Application of cardiac electrostimulation in strictly defined indications has been on the increase over the last few decades. Frequent use of this therapy as well as the fact that it is applied predominantly in patients in the seventh decade of life, implies possible significant comorbidities and need for various diagnostic and surgical procedures. These are the reasons we decided to point out certain specific features in approaching this patient group in preparation and implementation of these procedures.

Preoperative approach starts with usual patient history, with additional information on the type of pacemaker, last pacemaker check and electrocardiogram. This general approach is not substantially different for pacemaker or ICD patients.

What is specific is the possible interference caused by devices used in diagnostic or therapeutic procedures (diathermy, lithotripsy). Complications that may arise are usually related to the underlying disease rather than the pacemaker malfunction, but still, careful approach and pacemaker check are warranted, especially in the group marked as "pacemaker dependent". Adequate preoperative assessment, only slightly different from the usual, represents a sufficient guarantee for safe procedures - diagnostic, therapeutic or surgical.

Key words: preoperative workup, pacemaker therapy, surgical procedures, anaesthesiologic implications

INTRODUCTION

Planned surgical treatment of patients with implanted various types of pacemakers calls for a somewhat specific approach. History of this therapy began in 1958, and it has expanded over time, with development of various pacemaker types and much broader indication field. It has been assessed that in the USA about 2 million people out of total population are pacemaker carriers. In 2009, 3267 pacemakers were implanted pacemakers, and looking back we can see gradual increase over the years. From 64 pacemakers implanted per million inhabitants in the year 2000, this figure reached 427 per million by 2009. As the average age of these patients in our country ranges between 65 and 70 years, significant and frequent comorbidities may call for various diagnostic and surgical procedures requiring special care.

Based on pacemaker indications patients can be roughly divided into three major groups:

a) Patients with cardiac rhythm disturbances resulting in bradycardia

b) Patients with life threatening tachyarrhythmias

c) Patients with marked heart failure and inter or intraventricular asynchrony

In the first group, so-called antibradycardia pacemakers are implanted, implantable cardioverter defibrillators (usual abbreviation ICD) are used in the second group, and resynchronization devices (abbreviation CRT, from cardiac resynchronization therapy) in the third. Naturally, combinations of afore mentioned indications are possible, and specially designed pacing systems are applied in these cases. From technical point of view, it is of consequence for anestesiologist’s approach wether patient has an ICD or a pacemaker/CRT. Standard pacemakers and resynchronization devices create low voltage current of predefined frequency equivalent to normal heart rhythm, so designed to stimulate the heart. Malfunctioning during surgical procedures may jeopardize the patient if the pacing function becomes unreliable or if there is a prolonged arrest in stimulation. Pacing threshold is an important issue here - defined as the least voltage able to produce myocardial tissue response to artificial pacemaker stimulation. It varies depending on the local tissue reaction at the contact point between the lead and the endocardium, existence of scar tissue, cardiology status, myocardial fibrosis or pres-
ence of infarction scar. Variations may also be related to overall condition of the organism, endocrinologic profile, function of kidneys and lungs, oxygen saturation, and so on.

Basic role of ICDs is substantially different. They are designed to detect life threatening tachycardias (ventricular tachycardia and ventricular fibrillation) and treat them with condensed high output current, in the form of electric shock usually delivered to the area between the ICD can in the left pectoral zone and the right ventricular lead (DC shock electroconversion). These devices are implanted either for primary prevention or secondary prevention of sudden cardiac death. Naturally, these are the patients with higher operative risk, as they usually have a clinically manifested heart disease and comorbidities, but in case of inadequate preoperative approach, ICD check and programming, there is also a risk for the surgeon performing the operation.

PREOPERATIVE EVALUATION OF PACEMAKER PATIENTS

In preoperative approach a thorough patient history should be supplemented by type of the device and results of last pacemaker check, as well as an electrocardiogram. This applies for patients with ICDs as well.

History. Usual history data should be supplemented by indications for pacemaker implantation, especially if the device has been implanted recently.

Internist, cardiology and arrhythmology examination. Co-existent cardiology condition should be sought, as this is not uncommon in pacemaker patients. General assessment is that about 50% patients with pacemakers have some form of coronary disease, 20% are hypertensive and 10% have diabetes. Patients’ exercise tolerance should be carefully assessed and history and medical record on lung and kidney condition should be obtained.

Symptoms such as dizziness, near syncope, syncope, palpitations, chest pain or confusion, must be given special attention to, and pacemaker check scheduled.

Medication should also be carefully evaluated. Certain antarrhythmic drugs can affect the pacing threshold level and lead to unreliable pacing function (quinidine, fleca- nid, procainamid).

Status localis. During physical examination before scheduled procedure, the site of pacemaker implant should also be examined. Usual pacemaker site is left or right pectoral region, whereas abdominal position is rarely used nowadays, only as a result of complications. Antibrady- cardia pacemakers can be placed on either side, while ICDs and CRT devices are almost exclusively inserted on the left side. Inhibition of pacemaker by mio-potentials is rarely encountered, but is theoretically possible, due to detection of surrounding muscle activity by the pacemaker sensing circuit.

Laboratory investigations are usually aimed at assessment of the disease that is an indication for surgery. Electrolytes are of special importance, as they may affect the stimulation threshold. Potassium level is the most important parameter, since it may not only affect the threshold and pacing stability, but also precipitate rhythm disturbances during the procedure. PH disbalance may also significantly affect the pacing threshold. All these should be corrected before planned surgery.

Chest radiograph is usually not of importance in preoperative assessment of pacing system integrity, since telemetry control performed by an expert gives more precise data about the state of the generator and the lead(s). Sometimes it is necessary for identification of pacemaker type (when medical record is missing) and for visualization of the lead(s).

Electrocardiogram can show adequate pacemaker function, but in cases of intrinsic heart rate higher than the programmed base rate this can not be verified. This situation often causes doubt about adequate pacemaker function, especially when handled by less experienced medical staff. This can be avoided by preoperative pacemaker check in the refferent center. In rate adaptive pacemakers, pacing above the base rate is a normal finding. In dual chamber pacemakers several patterns of ECG tracings are possible: pacing spikes seen as preceding both the P wave and the QRS, ventricular paced complexes driven by intrinsic sinus rate, paced P waves with intrinsic AV conduction or completely intrinsic rhythm. In patients with implantable defibrillators, pacing rhythm is usually not seen on the ECG, as brady pacing rate is generally set to low values (40-45/min). This, of course, does not represent inadequate function.

Echocardiogram. Wider use of echocardiography allows better preoperative assessment of heart systolic function and valvular competency in all higher risk patients. For the majority of pacemaker patients this is not necessary, unless there is previous history of heart failure. As such history is always expected in patients with CRTs and defibrillators, echo should be obtained if a recent one is not available. Echocardiogram may reveal intracavitary, often endocardial thrombotic masses in patients with pacemakers and arrhythmias such as atrial fibrillation. If cardiosurgery is scheduled, such information is of utmost importance to the operating team. Thi si also the case with all major surgeries linked to higher operative risk. Perioperative echocardiogram in patients with pacemakers who undergo valvular surgery is not contraindicated, and can be carried out with no special limitations.

Nuclear magnetic resonance is not recommended in patients with standard pacemakers. Effect of the strong magnetic field may jeopardize patient safety, by causing changes in stimulation modality parameters, pacemaker inhibition or potentially proarrrhythmic high pacing rates. Lead problems can be also be expected, such as dislodgement of the lead or possible heating of the lead tip to temperatures over 50°C that may cause myocardial damage. Over the last two years, a new pacemaker generation has evolved, specifically designed to be NMR safe, but special care and ECG monitoring are still warra-nted. Such procedures require close monitoring by the anesthesiologist and pacemaker expert. Special attention and adjustment of parameters by radiologist in charge are also advised.
Pacemaker check is performed prior to scheduled surgical or diagnostic procedure. The type of pacemaker should be verified. If medical record is not available, this data can usually be obtained from device implant wallet card carried by the patient. If this is missing, as is often the case in emergencies, the type of pacemaker can be diagnosed by chest radiograph. It is optimal if the manufacturer can be discerned from the X-ray marks, as the pacemaker programmer used for telemetric control is different for each manufacturer. Number, type and position of the leads, as well as shape and size of the pacemaker are helpful in identifying the system. Control should be performed with appropriate reprogramming of the device if necessary.

It is important to assess whether patient is "pacemaker dependent", meaning that there is no intrinsic rhythm and heart rhythm is exclusively provided by the pacemaker. If the patient is not dependant, intrinsic rhythm can be seen to interchange with or override the pacing rhythm if this is set to lowest levels (programmable down to 30/min). If spontaneous rhythm exists, patient is relatively safe even in circumstances of short timed pacemaker inhibition, whereas in pacemaker dependent patients, higher level of care is necessary.

Battery. Pacemaker battery status and estimated longevity are of special importance. If time for elective device replacement (ERI - elective replacement indicator) has been reached, pacemaker should be replaced before any scheduled operative procedure. Newer generation pacemakers have relatively precise estimate of remaining battery longevity.

Magnet. Some former recommendations for operative procedures suggested applying a magnet (used for controlling the device) over the pacemaker case. Pacemaker reverts to so called asynchronouse mode of stimulation, and in most pacemakers paces at higher base rate. This pacemaker feature is called magnet rate, and differs from one manufacturert to the other (100 bpm, 99 bpm or 85bpm). In older models it was used as an estimate of battery status. Asynchronous pacing mode is a mode in which pacemaker stimulates the heart regardless of intrinsic activity. Another problem with applying a magnet is that in some pacemakers it automatically starts variate feature used for threshold measurement, i.e. pacing at a higher rate with gradual decrease of output during capture. This feature still exists in some older models. For the above mentione d reasons, magnet should not be applied, especially if adequate check and reprogramming can be done by an expert prior to procedure.

**APPROACH TO PACEMAKER PATIENTS DURING THE PROCEDURES**

In patients with implanted devices - bradycardia pacemaker, CRTs or ICDs, ECG monitoring and, if possible, hemodynamic monitoring is necessary during surgical procedures. For diagnostic procedures ECG monitoring is sufficient. In case of periprocedural or perioperative acute coronary event, there is a possibility of elevated stimulation threshold, and unreliable pacing at programmed parameters. Arrhythmias can also be encountered as a frequent complication. Approach to such patients is similar to patients without pacemakers. In patients with implanted ICDs, special attention is necessary, and intensive antiarrhythmic medication should be applied. It would be optimal to refer to pacemaker expert who should check pacemaker function with a programmer and make necessary adjustments.

Patients with temporary pacemaker lead should be given special attention. Care should be taken not to dislodge the lead during preoperative/preprocedural preparation manoeuvres. Temporary leads should be inserted in patients in which complications such as pacemaker inhibition or malfunction can be anticipated.

Electrical interference can affect the pacemaker in different ways, depending on the electromagnetic source and the circumstances. Electrocautery used in surgery emit frequencies in the range 0.5-5MHz, and may ope-rate in unipolar or bipolar mode. In unipolar mode, neutral plate is usually fixed in the lumbar area, or between lumbar and thoracic area. As the current circuit is formed between the tip of electrocautery knife and neutral plate, there is a risk of interference with electronic devices such as pacemakers. There is a major risk of ICD activation, as the current noise produced by electrocautery can be "interpreted" by defibrillator as tachyarrhythmia, and therapy shock delivered by the device. This puts patient at risk, but the surgeon is also at risk of electric shock. A standard, brady pacemaker, may also interpret the electromagnetic noise as intrinsic activity, which normally leads to pacemaker inhibition. The longer the electrocautery is applied, the higher the risk to patient. For these reasons if the patients are scheduled for major surgery, pacemakers are preoperatively reprogrammed, bipolar diathermy is advised, and ECG monitoring suggested during operation. Risk is especially high if the procedure is performed in body region close to the implanted pacemaker. Another device dysfunction that can occur as a result of electrocautery is a false signal of pacemaker battery end of life, registered by telemetric control during the operation or immediately after operation. EOL indicator (end of life), gives a false signal that battery has reached the end of life and that pacemaker should be replaced. Many pacemakers are constructed to swith to fixed mode operation regardless of intrinsic rhythm, in the circumstances of prolonged electromagnetic interference e.g. by diathermy knife. If diathermy is applied in short intervals and with pauses, such dysfunction will not occur. Newer generation pacemakers usually have a technicilly developed safety mechanisms and are less susceptible to EM inhibition.

Somatosensory evoked potentials and neuromuscular monitoring may only trigger sensors in rate adaptive pacemakers, and cause pacing at higher rates.

Of lately, electromagnetic interference related to cellular phones has become a topic of special interest. Latest research confirmed, and technological adaptation of pacemakers resulted in relatively insignificant effect of cellular phones on pacemaker function. It is considered that
the usual distance between the patient in the operating theatre from mobile phones and similar devices used by the staff is such that no effect on pacemaker function should be expected.\textsuperscript{15}

As for application of external defibrillators in patients with pacemakers during surgery or any other procedure, pacemaker manufacturers advice minimal distance from pacemaker can to be 15 cm, which is quite safe.\textsuperscript{16} There are cases reported in literature of lead insulation damage after external DC shocks, but we have not encountered any problems in our work.

**Radiotherapy.** Patients with pacemakers scheduled for radiotherapy, must be treated with special caution, and depending on the site and type of radiation. Ionizing radiation can damage pacemakers. Radiotherapy can be applied in regions that are not near to the pacemaker pocket, with the pacer side shielded, and if the treated site is in the immediate surrounding of the pacemaker, it may be necessary to surgically relocate the device to a safer position (contralateral hemithorax or abdominal region). In patients who have already undergone radiotherapy, detailed pacemaker checks should be performed prior to any surgical procedure.\textsuperscript{17}

Lithotripsy is possible in patients with pacemakers, but with certain limitations. DDD pacemakers should be programmed to VVI mode of stimulation, in order to functionally exclude atrial lead, for fear of proarhythmic effect of pulsations on atrial lead. Rules that apply for external DC shock also apply here - pacemaker must be at least 15 cm away from lithotripter. Also, during this procedure, it is necessary to switch off rate adaptive function in a pacemaker, as well as already mentioned atrial lead.\textsuperscript{18,19} In patients with ICDs, devices should also be reprogrammed, with therapy options switched off. Patient should be ECG monitored with an external defibrillator ready at hand. Immediately after the procedure, ICD can be reprogrammed back to initial settings. Apart from described limitations, general approach to pacemaker patients in this procedure is standard.

**POSSIBLE CAUSE OF PACEMAKER MALFUNCTION DURING SURGICAL AND ANESTESIOLOGY PROCEDURES**

Patients with pacemakers in need of emergency surgery or CPR should be treated the same. During CPR of patients with implanted ICDs, there is a possibility of internal DC shocks. The shock per se is not dangerous for the person who is performing CPR, but it can be very unpleasant. Therefore, in order to rule this out, especially during the heart massage, and with already applied gel for external DC shocks, the person who performs CPR should wear rubber gloves. Rubber gloves are advised for all the staff who is involved in resuscitation and immediate postoperative care of these patients. Myopotentials may cause pacemaker inhibition, and this can be seen even in patients with postoperative shivers. All medication that can have muscle fasciculations as an adverse event, should be generally avoided in pacemaker patients (depolarizing muscle relaxants).

Postoperative monitoring of these patients does not differ from usual, apart from the need to readjust the pacemaker parameters again if they were changed preoperatively. All patients should be scheduled for pacemaker check after cardiosurgery and thoracic surgery. In all other procedures, the chances of pacemaker malfunction are minimal.

**CONCLUSION**

Patients with implanted permanent pacemakers have no absolute contraindications for surgical treatment in any field of surgery. They do, however, require specific preoperative handling, and it is important to stick to guidelines to avoid complications. Possible complications are related to the underlying disease rather than to pacemaker malfunction, but careful approach and preoperative pacemaker check are mandatory, especially in the group of "pacemaker dependent" patients. Adequate preoperative assessment and preparation, only slightly different from usual, is a sufficient guarantee for safe diagnostic procedures and surgical treatment of patients with implanted pacemakers.

**SUMMARY**

PRISTUP BOLESNICIMA SA IMPLANTIRANIM PEJSMEJKEROM KOJI SE PRIPREMaju ZA HIRURŠKE Ili DIJAGNOSTIČKE PROCEDURE

Poslednjih decenija primena elektrostimulacije srca u strogom definisanim indikacijama je sve cešca. Učestalost primene ovih vrsta terapije, kao i činjenice da se ona dominanito primenjuje kod grupe bolesnika u sedmoj deciniji života implicira mogućnost značajnog komorbiditeta, čime i potrebe za drugim dijagnostičkim i hirurškim procedurama. Ovo su razlozi zbog kojih je neophodno ukazati na odredjene specifičnosti pristupa u pripremi i provođenju odredjenih procedura dijagnostike i lečenja ove specifične grupe bolesnika. Preoperativni pristup podrazumева uzimanje uobičajenih anamnestičkih podataka dopunjena podacima o vrsti ugradjenog pejsmejkera i posle ugradnje kontrolama, uz elektrokardiografski pregled. Ovaj, opšti preoperativni pristup nije značajno različit ni kod bolesnika sa ugradjenim defibrilatorima ni sa pejsmejkmera. Moguća interferncija sa aparatima kojima se vrši dijagnostika ili se koriste tokom procedura (dijatermija, litotripsija) zahteva specifičan pristup ovim bolesnicima. Komplikacije kod bolesnika sa ugradjenim pejsmejkmerom su preuzezane sa osnovnom bolesću, nego sa poremećajem funkcije pejsmejkera, ali i pored te činjenice, ova grupa bolesnika zahteva pažljiviji pristup i proveru funkcije ugradjenog pejsmejkera, posebno kod grupe bolesnika koje označavamo kao "pejsmejer zavisni". Ipak, adekvatna preoperativna praksa, koja se samo u detaljima razlikuje od uobičajene je dovoljna garancija za bezbedno provođenje procedura - dijagnostičke, terapijske ili hirurške.

Kljune reči: preoperativna procena, pacemaker terapija, hirurške procedure, anesteziološke implikacije
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