The impact of electromagnetic fields and other physical factors used in medicine on cardiac implantable electronic devices

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Abstract

Currently, implant devices to electrical stimulation of the heart is a routine procedure, which the frequency is constantly growing. The reason for this phenomenon is both technological developments, and the increasing number of indications for implantation of intracardiac pacing devices. With the evolution of technology, is also growing number of medical procedures and equipment, which may adversely affect the operation of these devices. Therefore, risk management of possible electromagnetic interference is still a problem in the course of some medical procedures. The adverse effect of the electromagnetic field and other physical factors can change the mode of operation, inappropriate discharges or inhibit the function of implantable devices. In practice, through the presence of appropriate filters, to ensure proper differentiation of cardiac from non-cardiac potentials, these abnormalities are rare or only temporarily disrupt the function of these devices. However, to ensure complete safety patient, should be observe certain rules regarding the conduct of medical procedures using equipment, that could interfere with the systems to electrical stimulation of the heart.

Key words:

Pacemaker, implantable cardioverter defibrillator, implantable cardiac devices, electromagnetic field

Introduction

A breakthrough in the treatment with electrostimulation of patients, can be estimated for the year 1952. That was when, the first implantation of the pacemaker in a patient with bradycardia caused by atrioventricular block was performed. That spectacular event contributed to the development electrotherapy of the heart. Since that time, mentioned treatment has become a routine procedure, used in the treatment of symptomatic bradycardia, and the development of technology has made also drafted a device for interrupting life-threatening ventricular tachyarrhythmias, and restore synchronous ventricular function in patients with heart failure. Implantation of a pacemaker is designed to protect the life and health of the patient, and enable to preserve them, the normal activity. The prerequisite for the implantation of a permanent pacemaker is occurring rhythm disorders, which are characterized by irreversibility, pose a serious threat to the life or health of the patient and cause severe symptoms. [1] Now intracardiac stimulation devices are divided into:

Implantable cardiac pacemakers (ICP) – for treating arrhythmias with slow ventricular rate (eg. bradycardia, sinus node disease, atrioventricular block). They replace the function of electrical conduction system of the heart.

Implantable cardioverter-defibrillators (ICD) – for treating arrhythmias with rapid ventricular rate (eg. tachycardia, ventricular fibrillation, a state after cardiac arrest). These devices continuously detect the heart rate and in case of identification of life-threatening arrhythmias, perform intracardiac cardioversion or defibrillation.

Cardiac resynchronization therapy (*CRT)* – used for the treatment of refractory congestive heart failure, with concomitant disorders of intra- and interventricular conduction. These devices induce the time-shift between the contraction of right and left ventricular, which improves the filling of the left ventricle and increases ejection fraction.

Despite the presence of appropriate filters to ensure proper differentiation of the local intracardiac potentials of non-cardiac and electromagnetic interference, there are physical factors that can interfere with the pacemaker. The correct function of implantable devices (proper diagnosis of arrhythmias, and proper stimulation) may disrupt electrical signals, electromagnetic and magnetic fields derived from non-physiological sources. [2]

Many devices with the patient come into contact in everyday life, can be a source of interference with the pacemaker (transient inhibition of pacing, rapid synchronous stimulation with the received signals), but only in exceptional cases, interference may pose a significant threat (permanent damage to the electrodes and/or circuits of the pacemaker or endocarditis burn). [3]

Electromagnetic fields. They are wherever electricity is used. Electric fields are related to differences in the electrical voltage, and strong electric fields occur, for example, under the high voltage lines.

Magnetic fields. They are associated with electric currents. Strong magnetic fields are formed, for example, in the process of arc welding and induction heating. The magnetic field strength decreases rapidly with increasing distance from the source of the field.

Electromagnetic fields are generated, for example, by permanent magnets, electric tools, computers, radio and television transmitters, cell phones, medical equipment and anti-theft systems. In most cases, the electromagnetic field is not strong enough to cause a malfunction of the pacemaker. Also, only certain frequencies of the electromagnetic field produced by these devices are included in the band, which is critical for the functioning of pacemakers. [4] In addition to the above-mentioned, conventional types of energy, for the pacemaker can adversely affect also *ionizing radiation* (used in the treatment of cancer), radiation, acoustic (used in lithotripsy) thermal energy (using during diathermy) and the pressure exerted by the water during diving [5].

Electromagnetic fields

External electromagnetic fields may interfere with pacemakers and adversely affect their functioning. These disturbances depend on the characteristics of the field, technical prosperities, attitudes pacemaker and individual's

predisposition and environmental factors. Typical interference with the pacemaker results in switching its functions to the mode in which individually programmed pacemaker settings are not functioning, and the unit operates with the universal settings. Usually, when such disturbances are temporary, malfunctioning pacemaker does not pose any danger to the patient. Spurious signals, caused by electromagnetic fields can imitate the functioning of the heart, causing the pacemaker erroneously interprets the situation, as normal and does not respond to the actual cardiac rhythm abnormalities. Therefore, the pacemaker ceases to stimulate, even when the internal rhythm of the heart is too slow. Such a malfunction can be asymptomatic, when the inner rhythm of the heart of a person is satisfactory. However, this may result in dizziness, loss of consciousness, and even endanger the lives of people are totally dependent on the pacemaker. The rule is that, all interference with pacemakers disappear when the distance from the source of the electromagnetic field increases. [6] The best way to prevent electromagnetic interference pacemaker is to avoid staying close to equipment generating strong electromagnetic fields. Modern pacemakers are well protected against electromagnetic fields. An important factor determining the susceptibility to interference is the polarity of the electrodes. Now, commonly used electrodes are bipolar, with double discharge electrode with the pacemaker. This arrangement removes electromagnetic interference better than monopolar configuration. [7]

Electromagnetic fields used in medicine

Electrocoagulation

In the study "Effects of Surgical and Endoscopic Electrocautery a Modern-Day Permanent Pacemaker and implantable cardioverter-Defibrillator" evaluated the effect of electromagnetic field to pacemaker or cardioverter-defibrillator (ICD), in patients subjected to different surgeries. [8] In total, there were performed 13 endoscopic procedures and 79 surgical procedures. In the case of ICD, high-energy treatment has been excluded, and pacemaker parameters have been unchanged. Only in 6 patients the device has been programmed to an asynchronous pacing mode, at the request of the anesthetist. There were any abnormalities of the pacing system noticed, in all patients. There were no significant differences in the inspection device after the operation in the field of stimulation parameters, furthermore, in all cases there was no inhibit the stimulation.

In summary, clinical experience suggests that the electromagnetic field associated with the use of electric knife has low impact on the functioning of implantable cardiac devices, while maintaining a safe distance. [9]

Magnetic resonance imaging (MRI)

Strong magnetic field lead to excessive mechanical strain on all types of pacemakers. Magnetic fields alternating current (AC) and direct current (DC) greater than 1.5 Tesla can therefore lead to their permanent dysfunction or damage. [10] In addition, there are tissue burns or hemodynamic disturbances, caused by asynchronous stimulation or lack of stimulation of extrasystoles. Therefore, MRI, in this group of patients is contraindicated. But, if its implementation is indispensable due to clinical reasons, it should be done under constant control of cardiovascular parameters and readiness for resuscitation. Field strengths should be as small as possible, so as not to overheat the electrodes. There should be also considered reprogramming the pacemaker in asynchronous mode. [10,11]

Defibrillation

Can induce current in the electrode, and in turn on - by slight damage, cause an increase threshold in pacing, and reducing intracardiac signal value. [12] High-energy defibrillation can reprogram the pacemaker or even permanently damage it. Therefore, when performing electrical cardioversion, it is recommended to control the pacing system. [13] Anteroposterior position and the principle of to the front electrode was a minimum of 10-15 cm from the

pacemaker are also indicated. After cardioversion, full control of the pacing system is recommended. An impact of ionizing radiation on pacemakers

Patients undergoing radiation therapy are under the influence of two types of radiation:

Non-ionizing electromagnetic radiation. Pacemaker can receive electromagnetic field disturbance, as the potential of the heart muscle, which may result in the following irregularities in the operation of these devices: abnormalities of detection in the form of oversensing, block output, stimulation with a constant rhythm or rarely, reprogramming the device. Most of these disruptions are transient and resolves spontaneously after turning off the electromagnetic field. In addition, they can be prevented by programming the pacemaker. This contrasts with the situation on cardioverters, which are about 5-10 times more sensitive to the influence of an external electromagnetic field. Therefore, in some patients, it is recommended to disable the device anti-tachy, before the introduction of the therapeutic device, to avoid accidental discharge during irradiation. [14], [15] *Ionizing radiation*. The influence of ionizing radiation on pacemakers work is difficult to estimate. The most frequently, observed change in the frequency of operation, but there were also disturbances in memory, manifested by resetting or reprogramming of the set parameters (especially in cardioverters - defibrillators) and even complete cessation of operation of the pacemaker. In contrast to the effects of non-ionizing electromagnetic radiation, ionizing radiation they are more often irreversible and are cumulative. Therefore, all the recommendations advise against radiation therapy in patients with a pacemaker in the irradiated field. [14,15]

Lithotripsy

This type of therapy, with the use of special protective guards is not a major threat.

The smallest permissible distance is approx. 10 cm. Lithotripsy must be performed by synchronizing it with the ECG, as this may cause tachyarrhythmias. In the case of dual-chamber pacemakers, indicated is their stimulation and reprogramming only a single electrode, that do not occur randomly recorded interference impulses in the atria. It is also important to turn off anti-arrhythmic function. [1617]

Summary

Each year, it comes of patients with cardiac implantable electronic devices -CIEDs. The population of patients with such a device is growing very quickly. Technological advances, that simultaneously with the increase in the number CIEDs, there are new electronic devices. Potentially, each of them can be a source of interference with the implanted device. Despite increasingly advanced devices with increasingly more perfect differentiating algorithms, the risk of damage to pacemakers still exists. While, due to development of technology, the majority of the procedures used to be contraindicated, now, they can be performed under special supervision and after adequate preparation of the patient and the device.

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