Urgent Pump Conversion: When Does It Occur and How Can We Prevent It?

8

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Abstract

Off-pump coronary artery bypass grafting is widely performed to prevent cardiopulmonary bypass complications. However, on-pump conversion occurs unexpectedly and is associated with high morbidity and mortality. We have determined the preoperative risk factors that predict conversion based on a large number of off-pump cases that we experienced. Careful intraoperative displacement of the heart and snaring of the coronary arteries are essential to prevent the hemodynamic instability that results in the need for an urgent institution of cardiopulmonary bypass. Transesophageal echocardiography is very useful for proper heart positioning. With this imaging modality, we can observe pulmonary artery obstruction, right ventricular obstruction, mitral regurgitation, and other conditions that can cause hemodynamic instability. If there are ST-segment changes on the electrocardiogram, an intracoronary shunt should be used. The grafting sequence is also important. When there is hemodynamic collapse despite several preventive measures, the patient must be converted to on-pump coronary artery bypass grafting (CABG). The increase in morbidity and mortality with conversion can be reduced by converting rapidly from off-pump to on-pump CABG before encountering significant hemodynamic instability.

Keywords

Urgent conversion • Heart displacement • Myocardial ischemia

8.1 Introduction

Off-pump coronary artery bypass grafting (OPCAB) is widely performed to prevent the complications that occur with cardiopulmonary bypass (CPB). However, on-pump conversion occurs unexpectedly and is associated with high morbidity and mortality [1–3]. The operative mortality in conversion cases ranges from 1.6 to 13.3 % [1–8]. In this chapter, we present our experience of the need for urgent pump conversion and the ways in which it can be prevented.

8.2 When Does Urgent Pump Conversion Occur?

8.2.1 Preoperative Predictors

Several preoperative predictors of the need for conversion have been reported in literature. Low ejection fraction (EF), congestive heart failure (CHF), myocardial infarction, emergent cases, and other predictors have also been reported. The preoperative predictors are described in Table 8.1 [1, 2, 5, 7, 8]. It is of our opinion that the most important variables are impaired cardiac function and extreme chamber dilation. If a patient scheduled for coronary artery bypass grafting

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Table 8.1 Preoperative predictors of conversion

Surgeon's prior experience with OPCAB
Previous CABG
Congestive heart failure
Previous myocardial infarction
Urgent states
Low ejection fraction
Preoperative hemodynamic instability
Extremely dilated heart
Higher New York Heart Association class
Mitral regurgitation
Chronic obstructive pulmonary disease
Cardiomegaly
Smaller body surface area

(CABG) has several predictors of on-pump conversion, the patient should be scheduled for on-pump rather than off-pump CABG.

8.2.1.1 Intraoperative Factors

On-pump conversion during OPCAB occurs unexpectedly. Urgent conversion to CPB may be needed during positioning of the heart or grafting or in patients with acute ischemia when there is hemodynamic collapse or ventricular arrhythmias. Conversion needs to be performed most frequently during an attempt to expose the posterior-lateral wall of the heart. Heart displacement to expose the posterior-lateral wall causes mechanical alterations of the normal cardiac geometry such as right ventricular compression, right ventricular outflow tract obstruction, mitral annular deformation leading to functional mitral regurgitation, and impaired left ventricular filling [5]. These changes take place whenever there is displacement of the heart, even when there is normal cardiac function preoperatively.

The other cause of hemodynamic instability is ischemia. Coexistent ischemia compounds the effects of mechanical dysfunction resulting in the need for urgent institution of CPB. During anastomosis, the proximal coronary artery is snared with a silicon-coated suture in our institute for adequate visualization. When the target coronary artery is large, ischemia may be a major cause for conversion, especially in cases with poor collateral vessels. Ischemia in cardiac conduction system supplied by the right coronary artery sometimes causes severe bradycardia. The surgical techniques for prevention of hemodynamic instability are described in the next paragraph.

To achieve a clear field to perform the anastomosis, a low-pressure carbon dioxide gas blower is used widely. It is very helpful, but results in a drop in myocardial temperature that may cause arrhythmias. Excess use of low-pressure carbon dioxide gas should be avoided. In emergent cases, especially acute myocardial infarction, the hemodynamics are sometimes unstable before CABG. In such cases, on-pump CABG should be selected rather than OPCAB, because ventricular arrhythmias and hypotension occur easily. The other circumstances leading to pump conversion intraoperatively are described in Table 8.2 [5].

Table 8.2 Intraoperative circumstances leading to conversion

Inappropriate heart displacement
Ongoing ischemia
Hypothermia
Deep intramyocardial vessels
Calcified or diffusely diseased target arteries
Diminutive vessels
Need for extended endarterectomy of the target vessel
Cardiomegaly
Arrhythmias

8.3 How Can We Prevent Urgent Pump Conversion?

8.3.1 Operative Monitoring

8.3.1.1 Parameters

For intraoperative monitoring, a combination of leads II and V5 is continuously displayed and used for ST-segment trend analysis. Radial artery pressure and central venous pressure are also monitored. In patients with poor left ventricular function (LVEF <35 %), pulmonary artery pressure should be monitored via a Swan-Ganz catheter, and the femoral artery cannulation site should be secured for emergency insertion of an intra-aortic balloon pumping (IABP). Patient temperature is constantly monitored via a properly placed rectal or bladder temperature probe and maintained at >35 °C. Normothermia also helps to achieve hemostasis and early postoperative extubation. Parameters are recorded at baseline, with the heart in the normal position. A CPB setup is kept ready, but not primed, and a perfusionist is readily available.

8.3.1.2 Transesophageal Echocardiography (TEE)

Continuous intraoperative TEE monitoring is very useful. A baseline TEE examination should be done before sternotomy to assess the following: (1) global left ventricular function, (2) regional ventricular wall motion, (3) mitral regurgitation, (4) right ventricular function, (5) right ventricular outflow tract and pulmonary artery, (6) tricuspid regurgitation, (7) aortic valve, and (8) thoracic aorta [7, 9].

TEE during heart displacement and grafting is used to monitor the following parameters: (1) deterioration of global left ventricular function, (2) regional wall motion abnormalities and left ventricular filling, (3) deterioration of mitral regurgitation, (4) right ventricular outflow tract and pulmonary artery obstruction, (5) right atrial filling and tricuspid

regurgitation, and (6) aortic regurgitation [7, 9]. Multiple views are monitored during the anastomosis because of difficulties in imaging due to movement of the heart, pericardial traction, and vertical positioning of the heart.

8.3.2 Surgical Techniques

8.3.2.1 Sequence of Anastomosis

The grafting strategy plays an important role in preventing ischemia that potentiates hemodynamic compromise. The anteroseptal vessels are revascularized and perfused first, especially in patients with poor left ventricular function or acute ischemia preoperatively. Heart positioning for exposure of the left anterior descending coronary artery is easy and seldom causes hemodynamic compromise. After revascularization of the anteroseptal vessels, the heart is displaced to graft the remaining target vessels [4]. With a free graft, the proximal anastomosis should be completed before tackling another stenosed vessel if hemodynamics are unstable. In addition, the collateralized vessels should be grafted before collateralizing vessels.

8.3.2.2 Prevention of Ischemia

In our institute, the anastomosis is performed by snaring the proximal coronary artery with a silicon-coated suture and the use of a low-pressure gas blower. They provide adequate visualization; however, simple proximal snaring causes more ischemia of the myocardium. When ischemia causes left ventricular mechanical dysfunction, we use an intracoronary shunt. The use of an intracoronary shunt is good for preventing ischemia but makes the anastomosis difficult due to restriction of visualization.

There is good collateral formation in patients with chronic ischemia; however, in patients with acute ischemia, there is an insufficient collateral formation. In those with insufficient collateral formation, regional wall motion deteriorates after snaring the proximal coronary artery. This abnormal regional wall motion can be confirmed by TEE. Furthermore, the color of blood that flows retrograde after arteriotomy in these patients is dark compared with that in patients who have sufficient collateral vessel formation. We use an intracoronary shunt in such cases with insufficient collateral vessel formation. After snaring the proximal right coronary artery, the severe bradycardia that sometimes occurs requires a temporary pacemaker and an intracoronary shunt.

Ischemic preconditioning is reported to be effective in protecting the myocardium from ischemic injury [10]. However, it is not useful for emergent ischemic cases and wastes time.

8.3.2.3 Heart Displacement

The following techniques are used to prevent urgent conversion when the heart is displaced, especially when exposure of the posterior-lateral wall is necessary: (1) extensive right pleurectomy and deep vertical right pericardiotomy are performed to allow cardiac herniation into the right pleural cavity; (2) patients are placed in a right decubitus Trendelenburg position to provide good access to the target arteries [7]; and (3) TEE is used to monitor the right ventricular chamber, outflow tract, pulmonary artery, and mitral valve. If there is an increase in mitral regurgitation or right ventricular outflow tract and pulmonary artery obstruction that leads to hemodynamic compromise during displacement of the heart, these changes can be reversed by repositioning the heart. The right ventricular outflow tract and pulmonary artery are easily collapsed just by slightly shifting the heart.

In some cases, hemodynamic collapse occurs despite these preventive measures during the anastomosis. The adequate use of inotropes and fluid management may improve hemodynamics in such cases. If bradycardia occurs, pacemaker leads are attached to the right atrium or ventricle. However, if hemodynamic instability continues after pharmacological therapy, the heart should be placed in the normal anatomical position [5, 7]. If hemodynamics is improved by placing the heart in the normal anatomical position, the surgeon can continue with the CABG procedure. In most cases, the anastomosis can be completed without further hemodynamic instability. If hemodynamics fail to improve after placing the heart in the normal anatomical position along with the administration of adequate inotropic drugs and volume management, then rapid conversion to on-pump CABG is necessary.

8.3.3 Hemodynamic Management

8.3.3.1 Pharmacological Management

To prevent hemodynamic instability due to mechanical dysfunction and ischemia, dopamine, norepinephrine, dobutamine, or epinephrine is used. They can help maintain blood pressure; however, they contribute to a hyperdynamic cardiac state that makes it difficult to perform the anastomosis. Furthermore, fluid management is an important factor for maintaining hemodynamic stability. To prevent arrhythmias during manipulation of the heart and coronary occlusion, administration of lidocaine or a short-acting β-blocker is useful. Patients are given potassium if their serum K^+ is less than 4.0 mEq/L. The arterial pressure and cardiac index should be restored to baseline levels before the surgeon attempts the next anastomosis. The details of pharmacological and fluid management are presented in another chapter.

8.3.3.2 IABP

The insertion of IABP preoperatively has been reported as an effective measure to prevent on-pump conversion [11]. In the setting of OPCAB, preoperative IABP improves cardiac performance and facilitates access to the target vessels, while

maintaining hemodynamic stability, even in high-risk patients such as those with impaired cardiac function or acute ischemia.

Intraoperatively, if the hemodynamic changes are not corrected with fluids and pharmacological management with the heart in the normal anatomical position, urgent IABP insertion is one of the measures that should be considered before on-pump conversion. Of course, the thoracoabdominal aorta and aortic valve must be evaluated preoperatively before urgent IABP insertion.

8.3.3.3 Communication with the Operating Room Staff

Intraoperative pharmacological and volumetric management is left to the anesthesiologist and the nursing staff. One of the most important factors to prevent urgent conversion is close communication between surgeons and anesthesiologists, nursing staff, and operating room technicians. During displacement of the heart and anastomosis of the coronary artery, the operating room staff should report even slight hemodynamic changes. Needless to say, in order to convert to on-pump CABG rapidly, a CPB setup and perfusionist must be readily available in the operating room.

8.4 Conversion

When there is hemodynamic collapse despite the preventative measures described above, conversion to on-pump CABG is necessary. When conversion is needed, the CPB machine should be set up as soon as possible. Surgeons and perfusionists should practice daily in preparation for urgent conversion cases. If a surgeon has experience with only a few OPCAB cases, he/she should have a low threshold for urgent conversion to on-pump CABG. Conversion should be initiated if there are any early indicators of electrical or hemodynamic instability, especially in high-risk cases.

8.5 Conclusions

The following factors should be considered to avoid potential hemodynamic problems resulting in the need for urgent institution of CPB: (1) careful preoperative patient evaluation and selection, (2) appropriate sequence of grafting, (3) extensive right pleurectomy and deep vertical right pericardiotomy, (4) correct positioning of the patient on the operating table, (5) careful heart displacement and positioning, (6) early recognition of mechanically induced cardiac collapse after heart displacement, (7) early recognition of ischemia induced by snaring, and (8) a prompt response to these problems. If hemodynamics is still unstable after these preventive measures, the surgeon should not hesitate to convert from off-pump to on-pump CABG. The increase in morbidity and mortality due to conversion can be prevented by converting rapidly before significant hemodynamic instability is encountered.

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