Inhibition of a Demand Pacemaker and Interference with Monitoring Equipment by Radio-frequency Transmissions

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Summary : During the initial testing of Radio Leicester a swept-frequency technique for testing radio antennae was shown to affect demand pacemakers by inhibition of the pacing impulse and to interfere with physiological monitoring equipment. Adequate filtering of demand pacemakers is necessary to eliminate this interference. There is no evidence that such testing has any effect on the function of fixed-rate pacemakers. There is also a potential danger to implanted demand pacemakers by the use of similar polyscope generators used for servicing radio and television apparatus in industry.

Introduction

The problems of interference with electronic monitoring equipment in hospitals by various forms of diathermy, neon lights, and inadequately suppressed motors are well known, and methods of preventing this interference have been described (Ministry of Health, 1965). This type of interference occurs most commonly with electrocardiographic (E.C.G.) and electroencephalographic (E.E.G.) apparatus. These units use A.C. amplification, and because of their very high sensitivity are apt to pick up alternating current interference. Most modern apparatus is fitted with suitable filters to attenuate the interference as much as possible without restricting the frequency response.

Certain cardiac catheterization laboratories sited in areas of high field strength have also required extensive screening. Hazards to fixed-rate pacemakers by radio frequencies have also been described (Jessen and Rosen, 1963 ; Lichter *et al.*, 1965). Most implantable pacemaker units used in this country are fitted with adequate filters to safeguard the unit against radio-frequency interference. If, however, a pacemaker is situated in a sufficiently powerful radio-frequency field, such as diathermy, dangerous interference with its function may occur in spite of filtering. The pacemaker may be affected by two mechanisms. If the interference is great enough it will cause the output stage of the pacemaker to be destroyed, resulting in the immediate cessation of the pacemaking impulses. If the output stage is not destroyed the high-frequency radiation can reach and affect the pulse-generating circuit, which will have a tendency to lock on to the frequency of the interfering field, causing the pacemaker greatly to increase its rate, with the possibility of ventricular fibrillation. Diathermy should not be used in the presence of a pacemaker unless it has been adequately safeguarded, and if possible it should not be used even if safeguards have been incorporated into the pacemaker design.

A recent development in pacemaker design is the introduction of the ventricular-inhibited or demand pacemaker. This type of pacemaker not only produces pacing impulses, but it also contains an amplifier to monitor the patient's own E.C.G. from the pacing electrode. In the absence of any E.C.G. signal from the patient's own heart pacemaking impulses are delivered, but should spontaneous ventricular contractions occur the out-

put of the pacemaker is totally inhibited by the ventricular complex of the E.C.G. By this mechanism the generation of a pacing impulse at the apex of the T wave, the vulnerable period of the cardiac cycle, is prevented, and the chances of producing ventricular fibrillation are greatly decreased. With endocardial pacing, low energy levels are most often utilized, and in chronic heart block the dangers of ventricular fibrillation resulting from this mechanism are relatively small. With acute heart block complicating myocardial infarction, however, the increased myocardial irritability increases the chances of ventricular fibrillation being produced by the impulses occurring in the vulnerable period. Thus demand pacing is probably the ideal method of treatment for heart block complicating myocardial infarction.

In the ventricular-inhibited pacemaker the pacing impulses are inhibited by a stimulus of less than 1 millivolt. The inhibiting sensitivity of the demand pacemaker is dependent on the frequency of the stimulus it receives. An inherent property of the amplifiers used is that they are most sensitive at about 50 cycles per second. This paper describes the interference with electronic monitoring equipment, and the inhibition of a ventricular-inhibited pacemaker by signals of relatively low frequency used for the testing of the component parts of a local radio transmission station. These particular hazards have not previously been reported.

Report

Britain's first local radio station, Radio Leicester, began testing on 28 September 1967. Unknown to us the transmission antenna of the station was being erected behind a screen of trees in a field about 400 yards (365 m.) from the cardiology department at Groby Road Hospital. It was only when the top of the antenna appeared above the trees, on the day before testing was due to begin, that we became aware of its existence.

At that time a demand pacemaker (Devices demand pacemaker type E) was being used on a patient in the hospital, and, though it was appreciated that high-frequency radio transmissions would be unlikely to affect the pacemaker, we decided that in the absence of knowledge concerning the frequency of the test signals, and because of the proximity of the antenna, it would be wisest to disconnect the patient from his demand pacemaker and attach a fixed-rate pacemaker. Closer inspection of the antenna that evening suggested that the broadcasting frequencies would be in the range of 90 megacycles. A field-strength meter¹ was immediately constructed to tune all frequencies between 50 and 100 megacycles. It was realized that because of the circuitry used the meter readings would not be proportional to the field strength but would follow a square law—that is, they would be proportional to the square of the voltage. This tends to exaggerate small adjustments to the antenna system, so that correlated field-strength readings throughout the hospital would not be of any great value. It was felt that the greatest benefit from this instrument would be obtained by keeping it in one place and basing all measurements on the results obtained, but on basic measurement and calculation it was estimated that some hundreds of microvolts

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¹ R.S.G.B. Handbook (Measurements), 1962.

resulting from the radio transmissions would be present in the cardiology unit.

All measurements of the interference were finally made on a Hewlett Packard 130C oscilloscope and a Tektronix type RM564 storage oscilloscope. Photographs were taken from the storage oscilloscope.

On the following day, 28 September, our field-strength meter indicated that a test signal was being transmitted from the antenna. At the same time interference was being experienced in various departments of the hospital. This interference was apparent on both the E.E.G. and E.C.G. channels of the monitoring equipment used in the operating-theatres and on the E.C.G. equipment and monitoring oscilloscopes in use in other parts of the hospital (Figs. 1 and 2). The effect was to make the E.E.G. unreadable, and examination of the E.E.G. tracings showed the superimposition of 50-cycle interference. The E.E.G. was disconnected from a patient undergoing open heart surgery and the leads were left free. A signal was then recorded consisting of square waves at a frequency of 50 cycles per second (Fig. 3). At this moment "pop" music was heard, apparently coming from the pen motor of the E.E.G. channel. We are unable to offer an explanation for this phenomenon, as it had never occurred before this incident or has since. During identical testing of the radio transmission equipment under similar controlled conditions this musical interference could not be reproduced. The demand pacemaker was then tested by connecting 6 feet (183 cm.) of wire to the catheter terminal, and with no load on the pacemaker the output was totally inhibited.

FIG. 1.—Interference on E.E.G.

FIG. 2.—Interference on E.C.G. from transmitter on sweep frequency 50 to 100 megacycles. Normal testing power.

At this juncture the engineers of the Leicester B.B.C. radio station, who had been contacted, arrived at the hospital, and after the demonstration of evidence of interference resulting from the testing of their antenna a series of control tests were devised. In order to test the antenna the B.B.C. engineers used a Polyscope signal generator, sweeping all frequencies between 50 and 100 megacycles at a sweep speed of 50 cycles per second. This had the effect of modulating the carrier wave with 50-cycle square waves, as demonstrated in Fig. 3, showing

superimposition of square waves on the E.E.G. When the sweep frequency was reduced there was a corresponding drop in the level of interference, showing that it was caused by the low-frequency component in the testing signal. This led us

FIG. 3.—E.E.G. disconnected from patient. Free leads receiving square waves of 50 cycles per second from transmitting station.

to believe that when the radio station started transmitting on its normal stable frequency such interference would not exist. When the signal generator was swept between only 90 and 96 megacycles there was negligible interference (Fig. 4), confirming this belief.

FIG. 4.—Interference from transmitter on sweep frequency 90-96 megacycles. Normal testing power.

The last test consisted in transmitting a signal on the radio station's normal broadcasting frequency of 95.05 megacycles. During this test an interference-free E.C.G. tracing was recorded (Fig. 5). Earlier in the day the problem of interference with the Devices demand pacemaker had been discussed with the manufacturers, and they immediately sent a suitable radio-frequency filter for attachment to the pacemaker. Transmissions with the swept-frequency techniques showed the filter to be completely effective. Transmissions at normal radio frequencies did not affect the demand pacemaker with or without the attachment of the radio-frequency filter.

FIG. 5.—An interference-free E.C.G. tracing recorded during normal transmission.

Discussion

We could find no evidence that fixed-rate pacemakers were affected in any way by the testing signal. At the time of testing there were five patients in Groby Road Hospital with implanted fixed-rate pacemakers, and the function of these

pacemakers was in no way affected. The main danger from this signal would appear to be the possible inhibition of demand pacemakers.

Its action on E.E.G. and E.C.G. monitoring equipment has mainly a nuisance effect. It has been brought to our notice, however, that the rotary pumps of the Sarns-Travenol pump oxygenator, used in this hospital for open heart surgery, are electronically controlled and that this interference could possibly affect their control, making them run at full speed, thus rapidly emptying the blood reservoir. The manufacturers are aware of this problem, and all but one of these pumps had been modified by the manufacturers before importation into this country. The remaining pump has now been modified.

The dangers of testing transmission antennae by the swept-frequency technique are obvious. This method of testing is in routine use throughout the world for new and established antennae. Patients with heart block secondary to myocardial infarction being treated with demand pacemakers will obviously be at risk if the hospital is within range of high-frequency high-field-strength test signals unless the pacemakers are adequately filtered, and Devices Implants Ltd. have recently incorporated a more effective filter into all type E demand pacemakers. In the near future implantable demand pacemakers are likely to be used in increasing numbers, and it is possible that such an implanted pacemaker might be inhibited if the patient passes near a transmitting station where these tests are being carried out. Under these exceptional circum-

stances adequate filtering of the demand pacemaker might not always be possible. Various safeguards against radio-frequency interference have been built into the few commercially available implantable ventricular-inhibited pacemakers. They have not, however, been tested in the vicinity of a functioning Polyscope signal generator, so far as we can ascertain. It has recently been brought to our notice that Polyscope generators are used extensively not only for testing radio antennae but also for the servicing of various types of radio and television receivers in industry. Thus while large public bodies such as the B.B.C., who are now aware of these hazards, will take maximum precautions, it is difficult to see how smaller private concerns will be able to adequately safeguard the use of this equipment. This aspect of the problem is apparently now being investigated by the engineering department of the Ministry of Health.

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CONFERENCES AND MEETINGS

Hammersmith Symposium on Finger-joint Prostheses

[FROM A SPECIAL CORRESPONDENT]

A workshop on finger-joint prosthesis in the management of rheumatoid arthritis organized by the Departments of Medicine and Surgery at the Royal Postgraduate Medical School was held there on 14 and 15 April.

Slowly the interaction of the muscles of the hand are being better understood. It is becoming increasingly evident that their action varies with the position of all the finger joints. The paramount importance of restoring muscle-tendon balance was repeatedly emphasized by several speakers, as was the part certain tendon-retaining ligaments play in maintaining function of the fingers. Some idea of the stresses that these ligaments undergo was given by Professor A. E. FLATT (Iowa City, U.S.A.), who showed that in order to produce a given pinch force a tendon pull of six times this amount was necessary: this resulted in a strain on the retaining ligaments of a load three times as great as the pinch force.

In assessing the disability of a hand it is important to understand what function each part of the finger plays. Thus the metacarpophalangeal joints are mainly concerned with precision movements, especially the second and third, and strength is not a major need, but mobility in several planes is necessary. The interphalangeal joints are for grasping or holding, requiring strength, but movement only in one plane.

The thumb is in a different category; strength and stability are the overriding necessities so that it can act as a pillar during pinch. Apart from the suggestion that excisional arthroplasty might be of use

in treating degenerative joint disease at the carpometacarpal joint, nobody advocated prosthetic replacement in the thumb.

Laboratory Tests

Professor Flatt was one of several who had tried to devise satisfactory laboratory models to test their prostheses. He showed the importance of finding the axis of the finger joint in determining the final range of movement of the finger and the power of this movement. This is a field in which bio-engineers are introducing interesting concepts, many of which are new to medicine but well known to engineering students—a sad reflection of many years of medical insularity. Strength is not a major prerequisite of a prosthetic finger joint, nor is rigidity. Stability during movement is important, and so the newer plastic and silastic type joints may be better than the original metal prosthesis, which limits movement to one plane and allows no rotation, abduction, or adduction—which are movements found in the normal metacarpophalangeal joints.

Five types of arthroplasty were discussed. Mr. J. O. VAUGHAN-JACKSON (London) and others obtained good results by excisional arthroplasty, in which the ends of the bones forming the joint were removed and the stability of the joint then depended on capsule, tendons, and ligaments, the gap between the bones being filled by fibrous tissue. This simple procedure could in the presence of good muscle-tendon function give satisfactory results—though this was by no means a

unanimous opinion. Silicone rubber joints were discussed by Dr. A. B. SWANSON (Michigan, U.S.A.) and Professor J. J. NIEBAUER (California, U.S.A.); they have had good results with few complications. The newer Niebauer modification, of a Dacron mesh sewn over the silicone rubber, appeared to give strength and a better "adhesion" to the bone. Mr. N. D. REIS (Safad, Israel) had the simplest prosthesis, the integral hinge joint, which is made of polypropylene: he was not enthusiastic about the results but pointed out that it was a prototype and experience was being gained all the time. Mr. B. N. BAILEY (Stoke Mandeville, Bucks) used the patient's own skin to line the joint, and by opposing the epidermal surfaces created a cavity or joint space; the preliminary results were encouraging.

Co-operation in Treatment

Several speakers emphasized the need for co-operation in treating patients with rheumatoid arthritis between physicians and surgeon. Dr. P. J. L. HOLT (London) gave the physician's viewpoint of the type of case to be selected and the possible complications that might arise after surgery, and Mr. J. N. BARRON (Salisbury, Wilts) gave the surgeon's viewpoint. In particular, the vasculitis which complicated rheumatoid diseases and the occult carpal tunnel syndrome could be made worse by the prolonged use of a tourniquet. The natural course of the inflammation in the various finger joints was obviously an important variable in deciding