Unusual response of demand pacemakers to magnets¹

S. Serge Barold, John J. Gaidula, and Roque Castillo

From the Department of Medicine, Highland and Genesee Hospitals,
and the University of Rochester School of Medicine and Dentistry, Rochester, New York, U.S.A.

Most contemporary demand pacemakers contain a magnetic reed switch easily actuated by the application of an external magnet over the pulse generator.

This report describes the unusual response of two implanted pulse generators to the testing magnet. The magnetic reed switch of one pulse generator was found to 'stick' in the open position making it impossible to revert the pulse generator to its fixed-rate mode with the magnet. The other pulse generator exhibited erratic pacing while the magnet was being held completely still over it, probably because the additional forces imposed by the magnet upon the already swollen batteries unmasked imminent pacemaker failure.

These observations constitute new additions to the growing list of demand pacemaker problems.

Every technological innovation in pacing systems creates its own set of diagnostic problems. The widespread use of the testing magnet to actuate the reed switch mechanism of contemporary demand pacemakers is no exception to this statement, as illustrated by the two examples described in this report.

Case reports

Case 1

In 1970 a 5842 Medtronic demand pulse generator was inserted in a 69-year-old patient with complete heart block to replace a failing transvenous 5841 model. Six months later, during apparent fixed-rate pacing the demand automatic interval measured 896.5-896.8 msec.² Upon application of the testing magnet, transient prolongation of the EE interval (spike-to-spike interval) occurred and the automatic interval stabilized at 879.0-879.4 msec.³ Upon removal of the magnet, the EE interval again lengthened momentarily and the automatic interval returned to its original value.

Ten months after implantation the demand automatic interval measured 895.6-896.0 msec and though the

EE interval lengthened momentarily upon application of the magnet, the automatic interval subsequently remained absolutely constant at 894.6-896.0 msec. The demand automatic interval failed to change despite careful exploration of a large area overlying the testing magnet. The pulse generator was easily suppressed by chest wall stimulation (Fig. 1, strip B) (Barold *et al.*, 1970). Repeated application of the magnet at various sites during chest wall stimulation did not actuate the reed switch so that fixed-rate pacing could not be achieved (Barold and Gaidula, 1971a).

Two months later, the demand automatic interval measured 895.4-895.7 msec and while the magnet again caused temporary prolongation of the EE interval, reversion to fixed-rate pacing did not occur during chest wall stimulation. The patient has remained well and when last seen in early 1972, the automatic interval was constant at 895.0-895.5 msec. On this occasion, repeated manipulation of the magnet toward and away from the pacemaker could no longer prolong the EE interval. The automatic intervals with and without the magnet over the generator were identical and unchanged. Chest wall stimulation easily suppressed the pulse generator but application of the magnet in various positions over the pulse generator could not actuate the reed switch. The procedure was repeated with two and later three magnets on top of one another, but reversion to fixed-rate pacing was found impossible.

Case 2

A transvenous 5842 Medtronic demand pacemaker was inserted transvenously in an 84-year-old man with complete AV block and congestive heart failure. The patient remained well and 6 months later the demand automatic

Received 21 April, 1972.

¹ Sponsored by a grant from the Genesee Valley Heart Association.

² Measured electronically with a Hewlett Packard 5216-A digital counter.

³ Upon application of the magnet, the automatic interval of all implantable Medtronic pulse generators should shorten by about 20 msec. However, we have occasionally observed diminution of the automatic interval by only 2 msec (determined by suppressing the generator by chest wall stimulation and applying the magnet afterwards (Barold *et al.*, 1970; Barold and Gaidula, 1971a).

FIG. 1 Case 1. 5842 Medtronic demand pulse generator. Upper strip: electrocardiograms showing apparent fixed-rate pacing and prolongation of the EE interval (at arrow) upon application of the testing magnet. A similar response was obtained when the magnet was removed. Lower strip: chest wall stimulation (CWS) completely suppressed the implanted pulse generator. Upon application of the magnet, the pacemaker remained completely suppressed, as shown in this recording.

interval measured 917.1–917.7 msec and diminished to 896.9–897.1 msec upon application of the testing magnet. Ten months later, a long electrocardiographic strip revealed normal pacing and sensing (Fig. 2, strip A) and the demand automatic interval was 918.0–918.4 msec. Upon application of the magnet, the automatic interval immediately diminished to 897.0–899.0 msec, but one minute later, while the magnet was being held completely still over the pulse generator, it began to fire irregularly with periods of complete suppression (Fig. 2, strip C–F). The optimal site for the production of the abnormality was easily mapped out. Application of the magnet over other areas produced a normal response while 10-hour electrographic recording by the Holter technique (Avionics¹) showed normal pacing and sensing.

The pulse generator was removed and replaced by another 5842 unit which has subsequently functioned normally. The defective pulse generator was returned to the manufacturers who confirmed the malfunction (see Discussion).

Discussion

Most contemporary demand (ventricular-inhibited) pacemakers contain a magnetic reed switch which allows the pulse generator to operate in a fixed mode upon application of a testing magnet. A magnetic reed switch basically consists of a pair of ferromagnetic slender flattened reeds hermetically sealed in a glass tube with a controlled atmosphere in cantilever fashion so that the ends align and overlap but are separated by a small air gap (Fig. 3). Since the reeds are ferromagnetic, the ends will assume opposite magnetic polarity under the influence of a magnetic field (Fig. 3). The attracting forces of the magnetic poles overcome the stiffness of the reeds and

¹ Avionics Research Products, Los Angeles, California.

cause them to flex towards each other and make contact. Upon removal of the magnet, the reeds once again separate and the switch reopens.

Moving a magnet towards a demand pulse generator creates a false signal or signals (Barold, Gaidula, and Keller, 1973), because closure of the magnetic reed switch shorts the input into the sensing amplifier, thereby causing a sudden change in voltage that is detected by the generator (Fig. 4). Removal of the magnet also generates a false signal by the same mechanism. These artificially produced signals may however not be sensed should they occur within the delivery refractory period of the pulse generator. Therefore, during apparent fixed-rate pacing momentary prolongation of the EE interval (spike-to-spike interval) upon application and removal of the testing magnet suggests but does not prove conclusively that the reed switch mechanism is fully operative. Waving a test magnet over an implanted Medtronic demand pulse generator (models 5842, 5942, 5943) rarely prolongs the EE interval to twice the basic automatic interval. Stanicor (Cordis) and General Electric demand pulse generators may be completely suppressed by this manoeuvre presumably because of the greater sensitivity of their reed switch mechanism to magnetic fields (Escher, Parker, and Furman, 1971). This provides a simple way of analysing the underlying spontaneous rhythm.

Malfunction of the magnetic reed switch constitutes a new addition to the growing list of demand pacemaker problems. The switch may 'stick' in the open position making it impossible for the testing magnet to convert a quiescent demand pacemaker into a fixed rate unit. Before deeming a reed switch

FIG. 2 Case 2. 5842 Medtronic demand pulse generator. Strip A shows normal pacing and sensing. Strip B shows reversion to fixed-rate pacing upon application of the magnet when the automatic interval appears essentially similar to that in strip A. Strips C to F show an irregular pacemaker response associated with complete suppression in strip C when the magnet was being held completely still over the pulse generator.

defective, the area overlying the pacemaker should be carefully explored with the magnet because we have encountered several patients with Medtronic generators in whom actuation of the reed switch only succeeded in positions that were quite localized and not readily found. Carotid sinus pressure, by allowing escape of the demand pacemaker, may be useful when the testing magnet produces no result. However, carotid sinus pressure is not entirely free of risk particularly when the pacing capability of the implanted generator is unknown and may occasionally fail to slow the spontaneous rate sufficiently. The pacing capability of the implanted pulse generator may be evaluated by rapid chest wall stimulation if carotid sinus pressure is considered potentially dangerous (Fig. 5, strips B and C). Application of

FIG. 3 Diagrammatic representation of a magnetic reed switch. The relative scales of the reed switch and the magnet are grossly out of proportion for illustrative purposes. In fact the reed switch is much smaller than shown and the magnet is many times larger than the reed switch.

FIG. 4 Strip A. Medtronic 5943 demand pulse generator. Production of false signals by application and removal of the testing magnet (at arrows). Strip B shows normal pacing and sensing by a Stanicor demand pulse generator which was completely inhibited in strip C by appropriate waving of the testing magnet over it.

FIG. 5 Medtronic 5842 pulse generator. Strip A shows a normally functioning reed switch mechanism upon application of the magnet at the arrow. Strip B from the same patient shows no effect from the application of 3600 2 msec square wave external impulses per minute from a Grass stimulator. In strip C, 15,000 similar impulses per minute push the pacemaker into its interference phase in the middle of the electrocardiogram. Note that the PP intervals exceed the sum of the basic automatic interval (860 msec) plus one delivery refractory period (about 250 msec). P, paced beat.

sixty 2 msec square wave pulses per second (3600/minute) does not consistently push contemporary Medtronic demand generators into their fixed-rate interference operation since they are designed to do so only upon detecting sinusoidal interference at this particular frequency; with 15,000 such pulses per minute, we have however consistently pushed these generators into their interference phase as shown in Fig. 5, strip C. Though it is claimed that the Medtronic demand generator during interference will pace in a fixed-rate fashion with an automatic interval longer by one delivery refractory period from its basic automatic interval, Fig. 5, strip C, shows that this is not always the case. Once the pacing capability of the generator is known, carotid sinus pressure may then be applied with relative impunity.

When a demand pulse generator continuously activates the heart, the reed switch may be tested by suppressing the pacemaker first by chest wall stimulation and then applying the magnet over the generator when it should revert to fixed-rate pacing.

When the reed switch 'sticks' in a closed position, the pacemaker behaves as a fixed rate generator. This disturbance must be differentiated from the following sensing problems. (1) Delivery of a low electrographic QRS signal to a normally functioning pulse generator (Barold *et al.*, 1971, 1973; Barold and Gaidula, 1971a, b). Low voltage QRS signals inadequate for sensing are often marginal and long electrocardiographic strips will often reveal normally sensed beats because the normal slight fluctuations of intracardiac voltage often allow borderline signals to reach the required amplitude for sensing. In addition, chest wall stimulation in this situation should completely suppress the normally functioning demand pulse generator. (2) Delivery of a relatively large electrographic signal to a malfunctioning pulse generator with a normally functioning reed switch mechanism. Sensing failure in this situation would most probably be associated with a significant change in the automatic interval (Barold and Gaidula, 1971a). A 'sticky' reed switch in the closed position would not be expected to cause any change in the automatic interval since the disturbance resides only in the non-vital testing mechanism leaving the basic electronics intact.

Although momentary prolongation of the EE interval upon application and removal of the testing magnet strongly suggests actuation of the reed switch, the defective reed switch in our patient did not prevent the production of false signals. Conceivably a metallic conducting particle lodged between the two leaves of the reed switch was capable of causing an intermittent and short-lived connexion while under the influence of a fluctuating

magnetic field, but could not maintain a consistent connexion between the two reeds.

Malfuction of a reed switch mechanism may be caused by the presence of an epoxy leak into the glass envelope causing progressive corrosion around the switch, but initial contamination of the system with tiny particles may also cause interference with its function.

The abnormality in the second patient was caused by the presence of epoxy resin between the inner and outer cans of the batteries. This particular model was designed to have the inner and outer cans touching to make the appropriate circuit connexion. Application of the testing magnet upon already swollen batteries (Furman and Escher, 1970) caused separation of the inner and outer cans and induced voltage and resistance changes in the battery system leading to an alteration in the pacemaker rate. At other times, application of the magnet created internal forces which caused intermittent complete disruption of the batteries from the rest of the circuit. This particular problem has been eliminated in the new units which contain solidly welded battery connexions to avoid such separation (J. E. Cheatham (Medtronic, Inc.), 1971, personal communication). This mechanism may have been responsible for the erratic pacemaker response to testing magnets previously described by other workers (Castellanos, 1971). This type of pacemaker malfunction illustrates the need of testing pacemakers with the magnet even when there has been no change in the demand automatic interval and normal sensing is observed on the electrocardiogram to bring out otherwise undetectable imminent pacemaker failure. In the second patient, it appears highly likely that complete disruption of the circuit would have soon occurred spontaneously but was precipitated prematurely upon testing by the additional magnetic forces imposed by the testing magnet.

References

- Barold, S. S., and Gaidula, J. J. (1971a). Evaluation of normal and abnormal sensing functions of demand pacemakers. *American Journal of Cardiology*, **28**, 201.
- Barold, S. S., and Gaidula, J. J. (1971b). Failure of demand pacemaker from low-voltage bipolar ventricular electrograms. *Journal of the American Medical Association*, **215**, 923.
- Barold, S. S., Gaidula, J. J., and Keller, J. W. (1973). Demand pacemaker arrhythmias. In *25th Hahnemann Symposium on Cardiac Arrhythmias*. Ed. by L. Dreifus and W. Likoff. Grune and Stratton, New York. In the press.
- Barold, S. S., Gaidula, J. J., Lyon, J. L., and Carroll, M. (1971). Irregular recycling of demand pacemakers from borderline electrographic signals. *American Heart Journal*, **82**, 477.

- Barold, S. S., Pupillo, G. A., Gaidula, J. J., and Linhart, J. W. (1970). Chest wall stimulation in the evaluation of patients with implanted ventricular-inhibited demand pacemakers. *British Heart Journal*, 32, 783.
- Castellanos, A. (1971). Technical problems with pacemakers. *New England Journal of Medicine*, 284, 1385.
- Escher, D. J. W., Parker, B., and Furman, S. (1971). Influence of alternating magnetic fields on triggered pacemakers. *Circulation*, 43 and 44, Suppl. II, 162.
- Furman, S., and Escher, D. J. W. (1970). *Principles and Techniques of Cardiac Pacing*, p. 44. Harper and Row, New York.
- Requests for reprints to Dr. S. Serge Barold, The Genesee Hospital, 224 Alexander Street, Rochester, New York 14607, U.S.A.