INFLUENCE OF THE ARC WELDING RELATED ELECTROMAGNETIC FIELD ON PACEMAKERS

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Abstract

The patients with implanted pacemaker or cardioverter-defibrillator are exposed to a certain risk of affecting this device by surrounding electromagnetic field. There are many sources of potential risky electromagnetic fields, arc welding is definitely one of them. The aim of this article is to present research focused on analysis of the pacemaker function during welding. There were performed in-vitro measurements with 9 pacemakers during metal inert gas (MIG) and tungsten inert gas (TIG) method arc welding. The responses of pacemakers were monitored by communication via programmer. Based on these measurements there are proposed safe distances from the main parts of welding machines, and also conditions and instructions for arc welding by patients with pacemakers. To ensure patient safety, patients should maintain suggested safe distances, use direct current with minimal possible amplitude, and weld in short intervals. Additionally, their pacemakers should be set to bipolar configuration.

Keywords

Pacemaker, arc welding, electromagnetic interference, EMI, CIED

Introduction

The number of patients having a pacemaker is growing every year. Simultaneously technological progress has enabled wide utilization electronics all around us. Therefore, patients with any cardiac device are exposed to many sources of potentially dangerous electromagnetic fields (EMFs) in their daily life. For this reason, there is a need to deal with principles of electromagnetic compatibility of cardiac implantable electronic devices (CIEDs), which are used for treatment of some heart rhythm disorders.

The spectrum of CIEDs involves mainly pacemakers (PCMs) for the treatment of bradycardia and cardioverter-defibrillators (ICDs) or the treatment of tachycardia. Pacemakers sense and interpret the signal from intracardiac electrodes placed in corresponding heart chambers (right atrium or right ventricle). When the pacemaker does not sense any electric activity of the heart it gives an electric impulse to stimulate myocardial cells. The goal is proper stimulation of myocardium to reach the most physiological heart function.

Detection of unphysiological (interfering) signals can have impact on the function of the device which may be dangerous for the patient. If the interference signal is classified as an own heart activity, it may inhibit the stimulation, which may lead to asystole (total absence of electrical activity from the heart).

For the patients with cardioverter-defibrillators there is the risk of induction of inappropriate defibrillation shocks. In this case the ICD detect interference signal, classify it as a tachyarrhythmia and initiate the therapy. In addition, electromagnetic interference (EMI) may cause less or more significant changes in programming or in extreme cases may damage the circuitry of the device.

Current trend is effort to minimize a risk associated with EMI, although it is not possible to completely eliminate it [1–3].

Potentially dangerous sources also include electric arc welding technology. A welding current source is capable of generating hundreds of amperes and thus being a source of strong magnetic field. Many cases when the function of PCM or ICD was affected have already been reported, e.g. as described in [4].

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As it is a source of potential risk, many doctors recommend avoiding it. In order to maintain the safety of patients with the least amount of restrictions in everyday life it is necessary to examine the effects of individual devices in more detail and establish the limits of their safe use. This article focuses on testing the function of cardiac pacemakers under the conditions that the patient is exposed to during the arc welding.

Methods

The experiments were carried out in two phases. First, the emitted electromagnetic field was mapped in the vicinity of the welding equipment. Two welding machines were used as a source of the interference. The first was TransPuls Synergic 2700 welding station (Fronius, Weis, Austria), which contained an inverter source, welding was performed with a melting electrode in a protective atmosphere using inert gases (MIG method), and a direct current with a maximum possible value of 270 A was used. The second was Magicwave 2200 welding station (Fronius, Weis, Austria). The source of the current was also an inverter source, welding was performed with non-fusing tungsten electrode in inert gases (TIG method), and an alternating current with a maximum amplitude of 220 A.

A Spectran NF-5030 spectrum analyzer (Aaronia, Strickscheid, Germany) with a measurement range from 1 Hz to 1 MHz was used to map the electromagnetic field. This range corresponded to the area of interest, as especially in low-frequency disturbance it poses a risk for interference with the pacemakers [4].

The measurement was carried out in three areas. The first area was in the immediate vicinity of the welding current source. The second was around the cable carrying the current to the welding electrode, which can be important if the cable is located near the patient's chest during welding or the patient supports it with his shoulder. The third area was the area of the welding site itself, where was analyzed the case where the patient inappropriately bends his chest to the point of welding. The measured values are the first comparison with safe field intensities as stated for example in [5, 6].

Table 1: The parameters of used pacemakers.

Model	Mode	Stimulation frequency (bpm)	Sensitivity A/V (bpm)	High rate A/V (bpm)	PVARP (ms)	Mode switch (bpm)
Enitra 8 DR-T	DDDR	60	0.1/0.5	180/180	225	160
Enitra 8 DR-T	DDDR	60	0.1/0.5	150/150	225	160
Etrinsa 8 DR-T	DDDR	60	0.1/0.5	180/180	225	160
Evia DR-T	DDDR	60	0.1/0.5	200/180	250	160
Effecta DR	DDDR	60	0.1/0.5	200/180	250	160
Enticos 4 DR	DDDR	60	0.1/0.5	180/180	225	140
Entovis DR-T	DDDR	60	0.1/0.5	200/180	300	140
Entovis SR-T	VVIR	60	0.5	180	-	-
Efffecta SR	VVIR	60	0.5	180	-	-

A/V – Atrium/Ventricle, Used modes DDDR and VVIR are described in [7].

In the second phase, an in-vitro measurement was performed, when the pacemakers themselves were exposed to interference. A total of 9 pacemakers from manufacturer Biotronik (Biotronik, Berlin, Germany) were tested, both single-chamber and dual-chamber devices in unipolar and bipolar configuration were included. The settings of the devices were left in their original state after explanation, only a uniform stimulation frequency to 60 bpm and minimal sensitivity were set. The settings of individual devices are in the Table 1.

The tested pacemakers were placed in a phantom with dimensions of 250×320×105 mm. The phantom was filled with a saline solution that simulated the electrical parameters of the human body. It was also equipped with a plastic plate with holes for setting the desired shape of the placement of the electrodes. The shape of the ventricular electrode was semicircular with a total area of 225 cm^2, which represents the maximum achievable effective induction area formed by the electrode, as described in [8]. For dual-chamber devices, the shape of the atrial electrode corresponded to frequent fixation in the right atrial appendage [9].

The phantom was then placed in the test areas while the welding station was in operation, as seen in Fig. 1. The pacemaker response was analyzed using programmer Renamic with software version PSW 2201.A (Biotronik, Berlin, Germany).

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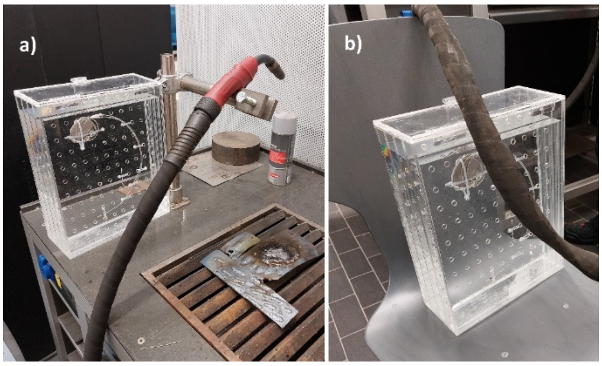

Fig. 1: Location of phantom with pacemaker: a) Near the welding site, b) Near the electrode cable.

An example of the monitored response is shown in Fig. 2. There is the proper function of the pacemaker, where a weak interference is visible on the atrial and ventricular channel, but it is not significant enough to affect the function of the device. It thus stimulates every approximately 1000 ms, which corresponds to the set stimulation frequency. These stimulated (paced) events are marked as Ap or Vp and highlighted in blue on the electrogram.

In Fig. 3. the incorrect behavior of the pacemaker can be seen, specifically the device interprets the detected interference as its own heart signal and inhibits the stimulation. These misinterpreted events are marked as As or Vs in red in the figure.

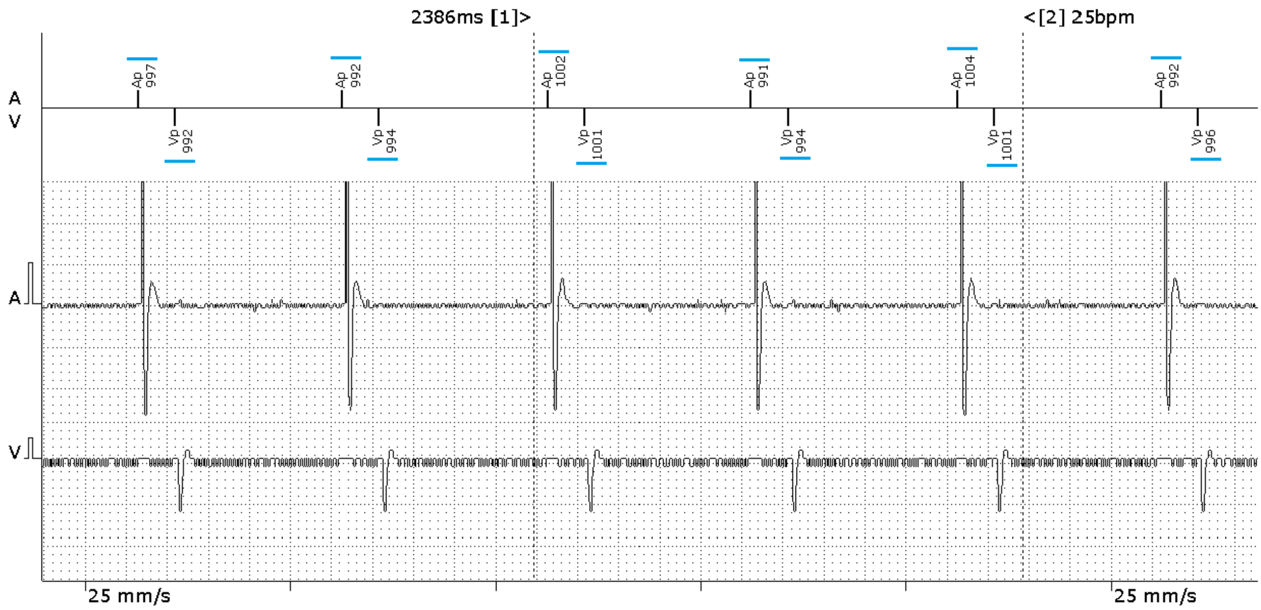

Fig. 2: Captured electrogram without pacemaker malfunction, blue markers indicate paced events.

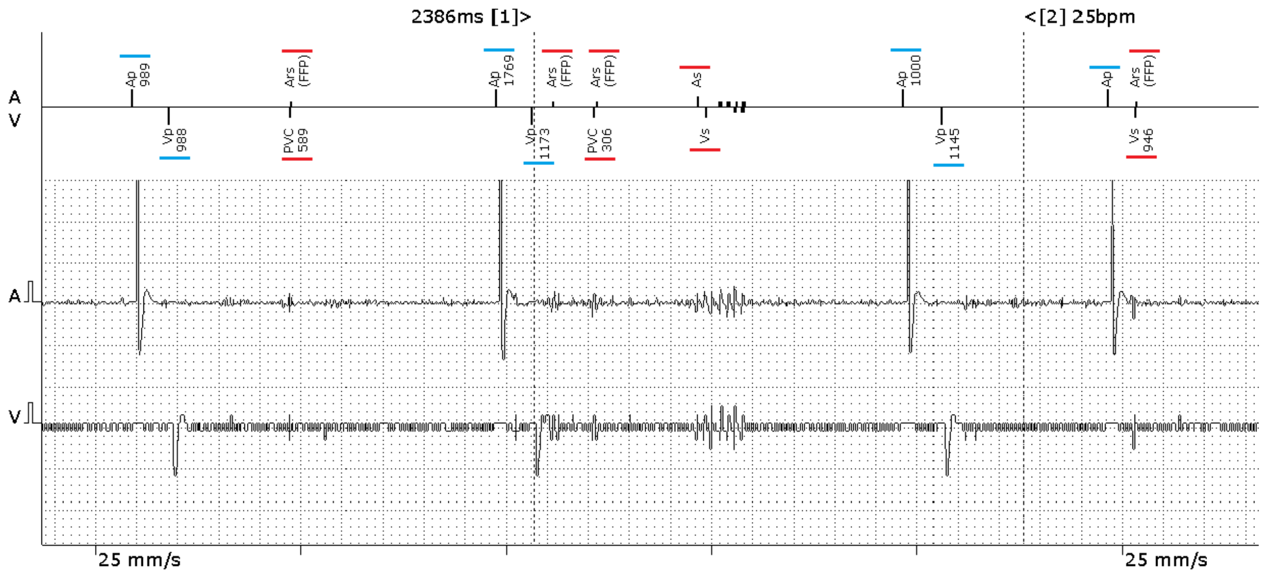

Fig. 3: Captured electrogram showing affected pacemaker function, blue markers indicate paced events, red markers are misinterpretations of interfering signals.

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Results

When a pacemaker was exposed to a sufficiently strong external field, it detected disturbing signals and interpreted as its own heart activity, therefore it interrupted the stimulation. As the distance from interference source increased, the number of misinterpreted events dropped. Based on the measurements, safe distances from the risk areas were determined, when the misinterpretation no longer occurred, and the function of the pacemakers was thus not affected. Table 2 shows the specified safe distances for 270 A direct current welding. The measurement also confirmed a greater risk of interference with the unipolar electrode configuration.

Table 2: Safe distances for direct current 270 A.

Placement	Bipolar sensing (cm)	Unipolar sensing (cm)
Welding site	20	40
Electrode cable	20	50
Source of current	10	10

Pacemakers have proven to be much more susceptible to interference during the welding with alternating current, safe distances are shown in Table 3.

Table 3: Safe distances for alternating current 220 A.

Placement	Bipolar sensing (cm)	Unipolar sensing (cm)
Welding site	60	80
Electrode cable	40	50
Source of current	20	40

Discussion

Patients with cardiac pacemakers are protected from interference by laws and standards that refer to the ICNIRP recommendations on exposure to non-ionizing radiation [10]. However, this is not sufficient, as the standards respond primarily to the limitation of primary effects, which are thermal effects. Affecting active implantable electronic devices by external EMF is one of the indirect effects, and it can be caused by even lower intensities of EMF. Pacemakers are also most sensitive to the interfering signals that are similar in frequency to the heart's own signal spectrum. This is in the area of low frequencies, where the thermal effects are the smallest, and therefore in this area the safe values set by ICNIRP reach the highest values of the entire spectrum. Moreover, the established threshold values are given as a mean value in time, while interference can be caused also by pulsed interfering signals with a larger amplitude and shorted duration. This is also why sufficient in vitro or in vivo experiments in a real environment are desirable to guarantee patients safety.

The limited number of tested cardiac pacemakers is a limitation of this study, therefore the measurements will be expanded to include other devices, especially models from other manufacturers, in the future. The welding current waveform also matters. In our experiments, a direct current and sinus alternate current with the maximum possible amplitude are chosen. It would be advisable to focus also on other current waveforms in the future studies.

Conclusion

This article presents a study focused on investigating the effect of electromagnetic interference from arc welding on pacemaker function. The paper describes performed series of experiments. A total of 9 explanted pacemakers were tested in a DC and AC welding environment. During the experiment, the most unfavorable conditions were simulated, and by monitoring the response of the pacemaker to the detected interference, safe welding distances were determined at a given current.

The conditions of safe use are then given by a set of rules. Welding should be done with direct current with the minimum possible amplitude, in short intervals with pauses between welds. The pacemaker should be set to bipolar configuration. A safe distance from the given parts must be kept (given for a maximum of 270 A), therefore the electrode cable must not be supported by the worker's shoulder. Furthermore, the electrode cable must not be coiled in order to avoid multiplication of the magnetic field. The worker must also keep a distance from other sources of electro-magnetic interference when welding.

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