Potassium-Induced Cardiac Resetting Technique for Persistent Ventricular Tachycardia and Fibrillation After Aortic Declamping

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We report a technique of injecting a high concentration of potassium chloride into the aorta root to resolve refractory ventricular tachycardia after aortic declamping, which occurs occasionally in open heart surgeries. Using this technique, normal sinus rhythm can be restored without the need for defibrillation and aortic clamping.

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In cardiac surgeries, such as valve replacement, ventricular tachycardia (VT), and ventricular fibrillation (VF) may occur after removal of the aortic cross clamp. In most of these cases, direct current defibrillation restored normal sinus rhythm, and the patients could be weaned off cardiopulmonary bypass. However, VT and VF occasionally persisted, despite repeated defibrillations. In this case, the only conventional measure is to administer lidocaine, magnesium, and various anti-arrhythmic agents, and then repeat defibrillation again. However, repetitive defibrillations not only have the risk of damaging the myocardium and lower cardiac function, but may also decrease the fibrillation threshold resulting in greater susceptibility to further fibrillations [1]. Clinically, this situation is called the VT storm. Once entering the spiral of the VT storm, it becomes difficult to exit [2]. We encountered three cases of such a rare complication and were able to resolve the VT storm using a simple technique. We describe the detailed procedures in this report.

Technique

Patients

Patient 1 was a 67-year-old man with aortic valve stenosis. The valve area was 0.5 cm^2 with severe calcification. At normal sinus rhythm and echocardiography, the patient had a left ventricular ejection fraction of 70% and left ventricular wall thickness of 15 mm. Aortic valve replacement was performed using a 21-mm mechanical valve. The aortic cross-clamping time was 45 minutes.

Patient 2 was a 74-year-old man with bicuspid aortic valve. The valve area was 0.4 cm^2 with severe calcification. At normal sinus rhythm, echocardiography showed left ventricular ejection fraction of 65%, and left ventricular wall thickness of 18 mm. The aortic valve replacement was performed using a 19-mm biological valve. The aortic cross-clamping time was 65 minutes.

Patient 3 was a 78-year-old woman with mitral insufficiency after percutaneous transvenous mitral commissurotomy. An electrocardiogram demonstrated atrial fibrillation. Her preoperative left ventricular ejection fraction was 68%. The mitral valve replacement was conducted using a 27-mm biological valve. The aortic cross-clamping time was 59 minutes. In all three cases, coronary angiograms showed no stenosis.

All 3 patients underwent conventional open heart surgery described as follows. The cardiopulmonary bypass was conducted at a body temperature of 32°C, with the arterial cannula placed in the ascending aorta and venous cannulae in superior and inferior vena cavae. A left ventricular vent was also inserted. The flow rate of cardiopulmonary bypass was 3.2 L/min/body surface area. Blood cardioplegia was used based on the original method of Buckburg. Terminal warm blood cardioplegia was infused before aortic declamping. In all three patients, VF developed after removal of the aortic cross clamp. Defibrillation failed to resolve the VF. Another 5 to 10 defibrillations at 50 joules were given, also without success. During this period, lidocaine, amiodarone, magnesium, pilsicainide, disopyramide, verapamil, and other drugs were administered. Thus, we tried the potassium-induced cardiac resetting technique.

Potassium-Induced Cardiac Resetting

Cardiopulmonary bypass was maintained at a normal body temperature (36°C). In all 3 patients, 20 mL (20 mEq) of potassium chloride solution (Terumo, Tokyo, Japan) was infused slowly from the aortic root toward the base of the heart. In the absence of cardiac pumping, potassium chloride reached a high concentration at the aortic root, causing asystole within a short time. With the potassium concentration maintained at a high level and in the absence of aortic cross clamping, the heart was maintained in an asystolic state for approximately 1

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minute. Then, a delayed heart beat re-started gradually at an idioventricular rhythm. With time, the wide QRS interval was normalized and the heart rate increased. The blood potassium level decreased slowly as a result of ultrafiltration. When the level reached 5 mEq, the patients were weaned from cardiopulmonary bypass. In all 3 patients, weaning was easy, and the postoperative course was uneventful with no electrocardiograhic abnormalities.

Comment

In patients with aortic stenosis, perioperative arrhythmia is a crucial factor that determines the prognosis. Myocardial protection in the perioperative period, especially during cardiopulmonary bypass, and management of arrhythmia during reperfusion are important issues [2]. Shigemitsu and colleagues [1] reported the postoperative occurrence of VT storm. Although the incidence of a VT storm complication is low, cardiac surgeons should always bear it in mind and acquaint themselves with the techniques to resolve this problem.

The mechanism of VT storm remains unclear, and it is not related to the time of aortic clamping or cardiopulmonary bypass, but it is associated with problems in the protection of hypertrophied myocardium and reperfusion of the myocardium. The factors implicated in VT storm include anisotropic conduction of the myocardium [3] and subendocardial ischemia in aortic stenosis [4]. Furthermore, the body has already been rewarmed to 36°C during reperfusion, and VF at normal body temperature consumes a large amount of oxygen and may progress to myocardial damage if untreated [5]. When VT and VF occurs during reperfusion after aortic declamping, direct current defibrillation is usually performed. However, studies on cardioverter defibrillator implantation have shown that repetitive defibrillations not only cause myocardial damage but also lower the VT threshold, leading to increased susceptibility to recurrent VT [6]. Therefore, to resolve VT and VF after aortic declamping, direct current defibrillation should be limited to 5 to 6 times, and then other methods should be used to recover normal heart beat as soon as possible. Needless to say, administration of anti-arrhythmic agents is important. If administration of lidocaine, magnesium, amiodarone,and other anti-arrhythmics, followed by defibrillation succeeds to resolve VT and VF, then the problem is solved [7].

However, if VT and VF persists, then two methods are plausible. The first method is to cross clamp the aorta and re-arrest the heart by infusing blood cardioplegia to the aortic root [8, 9]. Lazar and colleagues [9] have shown that rearresting the heart with a brief, continuous infusion of blood cardioplegia results in more complete reversal of ischemic damage than is possible with prolongation of cardiopulmonary bypass alone. Lazar and colleagues [9] suggested that better recovery with secondary cardioplegia is due to diversion of oxygen toward reparative processes rather than expending it on electromechanical work of prolonged cardiopulmonary bypass. However, this method has some drawbacks; aortic clamping is prolonged with a risk of decreasing cardiac function, and the optimal clamping time and amount of infusion are not defined. The second method is to lower the temperature of the perfusate to reduce myocardial oxygen consumption. However, although hypothermia reduces myocardial oxygen consumption, it also predisposes VF. Therefore, the second method is not being used.

In our method, cardiopulmonary bypass is conducted at normothermia. Without aortic clamping, we infuse a high concentration of potassium to the aortic root. Transient asystole is obtained, and VT and VF storm is successfully avoided when the heart beat re-starts. Our methods have several advantages. First, the aortic is not clamped and the heart is perfused continuously with warm blood, thus preserving the cardiac function. Second, the heart is in a nonworking state with no increased oxygen consumption. The general myocardium and specialized myocardium of the conduction system recover from a stunning state, and this is thoroughly reperfused in a relaxed condition. Although this method was used in only three cases so far, our experience suggests that high potassium-induced asystole under nonclamping and normothermic conditions is a useful method to reset the natural heart rate.

FEATURE ARTICLES

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