The patient played strenuous games of paddleball shortly after his injury. Whether this was a factor in the development of the aneurysm is moot. However, it does raise the consideration of exercise restriction in patients who are considered to have myocardial contusion.

Because of the potentially lethal complications, repair should be undertaken promptly after diagnosing an aneurysm similar to the one reported here. Pupello et al.9 reported problems at operation because the edges of a six-week-old aneurysm were friable and difficult to handle. However, in our patient, the aneurysm was 15½ weeks old and had a tough fibrous wall making placement of all stitches relatively easy. Maturity of the repair process within the injured tissues may enhance surgical repair, but delay increases the possibility of a major catastrophe.

We stress the importance of following patients with cardiac injury closely. It is important to realize that myocardial injury may be unrecognized especially in the presence of major trauma to other organs, and only with routine follow-up chest X-rays can disasters of omission be avoided. The limited literature on the subject, while lacking statistical validity, strongly indicates surgery for this lesion.

References

Fluoroscope-Generated Electromagnetic Interference in an External Demand Pacemaker

Report of a Case

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SUMMARY Electromagnetic interference presented as inhibition and resetting of the demand circuitry of a ventricular-inhibited temporary external pacemaker in a 70-year-old man undergoing surgical implantation of a permanent bipolar pacemaker generator and lead. The arrhythmia was found to be due to oversensing of waveforms modulated to simulate myocardial potentials emitted by a faulty fluoroscopy unit used in the vicinity of external temporary venous pacing equipment.

The documentation of this disruption of pacemaker rhythm reinforces the need for continuous monitoring of patients treated with external demand pacemakers and for the careful maintenance of all electrical equipment.

THE VENTRICULAR-INHIBITED DEMAND PACEMAKER is engineered to sense the R wave of ventricular myopotentials and reset to avoid competitive rhythms. The nondiscriminatory nature of these demand circuitries is well established. Oversensing of physiologic signals, "afterpotentials," "false signals," and signals from electromagnetic fields can cause various pacemaker arrhythmias. This report deals with the effect of electromagnetic interference (EMI) on an external demand temporary pacemaker caused by a faulty fluoroscopy unit, a previously unsuspected source.
Intermittent fluoroscopic observation of the cardiac silhouette to determine the position of the permanent lead was accomplished with a portable C-arm image intensification unit. It was at this time that irregularities in the delivery of the temporary pacing stimulus (S) occurred. Investigation of the problem led to the discovery of two different artifacts seemingly related to the operation of the fluoroscopy unit. Use of either the hand or the remote foot switch produced a small artifact when the fluoroscope was activated and a larger artifact upon deactivation and cessation of viewing (fig. 1, A). This latter deflection was sensed by and caused resetting of the temporary pacemaker's demand circuitry. The resultant ventricular pauses were equal to a sum of the coupling interval of the artifact (EMI) to the preceding paced beat plus the pacemaker's inherent escape interval.

Further examination yielded the following information. Fluoroscopic monitoring showed the catheter position to be stable without looping and interelectrode contact. There was no contact between the temporary pacing electrodes and those of the permanent lead. The temporary catheter was free from insulation damage and fractures, as checked prior to insertion and after removal. Its connection to the battery box was secure and protected from motion. The only operative electrical appliances in the room were the monitoring and fluoroscopic units, and their power lines (60 Hz) were not touching the patient or pacing equipment. Deliberate avoidance of personal contact with the patient while operating the fluoroscope did not eliminate the arrhythmia but ruled out the possibility of the transference of the EMI through another person.

The sense/pace indicator needle of the temporary pacer demonstrated the sensing simultaneously with the registration of the EMI on the oscilloscope. This recorded interference was seen only in the surface electrocardiographic leads and not in the coincidentally recorded intracardiac electrogram or time marker tracings.

The arrhythmia never occurred without the EMI and could be reproduced by deactivation of the fluoroscope. Its appearance had no relationship to the preceding cardiac cycle, but always occurred with resetting (850 msec) of the temporary pacemaker. These factors strongly supported the interpretation of the arrhythmia as one due to oversensing.

The patient remained unaffected by the arrhythmia. The permanent lead, having been positioned, was connected to the implanted generator without further incident. This permanent system appeared unaffected by the electromagnetic interference.

Subsequent investigation by the fluoroscopy manufacturer's service department personnel, the hospital safety engineer, and our staff confirmed that the fluoroscopic unit was the source of electromagnetic interference. A faulty relay interfered with the normal flux density of the transformer causing a build-up during viewing and a release of excess transient current across the circuit with deactivation. Replacement of the relay and the addition of a resistor and capacitor to the circuit eliminated the offending electromagnetic transmission.

**Figure 1.** Pacemaker inhibition by electromagnetic interference. All panels include standard leads I, II, and V6 and time markings (T) generated at 10 and 100 msec intervals. S denotes the external pacemaker stimulus artifact at a cycle length of 850 msec. EMI denotes the electromagnetic interference responsible for the pacemaker inhibition. Panel A shows the artifact associated with activation of the fluoroscope (fluoro on) which does not interfere with the pacing rhythm. On deactivation of the fluoroscope (fluoro off) EMI appears 775 msec after the sixth beat in the panel. The EMI results in resetting of the demand pacemaker and a ventricular pause of 1625 msec. Panels B and C demonstrate the random occurrence of the EMI in relationship to the preceding cardiac cycle and the constant 850 msec escape interval following each EMI. Note that at no time does the EMI interrupt or distort the simultaneously recorded time marker tracings. All measurements are in milliseconds. Recordings were made at a paper speed of 75 mm/sec.
Comments

The effect of electromagnetic interference on pacemakers has been studied using a variety of techniques covering a broad range of electromagnetic frequency waves.1-4 Implantable pacemaker generators of all types have been more extensively studied than external pacers. These studies have pointed out the increased sensitivity of pacemakers to electrotherapeutics (e.g., electrocautery, diathermy) as compared to household tools. In all situations, it appears that external pacing systems are more sensitive to electromagnetic interference than the hermetically sealed, integral circuits of implanted pacemakers.

The Medtronic 5880A technical manual indicates that it is suppressed by interference. It can be adjusted to a maximum sensitivity of 1-2 mV with a fundamental frequency of 25 Hz.5 This sensitivity control was at maximum demand at the time when the EMI was noted: a precautionary measure taken to assure sensing of any spontaneous or catheter-induced premature ventricular beats. The EMI caused by deactivation of the fluoroscope was within the external pacemaker's range of sensitivity, whereas, the initial artifact produced by activating the fluoroscope was outside this range and therefore not sensed by the pacemaker. Conversion to the asynchronous pacing mode would have eliminated the inhibition.1,6 A gradual decrease in the sensitivity might have allowed selective rejection of the EMI, again preventing oversensing but retaining the ability of the unit to sense myocardial potentials. These manipulations, however, were not performed, primarily because we were unfamiliar with this arrhythmia in this particular clinical situation.

The occurrence of the EMI was fortuitously outside the temporary pacemaker's refractory periods (220-250 msec after delivery of sensed event per manufacturer's specifications). Partial recycling and non-sensing did not complicate the arrhythmia.

Although not present in this case, other types of oversensing arrhythmias with random S-S interval changes could result from the sensing of either skeletal muscle potentials or the "false signals" of short circuits.

The monitoring equipment was the only other possible source of the EMI. The patient cable was connected through an isolation unit designed to prevent the transmission of current back to the patient. All the channels of the monitor are connected by a common ground. It would therefore follow that had the EMI been emitted from the monitor, artifacts would have been visible on all channels rather than only in the surface ECG.

Permanent pacemaker literature given to the patient cautions him to be alert to any untoward symptoms when operating any electrical devices. This caution should also be heeded by medical personnel. Some patients may not be affected, as in this case where only minor rate changes occurred, but this may not be true in all occurrences. Although there have been no reports of EMI acting directly on the myocardium, strong continuous interference could result in symptomatic pacemaker rate changes. The possibility of EMI propagating from a source not usually suspect must not be overlooked when pacing arrhythmias of this type are encountered. This incidence of documented effective EMI reinforces the necessity of knowing the specifications of all equipment utilized. Routine testing for leakage current, pacemaker wire continuity and equipment functioning is vital to the assurance of patient safety. Newly observed artifacts on recording equipment should be reported and investigated without delay.

Increased sophistication in pacemaker design has allowed more selectivity in sensing; yet, the list of appliances producing electromagnetic interference continues to lengthen. Recently, EMI has been reported to be emitted from such varied sources as ECG telemetry equipment and electric toothbrushes.6 A delicate balance exists between the risks of over- and undersensing. The benefits of using a demand unit to avoid competitive rhythms still outweigh the risks of oversensing.

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