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Anesthetic management of a patient undergoing cardioverter defibrillator implantation: usefulness of transesophageal echocardiography and near infrared spectroscopy

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Abstract: A case of a patient with sustained ventricular tachycardia (VT) undergoing implantable cardiovertor defibrillator (ICD) implantation, using transesophageal echocardiography (TEE) and near infrared spectroscopy (NIR) is described. A 67-year-old man with sustained VT associated with old myocardial infarction underwent ICD implantation. Anesthesia was induced with fentanyl and propofol and maintained with nitrous oxide, oxygen, sevoflurane, and fentanyl. Global hypokinesis of the left ventricle was observed in the short-axis view provided by TEE. Intraoperative systolic blood pressure was maintained between 100 and 120 mmHg, and cerebral oxygenated hemoglobin (HbO2) was between 63% and 65%. During periods of induced ventricular fibrillation, systolic blood pressure decreased to 60 mmHg, HbO2 decreased to 59%, and TEE revealed cardiac arrest. These changes were transient; HbO2 returned to baseline values immediately after the restoration of normal rhythm. TEE confirmed no remarkable change in cardiac function after defibrillation testing. TEE and NIR were found to be beneficial for the anesthetic management of a patient with sustained VT who was underdoing ICD implantation.

Key words Anesthetic management · Implantable cardioverter defibrillator · Transesophageal echocardiography · Near infrared spectroscopy

Introduction

In patients with life-threatening or antiarrhythmic-drug resistant arrhythmia, the best means of improving life expectancy may be the installation of an implantable cardioverter defibrillator (ICD) [1]. However, anesthetic management of patients undergoing ICD implantation is problematic [2,3]. Herein, we describe the use of transesophageal echocardiography (TEE) and near infrared spectroscopy (NIR) in a patient with sustained ventricular tachycardia (VT) undergoing ICD implantation.

Case report

The patient was a 67-year-old man, 160 cm tall and weighing 73 kg. An electrocardiographic abnormality had been noted during a medical examination 15 years previously, and he was told of the presence of an old inferior myocardial infarction at that time. He suffered a cerebral infarction 5 years later, and because angiography revealed right internal carotid artery stenosis, carotid endarterectomy was performed. Coronary artery stenosis was noted at that time. The postoperative course was uneventful and no restenosis of the right internal carotid artery was revealed on repeat angiography. The patient began suffering from VT 3 years before referral to us, and he had undergone repeated external cardioversions. Amiodarone had been administered with a good effect for the year before we saw the patient, but interstitial lung disease secondary to amiodarone toxicity prevented continued use of the drug. Thus, the patient was scheduled for ICD implantation.

Upon physical examination, the patient's arterial blood pressure was 130/70 mmHg, and his heart rate was 80 bpm. Peripheral blood examination was normal. Preoperative chest radiography revealed bilateral interstitial fibrosis, and electrocardiography suggested right axis deviation, first-degree atrioventricular block, and complete right bundle branch block. Coronary angiography showed total occlusion of segment 1 of the right coronary artery and 99% stenosis of segment 12 of the left circumflex coronary artery. Left ventriculography revealed akinesis of segments 4 and 5. Electrophysiologic testing showed many tachycardia foci in the

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ventricle, and preoperative transthoracic echocardiography revealed reduced left ventricular function (ejection fraction, 44%; fractional shortening, 18%), and severe asynergy in the postero-inferior wall. ICD implantation was scheduled to prevent sudden cardiac death due to sustained VT and because the amiodarone had been stopped.

On the day of surgery, 0.3 mg atropine was injected intramuscularly 30 min before the patient's arrival in the operating theater. The left radial artery was cannulated, under local anesthesia, for blood sampling and continuous monitoring of arterial pressure. An external cardioverter defibrillator was kept ready for emergency use. Anesthesia was induced intravenously with 0.2 mg fentanyl and 70 mg propofol and maintained with nitrous oxide, oxygen, sevoflurane, and fentanyl. Muscle relaxation was obtained with vecuronium. After tracheal intubation, a multiplane TEE probe (21369A; Phillips, Andover, MA, USA) was inserted into the esophagus and attached to a color Doppler imaging system (SONOS 5500; Phillips). Global hypokinesis of the left ventricle (especially, severe asynergy in the postero-inferior wall) was observed in the short-axis view. Cardiac output was monitored with TEE by Teichholz's method. An NIR system (INVOS 3100A Cerebral Oximeter; Somanetics, Troy, MI, USA) was used for continuous brain monitoring during induced ventricular fibrillation (VF), and a probe was attached to the patient's forehead. Dopamine (2–5 $\mu g \cdot kg^{-1} \cdot min^{-1}$) was administered to maintain satisfactory cardiac output and blood pressure, and 250 mg methylprednisolone was administered for brain protection.

A fourth-generation ICD system (Micro Jewel 00 II 7223; Medtronic, Minneapolis, MN, USA) was used. The endocardial electrode was an intravascular catheter placed in the heart through the subclavian vein. The position of the intracardiac catheter was confirmed in the four-chamber view provided by TEE (Fig. 1). The intracardiac R wave was 13–14 mV, and the pacing threshold was 1.0 V. The defibrillation threshold was determined by intraoperative testing of the ICD. Induced VF was successfully defibrillated with 20 joules two times in a row (Fig. 2). Electrophysiologic testing confirmed the ability of the device to consistently terminate dysrhythmias on repeated occasions. The ICD generator was implanted in a subcutaneous pocket. Intraoperative systolic blood pressure was maintained between 100 and 120 mmHg, and cerebral oxygenated hemoglobin (HbO2) was between 63% and 65%. During periods of induced VF, systolic blood pressure decreased to 60 mmHg, HbO2 decreased to 59%, and TEE revealed cardiac arrest. These changes were transient; HbO2 returned to baseline values immediately after the restoration of normal rhythm. TEE confirmed no remarkable change in cardiac function after defibrillation testing. Surgery time was 3 h 15 min, and anesthesia time was 5 h.

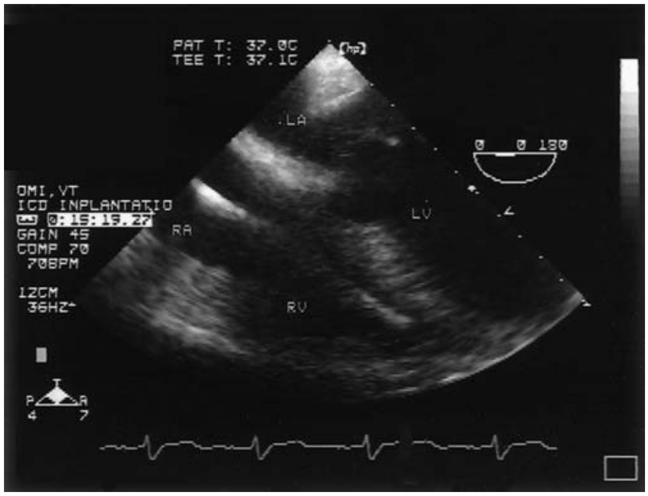

Fig. 1. The position of the transvenous electrode catheter was easily confirmed in the four-chamber view provided by transesophageal echocardiography. *RA*, right atrium; *RV*, right ventricle; *LA*, left atrium; *LV*, left ventricle

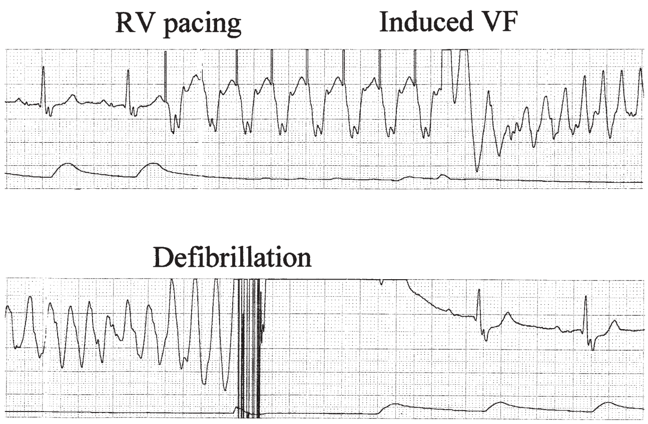

Fig. 2. Continuous physiologic recording during intraoperative testing of the implantable cardioverter defibrillator. In *each panel*, the *upper trace* is the external electrocardiogram, and the *bottom trace* is the radial artery pressure. *RV*, right ventricle; *VF*, ventricular fibrillation

On postoperative day 15, the patient suffered two attacks of VT, and proper functioning of the device was confirmed. He was discharged from the hospital on postoperative day 26.

Discussion

The ICD, first designed by Mirowski et al. in 1967 [4], is used for the treatment of life-threatening arrhythmia, such as VF or sustained VT. The first human implant, in

February 1980 [5], has been followed by many others, but anesthetic management for ICD implantation remains problematic [2,3]. Cerebral and cardiac monitoring are essential [6,7].

The first- and second-generation ICDs performed only a defibrillatory function and required thoracotomy for implantation. Third-generation units, however, can support pacing for post-defibrillation bradycardia and antitachycardia pacing. An endocardial electrode that can be implanted transvenously is used, obviating the need for thoracotomy. The fourth-generation ICD features a single-lead system with unipolar defibrillation, and implantation requires only one incision. The method of implantation has become less invasive, but the clinical efficacy of the ICD must be tested intraoperatively by dysrhythmia induction. Because a number of tests must be performed intraoperatively, general anesthesia is required for ICD placement. And because there is a high prevalence of ischemic heart disease and depressed cardiac function in patients scheduled for ICD implantation, special care must be taken in anesthetic management.

Amiodarone proved to be effective for the prevention of VT in our patient, but it had to be discontinued because of a severe side effect. Amiodarone is a Vaughan-Williams class-III anti-dysrhythmia agent that has been used successfully in the long-term treatment and prophylaxis of life-threatening ventricular arrhythmias that are unresponsive to other agents [8]. However, amiodarone has many side effects, the most serious of which is fatal lung toxicity. Some reports have therefore suggested that ICD implantation is superior to amiodarone for prolonging the survival of patients with life-threatening ventricular arrhythmia [9].

In the anesthetic management of ICD implant surgery, it is important, but difficult, to maintain both cardiac function and hemodynamic stability in patients with repeated and sustained VT and markedly depressed cardiac function. This requires optimal medical control. In patients such as ours, with repeated and sustained VT, an external cardioverter defibrillator should be readily available. Cardiac output was easily and noninvasively measured by the temporary use of TEE (Teichholz's method) and was maintained before and after the defibrillator threshold test. Anesthetics and antiarrhythmic drugs may alter the defibrillator threshold obtained during surgery, but now that ICDs can be reprogrammed, this is no longer a major concern. However, special care should be taken to avoid hypoxia, hypercapnia, and hypotension, all of which can alter the arrhythmia threshold.

It is important to determine what type of intraoperative monitoring is necessary. Because multiple inductions of VT and VF cause reduced cardiac and cerebral function, continuous monitoring is essential. Pulmonary artery catheterization is useful for the monitoring of patients with markedly depressed cardiac function, but it is invasive and may increase the risk of inducing a persistent rhythm disturbance during insertion. Furthermore, because the intraventricular ICD lead may be accidentally dislodged when the pulmonary artery catheter is removed, avoidance of intracardiac monitoring catheters is recommended. The use of TEE in the field of clinical anesthesia has evolved quickly because it is very helpful in evaluating chamber size, ventricular function, and cardiac valve function, and complications are rarely encountered [10,11]. At most institutions, a central venous catheter is commonly inserted, but we used TEE in our patient to monitor global and regional cardiac functions. Measuring cardiac output by TEE led to the use of dopamine in our patient. TEE was also used to confirm the position of the transvenous electrode catheter. With TEE we were able to monitor the position of the transvenous electrode catheter continuously and cardiac function simultaneously. This is in contrast to a portable radiographic C-arm image, with which we are able to monitor only the position of the transvenous electrode catheter.

Repeated induction of VF results in transient cerebral hypoperfusion caused by reduced cardiac output. Thus, protection of the brain is imperative. At some institutions, mild hypothermia and thiamylal or steroids are used. Because the period of induced VF in our patient was brief, only steroids were administered. Electroencephalography, transcranial Doppler, and somatosensory evoked potentials [12] are used for the continuous monitoring of cerebral function at some institutions. We used NIR because it is the simplest and least invasive method for monitoring cerebral function. NIR monitors changes in oxyhemoglobin and tissue oxygen availability by taking advantage of the skull's transparency to infrared signals [13]. The process is analogous to that used in pulse oximetry to distinguish between hemoglobin and oxyhemoglobin concentrations in systemic arterial blood. NIR is very useful because it allows cerebral oxygen saturation and hemodynamics to be assessed noninvasively, regionally, and continuously in real time. During the induced VF, HbO2 decreased transiently to 59%, but returned to baseline level immediately after the restoration of normal rhythm. If HbO2 values of less than 50% are expected to last for 5 min or more, we plan to use thiamylal, hypothermia, or another brain protection therapy.

In summary, TEE and NIR were found to be beneficial for the anesthetic management of a patient with sustained VT who was undergoing ICD implant surgery.

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