demands may vary widely.

Rate responsive pacemakers

A rate responsive (rate modulated or rate adaptive) pacemaker is one which can increase the pacing rate in response to a measured variable which correlates with physical activity (Figure 3). The commonest sensors are physical and respond to increased body movement. Thus the piezoelectric transducer consists of a piezoelectric crystal bonded to the inside of the generator can. This converts movement into an electrical signal which can then be processed. The other main sensor is the accelerometer which measures the rate of change of velocity of a mass suspended on a frame. Horizontal acceleration due to rhythmic body movement such as walking is averaged over time and the pacing rate is set using internal algorithms.

The only other widely available sensor continuously estimates minute ventilation through measurements of transthoracic impedance. This is done by passing a low level current between the pacing lead tip and the pulse generator. Changes in respiratory rate and tidal volume during exercise can then be translated into an increase in pacing rate.

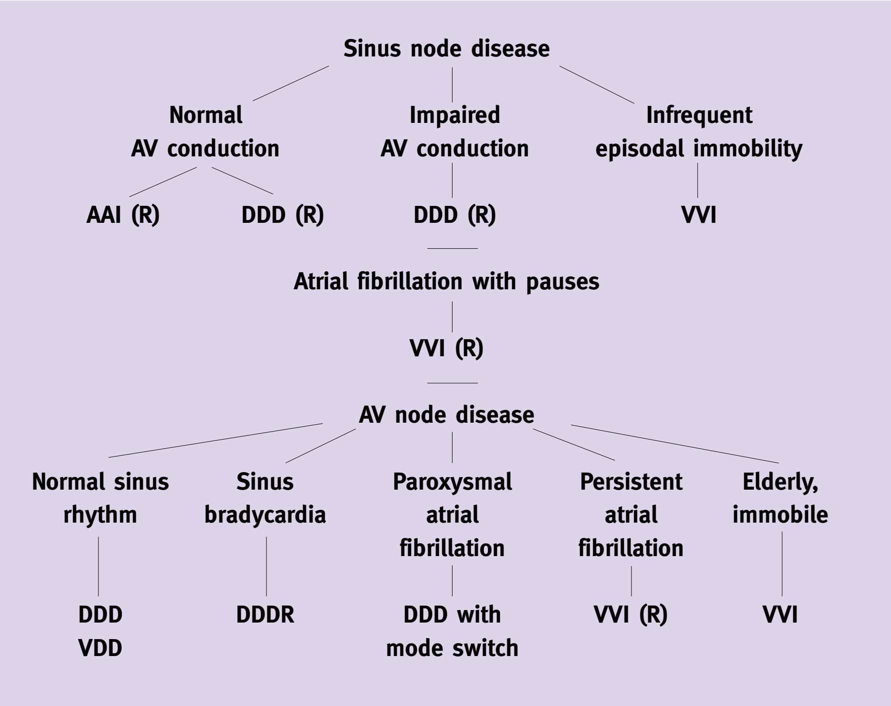
Rate responsive pacemakers increase the pacing rate in response to increased activity.

Again, no sensor can match the very finely tuned response of the sinus node to all our daily activities. Indeed, there is now a vogue for incorporating two different sensors in an attempt to produce a more physiological increase in pacing rate in response to different demands. However, the common single sensor devices work very well for the vast majority of patients.

Special patient subgroups

There has been considerable interest during the last decade in the possible role for pacing technology in the treatment of cardiomyopathies and heart failure. This had centred on manipulation of the AV delay and timing of ventricular stimulation in an attempt to ameliorate the adverse haemodynamic features of both hypertrophic and dilated cardiomyopathy. More recently, much research effort (and commercial investment) has been expended on dual site pacing in the atria or ventricles in the hope of reversing some of the adverse electrical and/or mechanical changes leading to atrial fibrillation and heart failure.

Early studies looking at dual chamber pacing with very short AV delays for patients with hypertrophic cardiomyopathy (HCM) and high outflow gradients reported significant improvement in haemodynamic and clinical variables. The AV delay had to be very short to guarantee early right ventricular apical activation and sometimes AV nodal blocking drugs and even AV node ablation



Algorithm for the selection of the appropriate pacing mode. AAI denotes atrial pacemaker, VVI denotes ventricular pacemaker, DDD denotes dual chamber pacemaker and R denotes rate responsive pacemaker.

were used. The precise mechanism by which the pacing worked was controversial.

These studies were uncontrolled however and a recent multicentre, double-blind crossover showed much less impressive results. While there was a reduction in outflow tract gradient, there was no associated improvement in exercise capacity or LV wall thickness. Thus, one cannot recommend dual chamber pacing as primary or routine adjunctive therapy for patients with HCM. It may have a small role in selected patients who fail or who are not suitable for standard medical or surgical therapy.

Studies looking at pacing for dilated cardiomyopathy involved small numbers and the story is similar to pacing for HCM; initial hope and enthusiasm boosted by favourable, short-term haemodynamic changes tempered by a failure to document any significant clinical benefit. However, one subgroup of patients with severe LV dysfunction who may be helped by dual chamber pacing are those with a long PR interval in whom LV filling can be improved by optimising the AV delay.

Dual site atrial pacing for the prevention of atrial fibrillation and biventricular pacing for the treatment of heart failure are both areas of much research at present. The former involves placing two atrial leads, one in the standard right atrial position and the other within the coronary sinus. This leads to more synchronous atrial depolarisation and may reduce dispersion of repolarisation which might reduce the frequency of paroxysmal atrial fibrillation. Anecdotal reports and small case series suggest there is a benefit but more rigorous trials have again raised doubts. Certainly, this will not be the cure for paroxysmal atrial fibrillation which is the electrophysiologists' holy grail at present.

No sensor can match the very finely tuned response of the sinus node to all our daily activities

In biventricular pacing, one lead is passed into the right ventricle and a second is passed into the cardiac venous system via the coronary sinus and great cardiac vein. It is advanced to a position where it paces the left ventricle from an epicardial location. Acute studies have shown beneficial haemodynamic changes in patients with heart failure but again one must await the controlled trials looking for long-term clinical benefit before coming to any conclusions. Whether this will have any role to play in the treatment of heart failure (the holy grail for pacemaker companies!) time will tell.

Conclusion

It is now time to draw the curtain on pacemakers. These devices have certainly come a long way over the last 30 years (Figure 4). Indeed, such have been the advances that heart block which was the initial stimulus for their development has become the most basic and straightforward indication for their implantation. They are now being tested in the treatments of many other more complex electrical and mechanical problems. That they don't always live up to our high hopes and expectations should not take away from their great fundamental success and reliability.

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