observations on the natural process in the dog's heart. Am Heart J 5: 351, 1930

Asystolic Episodes During Pacemaker Implantation

Eliezer A. Astrinsky, Ph.D., Seymour Furman, M.D., and Joe Florio

SUMMARY During normal rate programming of a pulse generator from slower to more rapid rates, intervals of output impulse suppression lasting 2 seconds plus the newly programmed interval to a maximum of 3.935 seconds are possible, and are a result of the pulse interval control system. These occur if programming falls within the susceptible window (the period between the existing interval and the new one) but will not take place if the programming command is given immediately after an output pulse. Four incidents with resulting ventricular asystole of up to 2.8 seconds are documented and explained. No significant clinical complications were observed.

IMPLANTABLE PULSE GENERATORS that have multiparameter programmability are being used more often. The number of modes in use requires that the idiosyncracies of each be brought to the attention of the user. Gould et al. and Furman have reported anomalous behavior modes.

Though the possibility of occurrence is mentioned in the technical manual and system clinical study report, there are no case reports of the possibility of an extended period of output pulse suppression during rate programming with the Medtronic Spectra-SX models 5984/5985 multiprogrammable pulse generators. Incidents of output pulse suppression with resulting ventricular asystole of up to 2800 msec during programming of these pulse generators have been recorded in our follow-up clinic. A delay of nearly 4 seconds is possible.

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Materials and Methods
The Medtronic Spectra-SX Model 5984 (bipolar) and Model 5985 (unipolar) implantable pulse generators are multiprogrammable, lithium-iodine-powered units. They are suitable for ventricular or atrial use.

Programming
Either the desktop model 9701 or simpler battery-powered model 9700 pacemaker programmers may be used for noninvasive programming. The programmer head contains both a permanent magnet and a radiofrequency (RF) coil. When placed in position over the pulse generator, the magnetic field closes the pulse generator’s magnetic reed switch converting it to asynchronous mode and enabling it to receive and accept the transmitted RF pulse train. These pulses contain a specific code for each pulse generator parameter or mode change. Selection of rate, pulse duration, pulse amplitude, sensitivity, refractory period, hysteresis and return to nominal values (NOMINAL) are possible, as are the modes VVI (AAI), VVT (AAT) or VOO (AOO). These changes may be either temporary (TEMP) or permanent (PERM). In the TEMP mode the change from previous settings is maintained until either the programmer head is
removed, or the "reset" and "program" buttons are pressed, or a new program sequence is carried out. In the first two cases the pulse generator returns to its original condition. In the PERM mode the change is permanent, and the pulse generator signals its receipt and acceptance of this change by emitting a program indicator pulse (PIP), 105 msec after the next output pulse.

Rate Programming

Rate programming sets the pulse generator's timing circuitry. The timing system used can best be illustrated as a 2-second (2000-msec) clock whose hand sweeps in a clockwise direction (fig. 1). The sweep always commences at the starting point (SP) and triggers an output pulse on reaching a marker set at the point corresponding to the desired pacing interval. The hand is then reset to SP and the cycle repeats itself. Reprogramming the rate from 50 to 70 beats/min causes the marker to be removed from point A and set to point B. When in the inhibited mode, the pulse generator can be inhibited by sensed R waves if these cause the sweep to reset before the hand reaches the marker. During normal programming, the pulse generator is in the asynchronous mode, as the programmer head magnet closes the magnetic reed switch, and reset by a sensed R wave cannot occur. However, inhibited-mode operation with the reed switch closed is possible if the TEMP inhibited program is used before rate programming. This prevents competition between the pulse generator and any underlying rhythm.

Patients

All patients in the cases presented were seen in the pacemaker follow-up center at routine visits.

Clinical Observations

Case 1

An 81-year-old man with complete atrioventricular block had a Medtronic 5985 pulse generator implanted for the treatment of complete atrioventricular block with neurologic symptoms. At a routine follow-up visit, a 2860-msec episode of ventricular asystole occurred during programming from a rate of 50 to 70 beats/min in the TEMP mode (fig. 2). The patient was not aware of the period of asystole.

Case 2

A 3½-year-old girl had a Medtronic 5985 pulse generator implanted. One month later, 2630 msec of ventricular asystole occurred while programming in the TEMP mode from a rate of 90 to 95 beats/min. The patient had a sensation of absent heartbeat.

Case 3

A 27-year-old man had a Medtronic 5985 pulse generator implanted after aortic valve replacement when complete atrioventricular block ensued. At a routine visit 2 months later, 2750 msec of ventricular

Figure 1. The rate-timing system of the Medtronic Spectrax-SX. One revolution equals 2000 msec. The output pulse is generated when the clock hand reaches the programmed marker A before resetting to the starting point. This cycle repeats itself until the marker is shifted from A to B by reprogramming from 50 to 70 beats/min.

Figure 2. Asystole of 2860 msec occurred during temporary programming from a rate of 50 to 70 beats/min. Programming took place within the 343-msec susceptible window, 857 msec after X (case 1).
asystole occurred when the programmer head was removed after TEMP programming from a rate of 80 to 70 beats/min. The patient had a sensation of absent heartbeat.

Case 4

An 85-year-old woman had a Medtronic 5985 pulse generator implanted at pacemaker replacement and conversion of a lead from bipolar to unipolar. At the postoperative test 1 day later, 2370 msec of ventricular asystole, followed by an intrinsic escape beat, occurred when the programmer head was removed after TEMP programming at a rate of 70 to 60 beats/min (fig. 3). The patient was not aware of the period of asystole.

No major difficulties were encountered in any of these patients.

Discussion

The extended period during which the pulse generator does not emit a pulse results from the timing circuitry used. If the pulse generator is programmed to a rate of 50 beats/min, the hand will sweep from SP, taking 1200 msec to reach marker A when a pulse is emitted (fig. 1). The timer immediately resets to SP and the sequence is repeated. If the pulse generator is reprogrammed to a rate of 70 beats/min, the marker is removed from A and set at point B so that the sweep takes 857 msec to go from SP to B. If reprogramming occurs after marker B has been passed, the sweep continues, does not find marker A, which has been removed by reprogramming, and continues past the SP until it reaches marker B, when a pulse is emitted and the hand is reset to SP. An interval of 2857 msec (2000 + 857 msec) may pass before the pulse is emitted when reprogramming from 50 to 70 beats/min.

If the patient has an underlying escape rhythm during the period of output pulse suppression, it will be ignored by the pulse generator till marker B is reached. However, if the pulse generator is in the TEMP inhibited mode and an escape beat occurs at any time after the rate programming, the timing circuit will immediately reset and the extended output pulse suppression interval will be correspondingly shortened to the patient’s escape interval.

In general, when programming from a low rate to a higher rate (long pulse interval to a shorter one), the pulse generator will not emit a pulse for 2000 msec plus the interval corresponding to the new higher rate if the programming takes place during the susceptible window, A minus B, i.e., 343 msec in our example. In this case, the probability of its occurrence during random programming is 28%.

The following circumstances produce a susceptible window:

1) Programming a PERM change from a lower to

<table>
<thead>
<tr>
<th>Case</th>
<th>Program mode</th>
<th>Program sequence (beats/min)</th>
<th>Susceptible window (msec)</th>
<th>Output pulse suppression (msec)</th>
<th>ECG response (msec)</th>
<th>Asystolic period (msec)</th>
<th>Patient awareness</th>
<th>Comments</th>
</tr>
</thead>
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<td>1</td>
<td>TEMP</td>
<td>50 to 70</td>
<td>343</td>
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<td>Asystole</td>
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<td>Programmer head removal</td>
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<tr>
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<td>2750</td>
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</tr>
<tr>
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<td>TEMP</td>
<td>60 to 70</td>
<td>250</td>
<td>3000</td>
<td>Escape rhythm</td>
<td>2370</td>
<td>No</td>
<td>Programmer head removal</td>
</tr>
</tbody>
</table>

Figure 3. Pulse generator (PG) output would have been suppressed for a period of 2857 msec when removing the programmer head during the 143-msec susceptible window that started 857 msec after X. The pacemaker had been programmed to a temporary rate of 70 from 60 beats/min. Once the programmer head had been removed, the intrinsic beat at Y, 2370 msec after X, reset the timer to the starting point. All following beats were captured by the PG, which maintained a rate of 70 beats/min.
a higher rate (fig. 4). (2) Programming to NOMINAL from a rate lower than 70 beats/min. The NOMINAL program always sets the rate to 70 beats/min. (3) Programming a TEMP change from a lower to a higher rate (fig. 2). (4) Removing the programmer head after TEMP programming from a higher to a lower rate. This causes the pulse generator to revert to its original higher rate. Note that as the programmer head is removed, the pulse generator can be reset by intrinsic R waves (fig. 3).

If programming takes place between SP and B, then a smooth transition from the low rate to the high rate occurs. When programming from a high rate to a lower rate (short interval to a longer interval), the transition in rate change will always be smooth, as the marker will then move in a clockwise direction and the sweep hand will always reach the new marker without having to first make one complete revolution.

The maximum possible output pulse suppression occurs when programming from a rate of 30 to a rate of 31 beats/min, i.e. 2000 msec + 1935 msec = 3935 msec, or nearly 4 seconds. The susceptible window for this to happen is only 65 msec.

Output pulse suppression occurring during rate programming has been eliminated from the coming generation of Medtronic Spectrax programmable pulse generators. During programming the pulse generator will store the desired rate and change smoothly to this rate only after the next output pulse.

The possibility of a ventricular focus producing premature ventricular complexes during the period of output pulse suppression should be considered. All necessary rate programming should be initiated immediately after a pacemaker output pulse to ensure that output pulse suppression does not occur. In the case of TEMP rate programming, the magnet should be removed immediately after an output pulse.

References
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