EMF interference detection utilizing the recording feature of cardiac pacemakers

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Abstract

Electromagnetic (EMF) interference with cardiac pacemakers may occur in various work environments. In the case of interfering external signals, the pacemaker may misinterpret the signal as a heart-related problem and initiate treatment procedures unnecessarily. We evaluated the applicability of the interference recording feature of cardiac pacemakers to identify the interfering sources. The pacemakers were exposed to a wide variety of magnetic fields in a sophisticated exposure setup in which the exposure was controlled by a computer programme. In cases where a pacemaker experienced interference, the time of interference was compared with the magnetic field exposure schedule. The study shows that interference recordings can be linked together with the exposure correctly, and it is possible to differentiate the EMF-induced pacemaker interference from other types of interference. At workplaces, an EMF recorder can be given to a pacemaker patient to wear for a few days, asking to keep a diary of his or her activities. After an appropriate time, the EMF recordings are read and compared with the interrogated pacemaker data. The interference source can be identified by combining the time of interference with the patient's diary activities.

1. Introduction

The number of workers with cardiac pacemakers and implantable cardioverter defibrillators (ICD) is increasing rapidly as the mean age of workers is rising. The European EMF Directive (2004/40/EC) requires employers to consider specifically the factors that affect the health and safety of workers at particular risk, like those wearing a pacemaker. This creates great challenges especially in industrial work environments, where high magnetic fields can be found. Modern pacemakers record the heart's electric activity and the pacemaker's function during clinical disorders or environmental interference as stored electrograms (EGM) [1, 2]. In the case of interfering external signals, the pacemaker may misinterpret the signal as a heart-related problem, and initiate treatment procedures. Several cases of false recognitions and treatments due to electromagnetic interferences have been reported [3-5]. The pacemaker records the incidences with a timestamp, and these recordings have been used to connect the interferences with external electromagnetic sources [6]. In many cases, the connection can be made with situations and points in time when the interference has occurred. In some studies, a real-time pacemaker monitoring, or ambulatory electrocardiogram (ECG) recordings have been used to study how the pacemaker reacts to outside interferences [7-9]. Continuous monitoring by telemetry is not feasible in many cases due to susceptibility to EMF interference [10, 11].

Separate measurements of the EMF strengths are time consuming and not applicable to ambulatory ECG type measurements, in which the results are analysed after a longer time period to find the possible interference sources. We investigated the possibility of connecting time-stamped EMF strength measurements (e.g. EMF logger) to the pacemaker's recordings. To examine this, a Helmholtz-coil setup was built to produce the magnetic fields, which were measured with an oscilloscope. This *in vitro* setup can easily be applied to a real exposure situation by replacing the oscilloscope with a device that can record the measured EMF exposure with a time-stamp. A similar measurement approach has previously been used to study the possible dysbalance of autonomic nervous system regulation in patients with perceived electrical hypersensitivity, by using external ambulatory ECG recordings and magnetic field recorders [12].

2. Materials and Methods

Low frequency magnetic fields for interference testing were produced by a setup consisting of Helmholtz coils with 17 turns (diameter 74 cm, gap 37 cm), a waveform generator (33220A Function Generator / Arbitrary Waveform

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Generator, Agilent Technologies), a power amplifier (KEPCO 20-20 bipolar power amplifier, KEPCO) and a current meter and current shunt (Agilent 34411A Digital Multimeter and 34330A 30 A Current Shunt, Agilent Technologies,) The tests were controlled by a computer programme developed in the Agilent VEE graphical programming environment (Agilent VEE 7.5). The programme controlled the test sequences, waveforms and amplitudes. Magnetic fields were continuously monitored and recorded using a virtual oscilloscope (PicoScope 3424, Pico Technology) during the tests.

The tested pacemaker was placed in a phantom container filled with 0.9% saline solution and centred in the Helmholtz coils. The container dimensions were 225*290*55 mm. The pacemaker and the lead formed an area of 190 squared-cm, which corresponds to the worst-case anatomical configuration from an electromagnetic interference. The phantom was placed inside the Helmholtz coils and measured in three orthogonal directions to take into account the directional effects. The control programme directed the waveform generator during the test schedule.

It is possible to choose the waveform (e.g. sine, square, pulse, ramp) and the characteristics of certain waveforms (e.g. rise time), the frequency and frequency sweeps (1 Hz - 200 kHz), the amplitude, the duration of the exposure, and rest time between the exposures. The magnetic field strength can be reliably calculated from the analytical formula for Helmholtz-coils. The test sequence length is not restricted by the exposure setup programme; only by the pacemaker recording feature. If the number of recordings in the pacemaker is restricted, the maximum number of test signals/interferences in one test run is also restricted. Before the test, the pacemaker was programmed to the appropriate settings. The most sensitive settings are usually used to simulate the worst-case situation. When the test begins, both the pacemaker and the oscilloscope record the events, and the corresponding time-stamped oscilloscope recording is used to verify the actual magnetic field strength at the moment of interference.

The test protocols included several successive exposure situations. Exposures differed from each other by magnetic field strength, frequency, waveform type and durations. In some cases the pacemakers experienced interference; in others it did not. By comparing the protocol schedule and interrogated pacemaker information, it was possible to reveal the conditions which induced the interference.

3. Results

An example of EMF interference events is shown in Figure 1. The interference situation was as follows: during a 10-sec magnetic field exposure (50 Hz, 520 μT), an implantable cardioverter-defibrillator (ICD) experienced interference lasting also 10 seconds. At the beginning of the exposure, the ICD programmed for ventricular rate modulated pacing (VVIR) mode shifted into a ventricular demand (VVI) pacing noise mode. The pacemaker categorised interference as ventricular tachycardia (VT), and anti-tachycardial pacing (ATP) was activated. Seven seconds after the end of exposure, the ICD returned to normal mode and pacing. The ICD time tagging accuracy is limited to a one minute precision, which is adequate to make a temporal distinction from different interference sources in practical circumstances.

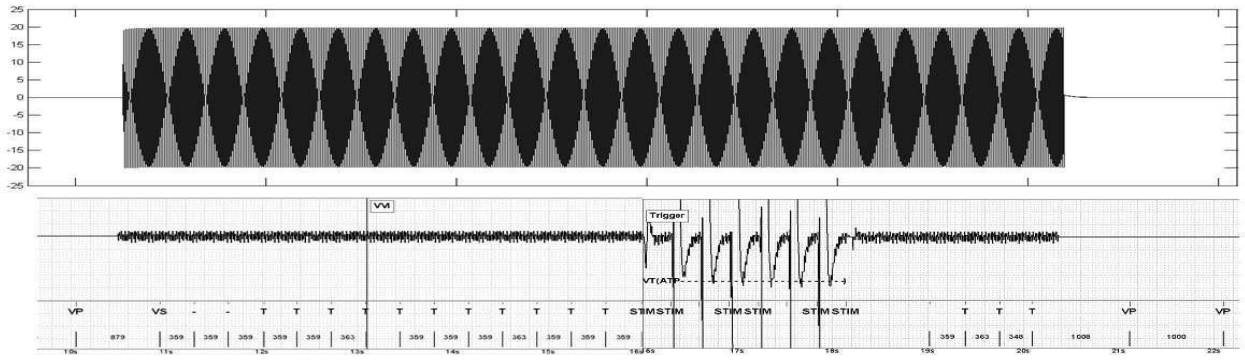

Figure 1. Simultaneous recordings of magnetic field exposure (above) and ICD's interference (below). The applied magnetic field and the detected interference occur exactly during the same duration.

In Figure 2, another interference case is presented. An arrhythmia pacemaker was exposed to 60 Hz sinusoidal magnetic field (B = 430 μT). The pacemaker interpreted the interference as ventricular tachycardia and recorded the EGM.

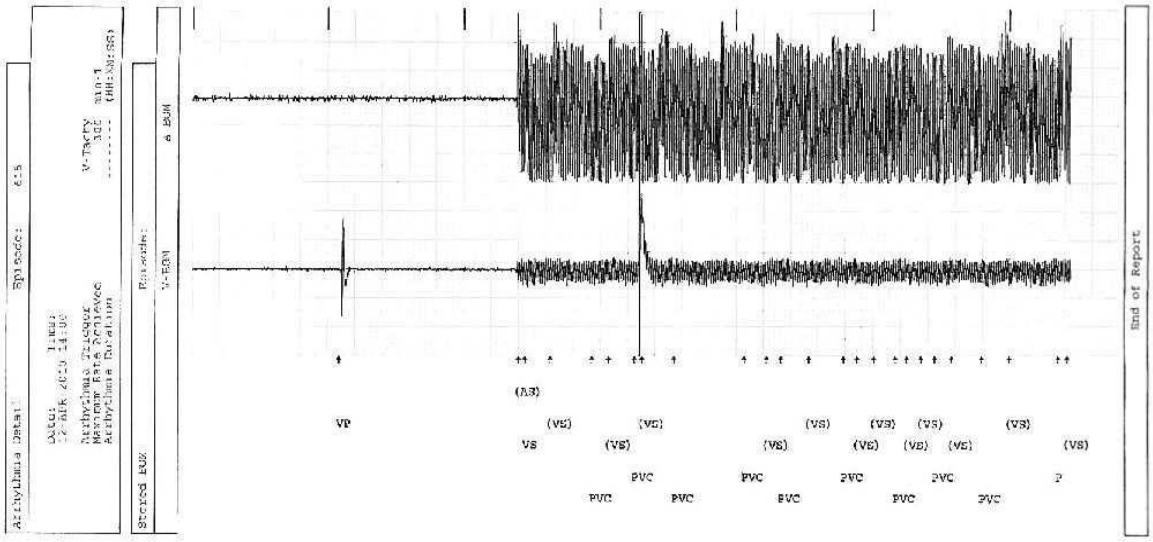

Figure 2. Magnetic field interference interpreted by a pacemaker as tachycardia.

4. Conclusion

The findings of our study indicate that pacemaker EMF interference sources can be identified by connecting pacemaker recordings to EMF recordings. When the measurement times of the two devices are correlated, it is possible to recognise the EMF induced pacemaker interference correctly. The measurement result gives the best representation of an effective electromagnetic field to the pacemaker when the recording device is close to the pacemaker. The pacemaker EGM recording features, e.g. time-tagging accuracy, may limit the usability of this method. Nevertheless, as the goal is to differentiate EMF-induced interferences from other disturbances, the existence/absence of EMF also gives valuable information, and the recorder can be carried, for example, on a belt.

This assessment method can only be used in circumstances where it is known that the interference from the EMF sources is so small that it does not pose a threat to the pacemaker wearer. The method can also be used when moderate interference is perceived in medical checks, to exclude EMF interference from those caused by clinical problems. An EMF recorder can be given to a pacemaker patient to wear for a few days, asking to keep a diary of his or her activities. After an appropriate time, the EMF recordings are read and compared with the interrogated pacemaker data. The location of the interference source can be revealed by combining the time of interference with the patient's diary activities.

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7. References

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