The Advantages of Demand Over Fixed-Rate Pacing

Report of Clinical Experience

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Clinical experience with both fixed rate and demand pacing suggests that the latter mode should probably be utilized in patients with second degree or intermittent high grade A-V block. Instances of ventricular tachycardia and fibrillation following a propagated pacemaker beat, competition between sinus rhythm and fixed rate pacing, and rapid ventricular rates due to coupled ventricular premature systoles also suggest pertinent arguments in favor of demand pacing. Although it is probably too early to advise demand pacing for all patients, inferential reasoning from clinical experience is offered to identify more clearly the advantages of demand over fixed rate pacing.

Pioneering efforts by Hyman (1932) and by Calaghan and Bigelow (1951) established the principle of direct electrical stimulation of the heart as a means of restoring and regulating cardiac rhythm. However, it was not until 1952 that external cardiac pacing was introduced into clinical medicine by Zoll. Temporary direct myocardial stimulation by Weirich et al (1957), and an implanted self-contained electronic prosthesis was reported by Chardack et al in 1960. Thereafter, an era of sophistication featured (1) pacemakers utilizing P-wave synchronization, (2) pacing on demand to prevent competition between electrical and natural pacemakers, and (3) the practical application of permanent transvenous pacing which facilitates access to the myocardium without the requirement of thoracotomy. Considerable imagination and effort have been applied to the development of myocardial electrodes, transvenous catheters, and power sources.

At present, there are more than 30 different pacemakers available for clinical use. Selection of the best mode of cardiac pacing can be quite difficult; as more sophisticated circuitry is developed, the problem will become even more complex. However, the early observations of Lemberg et al suggested that demand pacing offered certain advantages that could not be achieved by fixed-rate pacing. The purpose of this communication is to describe recent clinical cases where temporary and permanent demand pacing was clearly preferable to fixed-rate pacing. The inferential reasoning from this clinical experience is offered to identify more clearly the advantages of demand over fixed-rate pacing.

Ventricular Tachycardia and Fibrillation following a Propagated Pacemaker Beat

There is considerable controversy as to whether the electrical impulse delivered by commercially produced pacemakers can engender a repetitive response. In general, most pacemakers on the market deliver a short (1.7 to 3 milliseconds) stimulus with an energy level varying from 70 to 190 microjoules. Unless the diastolic threshold is unusually low, a stimulus of this magnitude may be incapable of fibrillating the heart. However, if the stimulus generates a propagated response, and this response falls within the vulnerable period of the ventricles, ventricular tachycardia or fibrillation may ensue (Fig 1). This may occur with a fixed rate pacemaker if A-V transmission later returns and the
pacemaker stimulus produces a propagated response in the vulnerable period of a conducted supraventricular beat. Sowton observed that in patients in whom competition developed following implantation of fixed rate pacemakers, 53 per cent died within the first six postoperative months, and half of these had gone into ventricular fibrillation while still in the hospital. The death rate was five times that observed in patients maintaining paced rhythm without interference. Another situation of potential danger can arise if a fixed-rate pacer stimulus falls within the vulnerable period of a ventricular premature systole and engenders a repetitive response. Admittedly, this is also a rare occurrence, but several cases have been published in the literature to document the possibility of these mechanisms.

Our experience with 288 pacemakers implanted since 1961 revealed 20 late deaths. Eleven patients died of known causes, seven from lead or battery failure, one each from unrelated conditions of bleeding duodenal ulcer, suicide, proved myocardial infarction, and one of hemorrhage at the time of re-operation for lead wire breakage. The other nine patients died of unknown causes, but pacemaker-induced ventricular fibrillation cannot be ruled out as a possible cause of death in this group.

**Competition between Sinus Rhythm and Fixed Rate Pacing**

Most pacemakers are implanted after the development of a second degree and high grade A-V block. Nathan et al. have recorded a 24 per cent incidence of reversion of high grade A-V block to either normal A-V transmission or second degree block. Nathan et al. have recorded a 24 per cent incidence of reversion of high grade A-V block to either normal A-V transmission or second degree block. Our experience with 288 pacemakers implanted since 1961 revealed 20 late deaths. Eleven patients died of known causes, seven from lead or battery failure, one each from unrelated conditions of bleeding duodenal ulcer, suicide, proved myocardial infarction, and one of hemorrhage at the time of re-operation for lead wire breakage. The other nine patients died of unknown causes, but pacemaker-induced ventricular fibrillation cannot be ruled out as a possible cause of death in this group.

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sec. The electrical artefacts after onset of QRS indicates
that they were sensed by the pacer. Hence, cycle lengths
of less than 0.52 sec. may increase the ventricular rate by
inducing competitive demand pacing beats. Lead 2: atrial
fibrillation is present. QRS complexes 3 and 5 are pacer
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pacer artefacts approximately 0.04 sec. after the initiation
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beat (Fig 3A). Therefore, repetitive ventricular dis-
charge cannot occur. This feature of a demand cir-

ment will also prevent competition in the presence
of atrial flutter and atrial fibrillation should A-V
transmission return (Fig 4, lower strip).

COMMENT

Careful analysis of these cases of competition and
repetitive excitation of the ventricles caused by
fixed-rate pacing suggests certain advantages of a
demand type circuit. These advantages are even
more pertinent in the presence of acute myocardial
infarction, when temporary transvenous pacing is
required for slow sinus rates or for intermittent
second-degree or higher grades of A-V block.

Seventy-eight permanent demand pacemakers
have been implanted since April 5, 1966. Twenty-
five of these units have functioned without battery
or circuit failure for more than one year (Table 1).
While the Medtronic, American Optical and Ven-
tricor II (Cordis) units are not activated during
sinus rhythm and have the advantage of battery
function during periods of sinus rhythm (Fig 5)
may have favored the selection of the Ventricor III
unit. This earlier model of the Ventricor III allowed
the pacer artefact to appear after intrinsic ventricu-
lar excitation (Fig 6). The circuitry of this earlier
unit embraced a refractory period of 0.50 seconds

to protect the patient from the extremely rapid
heart rates that could develop if external extraneous
signals from nearby electronic equipment were
sensed by the pacer electrode system. Hence, the
appearance of ventricular beats with coupling in-
tervals of less than 0.50 seconds were not "sensed"
and this prototype pacer discharged on demand
after 1.0 seconds. Hence, this earlier Cordis unit
could engender group beating in the presence of
ventricular premature systoles with short coupling
intervals, and also precipitate a rapid ventricular re-

de in the presence of atrial fibrillation upon the
return of A-V transmission (Fig 4, upper strip).
All Ventricor III (Cordis) models manufactured
after April 15, 1968 will incorporate a 0.40 second
refractory period and reduce the possibility of group
beating. However, extraneous electric signals
would cause the pacemaker to discharge at a maxi-
mum rate of 150 beats per minute. On the other
hand, the American Optical model reverts to fixed
rate pacing when exposed to extraneous electrical
signals. Battery life of the Ventricor III models are
still expected to be two years. Circuitry failure has
not occurred in this group of demand pacemakers,
but wider clinical experience for a longer period of
time would be required to answer this question
fully. Further progress in catheter electrode tech-
nology may develop a fail-safe transvenous syn-
chronous pacemaker to take advantage of the atrial
contraction to ventricular filling.

FIGURE 4. Lead 1: in the presence of atrial fibrillation, A-V
transmission has returned to produce a rapid ventricular
response. Since the Ventricor III can sense ventricular
complexes only after 0.50 sec. of "refractory period,"

beats 3.0.9.12 and 15 which follow the preceding beats
by intervals of 0.44 to 0.48 sec. are not sensed. Hence, beats 4, 7, 10, 13, and 16 are initiated on demand by the
pacemaker following an escape interval of 0.84 sec. Beats
2, 5, 8, 11, and 14 are conducted supraventricular beats
following pacemaker-induced beats by intervals of 0.52 to 0.54
sec. The electrical artefacts after onset of QRS indicates
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Table 1—Fate of 78 Demand Pacemakers

<table>
<thead>
<tr>
<th></th>
<th>Ventricor II</th>
<th>Ventricor III</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Cases</td>
<td>11</td>
<td>67</td>
</tr>
<tr>
<td>Premature</td>
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<tr>
<td>Died</td>
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<td>3</td>
</tr>
<tr>
<td>In service &gt; 14 months</td>
<td>0</td>
<td>25</td>
</tr>
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</table>
DEMAND VS. FIXED-RATE PACING

Figure 6. Ventricular III. Sinus rhythm is present with second degree (Mobitz II) A-V block. Beats 2 and 6 are pacer induced after a ventricular pause of 1 sec. Pacer artefacts inscribed 0.08 seconds after the onset of the sinus conducted beats imply that the pacing circuit is intact.

The purpose of this communication is to bring into sharp focus the present status of cardiac pacemakers. The clinical experience of a rather large group of 78 patients with demand type units has been described. The demand mode probably should be utilized in patients with second degree or intermittent high grade A-V block. It may be too early to advise demand pacing for all patients, but the pertinent arguments against fixed rate pacing have been illustrated by several clinical instances of competition and symptomatic group beating.

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REFERENCES

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