6 Intraoperative Management and Anesthesia

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Abstract

General anesthesia using continuous infusion of remifentanil and propofol (or inhalational anesthetic drug) is the most popular anesthetic technique during off-pump coronary artery bypass (OPCAB) surgery due to established early awareness and extubation. Maintain of peripheral temperature using a warming system and continuous infusion of vasodilator is also important. Monitoring of transesophageal echocardiography is essential to diagnose not only ventricular systolic function but also ventricular diastolic function in most patients. Measurement of pulmonary artery catheter including continuous monitoring of central venous oxygen saturation is more useful during OPCAB pulmonary surgery compared with conventional coronary artery bypass (on-pump CABG) surgery. During anastomosis of circumflex artery or right coronary artery, Trendelenburg position is effective to maintain venous return. Preoperative induction of intra-aortic balloon pumping is effective for patients with acute coronary syndrome or severe heart failure. In patients with severe mitral regurgitation or low diastolic function, it is important to determine elective conversion to on-pump CABG.

Keywords

Anesthesia • Transesophageal echocardiography • Pulmonary artery catheter • Diastolic function • Intra-aortic balloon pumping

6.1 Anesthesia

6.1.1 Anesthetic Concept

Off-pump coronary artery bypass (OPCAB), which was introduced in Japan in the mid-1990s, is now used in more than 60 % of coronary artery bypass grafting (CABG) surgery. Recently, due to the advancement of medical devices such as stabilizers and positioners, the development of more efficacious anesthetics and cardiovascular management, and improvements in blood volume control, most OPCAB patients can be well managed intraoperatively without the use of emergency heart-lung assist devices. Blood loss and transfusion volume in OPCAB are markedly lower than those in on- pump conventional CABG, which requires cardiopulmonary bypass circulation. The risks of an inflammatory response and aortic injury are also reduced. Moreover, OPCAB is favorable from a cost perspective because an extracorporeal circulation is not used. However, prognosis is poor for OPCAB patients who emergently need a heart-lung assist device [1]. OPCAB involves more techniques and higher skill levels in terms of cardiovascular control and anesthetic technique compared to conventional cases involving heart-lung machines [2]. Early extubation and ambulation are also often required.

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T. Asai et al. (eds.), *Off-Pump Coronary Artery Bypass*, DOI 10.1007/978-4-431-54986-4_6

6.1.2 Preoperative Cardiac Evaluation

Since an extracorporeal circulation is not used in OPCAB, cardiac valve surgery cannot be performed concomitantly. Intraoperative management of patients with severe mitral regurgitation is difficult, and tricuspid regurgitation also greatly affects cardiovascular hemodynamics when the heart is reversed to the vertical position; therefore, accurate preoperative evaluation of cardiac function is important. In patients with severe atrioventricular valve regurgitation, OPCAB with simultaneous heart valve repair using an extracorporeal circulation is indicated. Moderate aortic regurgitation or aortic stenosis can be managed without an extracorporeal circulation. If a patient has definite patent foramen ovale (PFO), open heart surgery should be performed using a cardiopulmonary bypass.

The size of diastolic and systolic diameter and the ejection fraction (EF) of the left ventricle are evaluated precisely. At our institution, we consider on-pump CABG surgery for patients with a left ventricular EF <25 % [3]. Intraoperative management is often more difficult for patients with both ventricular wall hypertrophy and small left ventricular blood volume. In patients with diminished diastolic function, such as those with severe mitral or tricuspid annular calcification or thickening of the pericardium, intraoperative management is also often difficult. Since the left ventricular preload is related to the right ventricular EF, a decline in the right ventricular function markedly affects cardiac output [4]. In patients with severe left main coronary artery stenosis, strict maintenance of systemic blood pressure is required.

In patients who have carotid artery stenosis or occlusion of the cerebral arteries, the order of surgery needs to be considered in terms of priority. In many cases, OPCAB, in which systemic blood pressure is maintained somewhat higher than normal, is performed first [5].

In patients with renal failure, dialysis is performed on the day prior to surgery. Since atherosclerotic lesions can be severe in patients with renal failure, there is increased variation in blood pressure; therefore, strict blood volume control is required. Postoperative renal impairment is a severe potential complication of OPCAB, so preoperative evaluation of renal function is important.

6.1.3 Intraoperative Anesthetic Management

General anesthesia is the norm, but general plus epidural anesthesia is effective for reducing postoperative pain. OPCAB surgery can also be performed with only epidural anesthesia in some cases. However, catheter insertion into the epidural space is unlikely to be the best method for delivering anesthesia because there is a risk of intraoperative epidural hematoma due to the use of high-dose heparin. For intraoperative systemic anesthesia management, inhalational anesthetics are effective in protecting cardiac function as a part of anesthetic preconditioning. However, the heart rate should be maintained at less than 80 bpm during anastomosis in OPCAB. Therefore, the use of inhalational anesthetics often requires administration of short-acting β-blockers such as landiolol to slow the heart rate. Preconditioning with tourniquet compression of the upper arm during CABG has been reported to have a cardioprotective effect.

With the introduction of remifentanil, a potent ultrashort-acting analgesic infusion drug in Japan since 2006, heart rate control has been more effective. On the contrary, intraoperative pacing is still often required [6]. Due to the recent development of reliable mechanical stabilization devices such as the Octopus Tissue Stabilizer and apical suction devices such as Starfish Heart Positioner, heart rate control requirements are not as strict as before.

For anesthetic induction, benzodiazepines, such as midazolam (0.02–0.1 mg/kg), diazepam (0.02–0.1 mg/kg), and fentanyl (2–5 μg/kg), are commonly used intravenous agents. For maintenance of intravenous anesthesia, continuous infusion of remifentanil (0.3–0.6 μg/kg/min) and propofol (5–6 μg/kg/min) is preferred. For maintenance, inhalational anesthetic drugs, isoflurane (0.5–1 %) or sevoflurane (1–2 %) combined with remifentanil, are administered in anticipation of preconditioning effects.

The purpose of intraoperative anesthesia management is twofold: to minimize the effort on the heart as much as possible and to maintain systemic blood pressure at a level that ensures appropriate coronary blood flow. Maintaining the heart rate at an appropriately low level is crucial for minimizing the effort on the heart. Continuous administration of remifentanil can control the heart rate at a stable level. Selective β1 blockers are effective for controlling tachycardia. Appropriately decreasing systemic vascular resistance is effective for reducing the strain on left ventricular function because of afterload reduction. Phosphodiesterase (PDE) III inhibitors are useful because they not only reduce systemic vascular resistance but also slightly increase cardiac contractility [7]. Since it takes approximately one hour for PDE III inhibitors to achieve effective concentration, continuous administration should be started during graft anastomosis so that they take effect at the end of anastomosis. Milrinone (0.5 μg/kg/min) and olprinone (0.3 μg/kg/min) are frequently used PDE III inhibitors. However, over-reduction of systemic vascular resistance can cause a decline in systemic diastolic blood pressure, thereby reducing coronary blood flow. To maintain systemic blood pressure, continuous administration of phenylephrine or small doses of noradrenaline is effective. Under low-stimulation conditions, such as between anesthetic induction and the start of surgery, reductions in blood pressure are likely to occur; thus, continuous administration of phenylephrine is effective. For blood pressure drops during and after graft anastomosis, continuous administration of noradrenaline is effective.

Table 6.1 Anesthetic considerations for OPCAB surgery

1.	Continuous infusion of propofol and remifentanil is recommended for maintenance of anesthesia
2.	Pulmonary artery catheter is a useful monitoring system while the heart is in a vertical position
3.	Transesophageal echocardiography is essential in all patients unless there are contraindications
4.	The use of a warming system to maintain normothermia is important
5.	Fast-track anesthesia technique including postoperative pain management is favorable
6.	Prevention of severe atrioventricular valve regurgitation and ventricular outflow tract stenosis using conventional stabilizer and positioner is needed
7.	Trendelenburg position during Cx or RCA anastomosis is effective

While fentanyl (5–10 μg/kg) is administered as necessary toward the end of surgery, administration of remifentanil is gradually discontinued. Continuous propofol combined with dexmedetomidine is started, and the patient is subsequently transferred to the intensive care unit (ICU). The total dose of fentanyl is set to 500–800 μg and early extubation should be the goal (Table 6.1).

6.1.4 Intraoperative Monitoring

As with most cardiac surgical procedures, monitoring of electrocardiography using leads II and V5, pulse oximeter, capnometer, and direct arterial and central venous pressure is needed. Electroencephalography such as bispectral analysis is used to monitor anesthetic depth. Core body temperature is usually monitored using pharyngeal or bladder temperature. Tympanic temperature is occasionally used for this purpose. Peripheral temperature is monitored through the surface temperature of the palm or forearm.

It has been reported that there were no significant differences in mortality and morbidity based on whether a pulmonary artery catheter monitoring is used in CABG surgery involving a cardiopulmonary bypass. In OPCAB surgery, however, a pulmonary artery catheter is often useful for monitoring abrupt increases in pulmonary arterial pressure and decreases in central venous oxygen saturation (SvO_2). A pulmonary artery catheter is also needed for postoperative management in some cases [11]. Transesophageal echocardiography (TEE) is needed to evaluate mitral and tricuspid regurgitation and ventricular wall motion, as well as to diagnose narrowing of the pulmonary artery and left ventricular outflow tract. TEE is also useful for evaluating diastolic ventricular function.

In the OPCAB procedure, anastomoses are generally performed in the following order: left anterior descending coronary artery (LAD), circumflex artery (Cx), and right coronary artery (RCA).

During LAD anastomosis, SvO_2 and cardiac output sometimes decrease. If pulmonary arterial pressure increases significantly, left ventricular compression and pulmonary venous obstruction should be suspected. On the other hand, low pulmonary arterial pressure indicates the possibility of right ventricular outflow tract stenosis and right heart compression. To diagnose these conditions, TEE is used to evaluate the shape and motion of the left and right ventricles.

The electrocardiographic output voltage decreases when the heart is in a vertical position during Cx or RCA anastomosis, and thus ST changes cannot be identified. Additionally, SvO2 is almost always markedly decreased when the heart is in a vertical position, reflecting a decrease in cardiac output. Decreased pulmonary arterial pressure indicates that there is a high likelihood of right ventricular outflow tract obstruction, right heart failure, or exacerbation of tricuspid regurgitation. In contrast, elevated pulmonary arterial pressure suggests left heart failure or exacerbation of mitral regurgitation. To diagnose these conditions, TEE is useful to evaluate the degree of mitral and tricuspid regurgitation.

Moreover, TEE is important for intraoperative evaluation of left ventricular diastolic function. Diastolic dysfunction and pseudonormalization are diagnosed by the evaluation of left ventricular inflow waveforms (Fig. 6.1). By combining them with measurements of tissue Doppler and pulmonary venous inflow waveforms, a more accurate diagnosis becomes possible. If the ratio of the E-wave velocity from the left ventricular inflow waveform to the tissue Doppler-derived velocity (E/e') is ≤ 8, then left ventricular diastolic function is considered normal. If E/e' is ≥ 15, then diastolic dysfunction is present (Fig. 6.2). Since diastolic dysfunction significantly affects cardiovascular management in OPCAB surgery, identifying diastolic dysfunction is important.

During OPCAB surgery, evaluation of right ventricular function is also of importance. Central venous pressure and waveforms are useful for the evaluation of the right heart. Pulmonary arterial pressure waveforms, determined using a pulmonary artery catheter, are also useful for monitoring right ventricular function. Although the evaluation of right ventricular EF with TEE is difficult because the right ventricle is not round like the left ventricle, TEE provides important information. TEE is also needed for the evaluation of right ventricular diastolic function. The myocardial performance index, which is a ratio related to the right ventricular systolic time interval, is useful for evaluating right ventricular function. For monitoring right ventricular systolic

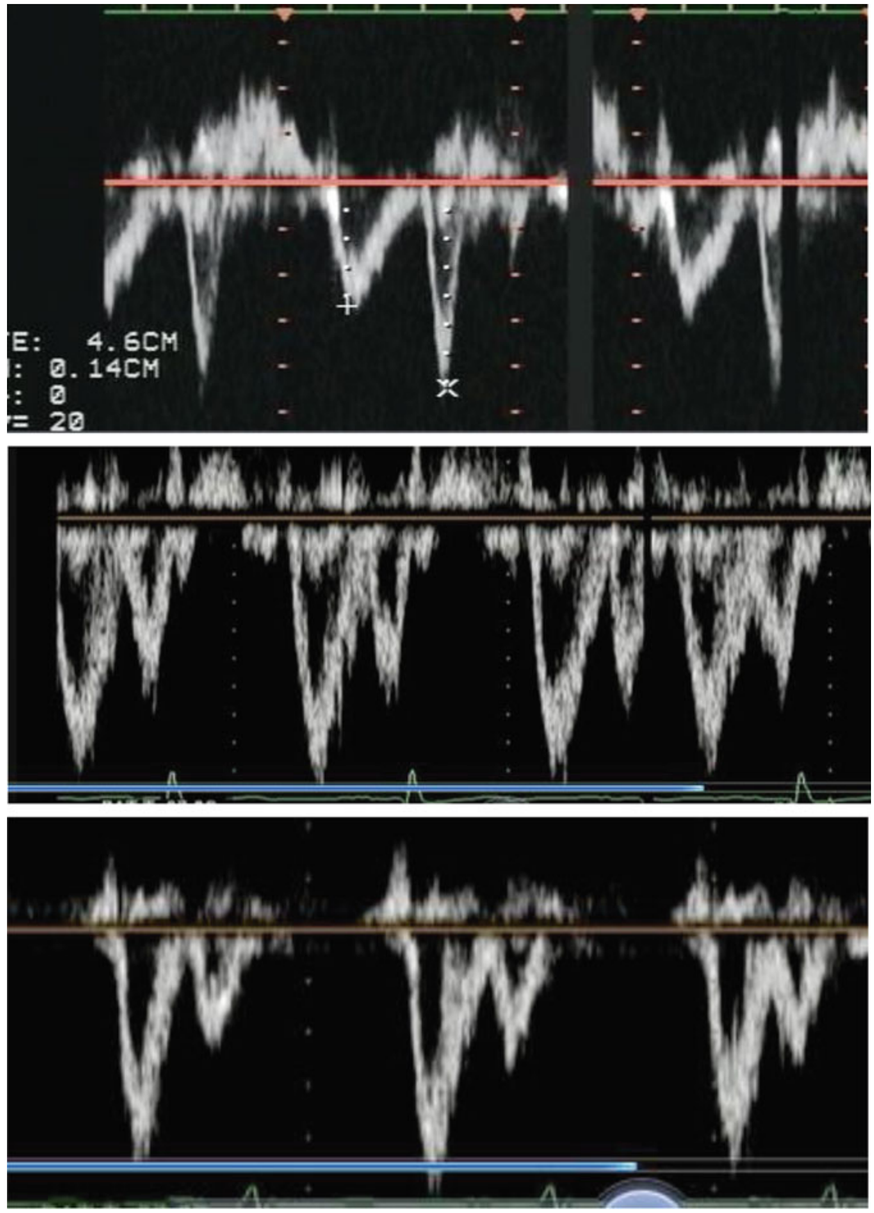

Fig. 6.1 Intraoperative left ventricular diastolic function is evaluated by transesophageal echocardiography. Mitral inflow pattern is measured using a pulse wave Doppler. (**a**) Abnormal relaxation pattern showed that peak E-wave is decreased and deceleration time is expanded, and peak A-wave is increased. (E/A wave ratio <1). (**b**) Pseudonormalization pattern showed increasing of peak E-wave and decreasing of peak A-wave. Deceleration time of E-wave is gradually reduced (E/A wave ratio >1). (**c**) Restrictive pattern showed high-peak E-wave. E/A wave ratio increased >2. Early diastolic pressure of left ventricle is rapidly increased

function, measurement of tricuspid annular plane systolic excursion (TAPSE) is also useful.

To monitor brain function in patients with carotid stenosis or cerebrovascular occlusion, near-infrared spectroscopy is performed.

6.1.5 Postoperative Anesthesia

After surgery, patients are generally managed in the ICU. Continuous infusion of both propofol (2–3 mg/kg/h) and dexmedetomidine (0.2–0.4 μg/kg/h) is applied for sedation. Appropriate fluid administration is needed to maintain diuresis. Once the peripheral temperature has sufficiently recovered, early extubation is attempted. Spontaneous breathing returns soon after patients are transferred to the ICU, and extubation is commonly performed within 3–6 h after surgery. In most cases, patients are discharged from the ICU the next day. Fentanyl is continuously infused to relieve postoperative pain.

6.2 Intraoperative Management

6.2.1 Intraoperative Cardiovascular Control

Following anesthetic induction, the dose of remifentanil is reduced to 0.05–0.1 μg/kg/min until the start of surgery. For patients with a decrease in systemic blood pressure, phenylephrine (0.1–0.2 mg) is administered intravenously to

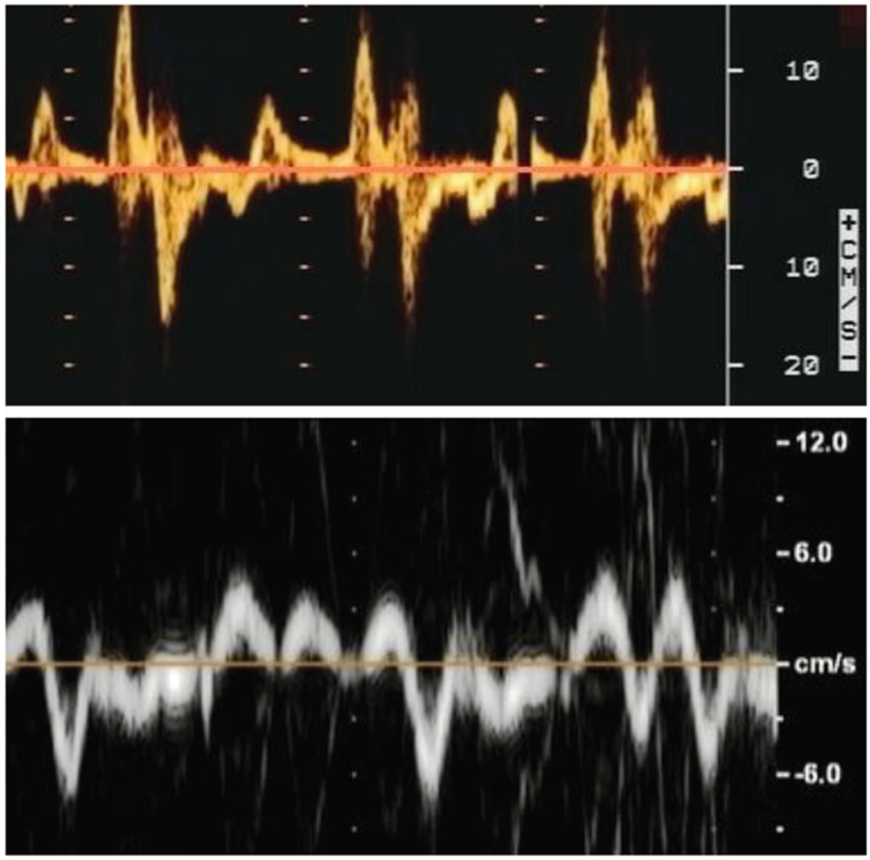

Fig. 6.2 Tissue Doppler pattern is measured at lateral mitral annulus using 4-chamber view. (**a**) Abnormal relaxation pattern of tissue Doppler showed increasing of a′-wave and decreasing of e′-wave. However, e′-wave remained over 8 mm/s. (**b**) Restrictive pattern of tissue Doppler showed decreasing of e′-wave under 8 mm/s

maintain the blood pressure. If peripheral vascular resistance declines with anesthetic induction, crystalloid solution should generally be given.

During internal thoracic artery or radial artery harvesting, fluid replacement should be sufficient to compensate for blood loss. The size of the heart, EF, and diastolic function are monitored using TEE. Mitral and tricuspid regurgitation are also evaluated. During internal thoracic artery harvesting, thoracic motion due to breathing may, in some cases, interfere with surgical manipulation. Increasing the respiratory rate to 30–50/min while decreasing tidal volume to 100–200 ml may reduce such respiratory motion.

Before the anastomosis procedure, low-dose heparin (100–150 u/kg) is infused and activated clotting time (ACT) is maintained over 250 s. During LAD anastomosis, a sling is inserted under the inferior part of the pericardium or a piece of gauze is inserted under the inferior part of the heart, and the left ventricle is lifted slightly. Compression of the LAD with a stabilizer may cause mitral regurgitation and diastolic dysfunction of both ventricles. After a small incision is made in the LAD, an intraluminal coronary shunt is inserted into the LAD coronary artery to maintain blood flow to the LAD; therefore, blood flow to the distal side of the anastomosis is maintained [8]. During end-to-side anastomosis, reducing volume overload and maintaining coronary blood flow by raising blood pressure with vasoconstrictors such as phenylephrine are recommended. The same procedure is also applied during diagonal branch anastomosis.

During Cx anastomosis, the patient is placed in the Trendelenburg position to increase venous return flow. The apex is pulled with a positioner so that the heart is in a vertical position (Fig. 6.3). For Cx anastomosis, torsion of the heart may exacerbate mitral and tricuspid regurgitation. Mitral and tricuspid valve regurgitation is markedly increased when the heart is in a vertical position, which reduces cardiac output remarkably [9]. When regurgitation is severe, changing the direction of the positioner and reducing the torsion may reduce regurgitation. Although compression with a stabilizer does not have a significant effect, there are negative effects on circulation when the heart is extensively twisted or vertically positioned (Fig. 6.4). Since cardiac output decreases when the heart is positioned vertically, transfusion is needed to maintain preload. Continuous infusion of vasopressors such as dopamine or noradrenaline is necessary in many cases.

Most of the time, the RCA is anastomosed to the atrioventricular node branch and the posterior descending coronary artery when the heart is vertically positioned. Although the heart is pulled into a vertical position with a positioner during RCA anastomosis, there is less twisting and thus less

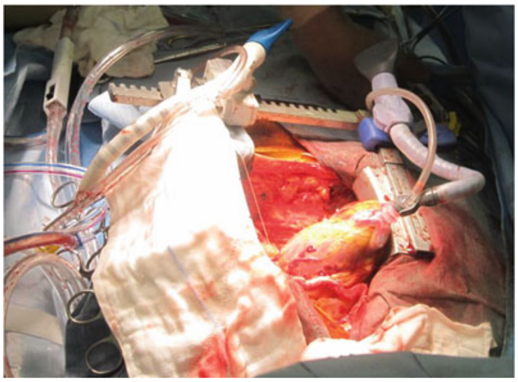

Fig. 6.3 The apex of a heart is absorbed and retracted to the vertical position using a heart positioner

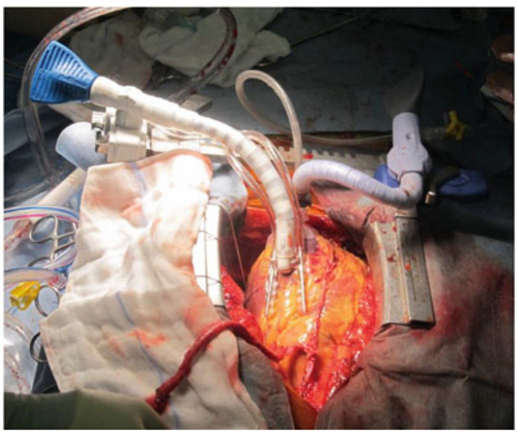

Fig. 6.4 Cx coronary artery is stabilized using a heart stabilizer

atrioventricular valve regurgitation than during Cx anastomosis. Transfusion becomes important due to the continuous decrease in cardiac output. In such cases, inotropes with vasodilatory effects, such as PDE III inhibitors and dobutamine (3–5 μg/kg/min), are used.

After the completion of the anastomoses, the heart is returned to its original position and hemostasis is performed before the chest is closed. In order to raise body temperature back to normal, the operating room temperature is raised and hot-air warming devices are applied. Infusion of amino acid preparations may also help with body temperature recovery [10]. Low doses of calcium antagonists such as nicardipine and diltiazem are continuously infused to prevent spasm of the arterial grafts. In many cases, it is helpful to administer a small dose of vasopressors such as catecholamine for cardiac function support, as well as vasodilators for afterload reduction.

6.2.2 Transfusion Management

Colloidal solutions are most commonly used, but crystalloid solutions may also be applied. Since stabilizers restrict diastolic function during LAD anastomosis, intraoperative management entails controlling infusion volume. A transfusion is required during Cx anastomosis because the heart is reversed and positioned vertically. However, during RCA anastomosis, a higher transfusion load is needed. The risk of postoperative atrial fibrillation can be reduced with an appropriate transfusion load.

As blood transfusions may enhance the inflammatory response, it is desirable to postpone transfusion until the LAD anastomosis is completed. However, it is also necessary to avoid anemia because it markedly affects the balance between oxygen supply and demand. Due to the increasing number of elderly patients and small female patients, nearly half of the patients receive blood transfusions during OPCAB surgery.

Among elderly patients and patients with arteriosclerotic lesions, there is an increasing number of cases in which achieving hemostasis is difficult due to bleeding from calcified areas. Excessive fresh frozen plasma and platelet transfusions should be avoided, but achieving hemostasis may be difficult.

It is reported that minimizing the transfusion volume reduces the incidence of several complications [12]. If cardiac output is somewhat maintained, smaller transfusion loads can effectively reduce the number of pulmonary complications. During LAD anastomosis, bloodletting may alleviate mitral regurgitation in cases where it is exacerbated by compression of the heart due to the use of a stabilizer or positioning device. Strict blood volume control is often needed in patients with diminished ventricular diastolic function, because there may be little reserve for controlling the circulating blood volume.

Control of urine volume is also necessary. The incidence of renal failure is lower with OPCAB compared to CABG with cardiopulmonary bypass. However, postoperative renal failure can be serious. Intravenous furosemide and continuous administration of human atrial natriuretic peptide (hANP) can be effective.

6.2.3 Cardiovascular Agonists

Catecholamines such as phenylephrine (0.1–0.4 μg/kg/min) with α-agonist activity and noradrenaline (0.01–0.1 μg/kg/min) are often used prior to and during LAD anastomosis to support cardiac function. It is not preferable to use catecholamines with β-agonist activity, such as dopamine and dobutamine, before LAD anastomosis.

After the LAD anastomosis is completed, anastomosis in the Cx region is initiated while the heart is vertically positioned. If cardiac output is markedly reduced, administration of β-agonists such as dopamine should be considered. When arterial grafts are used, continuous administration of calcium antagonists such as diltiazem (2–5 mg/h) and nicardipine (1–2 mg/h) is preferable. The administration of PDE III inhibitors, such as olprinone and milrinone, is indicated to reduce high afterload. Continuous noradrenaline is given for the patients with systemic hypotension.

During RCA anastomosis, α- and/or β-agonists are administered in order to maintain systemic blood pressure if necessary. hANP (0.01–0.05 μg/kg/min), which has a diuretic effect, is continuously infused when indicated.

After the anastomosis is completed, β-antagonists are often continuously infused to maintain adequate heart rhythm and cardiac output. Landiolol (0.005–0.02 μg/kg/min) is continuously infused to treat tachycardia and prevent postoperative atrial fibrillation. PDE III inhibitors are also effective for reducing afterload.

6.2.4 Management of Patients with Heart Failure

Cardiovascular control is more challenging in patients with heart failure. With lower left ventricular EF, afterload reduction using vasodilators and preload reduction using appropriate infusion are needed. However, a lower left ventricular EF does not portend worse prognosis if some degree of cardiac output is maintained. At our institution, we consider performing on-pump CABG when EF is ≤25 % or when moderate mitral regurgitation is present. In patients with EF >25 %, the following three factors are taken into account: the size of the heart, the presence or absence of dyskinetic areas, and the severity of mitral annular calcification. However, OPCAB is often possible. In general, low EF is not likely to be an intraoperative risk factor of hemodynamic management because there is a smaller angle of reversal and less torsion in the enlarged heart with low EF when positioned vertically than in a smaller heart. In cases where mitral or tricuspid regurgitation is exacerbated by positioning during Cx anastomosis, the direction of pulling by the positioner at the apex is adjusted to alleviate regurgitation. Some volume overload is needed when the heart is vertically positioned. Appropriate α-agonists are continuously administered in order to maintain coronary perfusion pressure. In patients with large dyskinetic areas, functional mitral regurgitation, or severe mitral or tricuspid annular calcification, it is difficult to control intraoperative cardiovascular hemodynamics.

In patients with low left ventricular diastolic function, the heart is compressed with a stabilizer during anastomosis, which diminishes cardiac output and SvO2. During anastomosis or when vertical positioning exacerbates mitral or tricuspid regurgitation, cardiac output is excessively reduced. An increase in E/e′ measured by echocardiography is used as an index of diastolic function. In general, diastolic function is considered normal when E/e′ is ≤8 and markedly deteriorated when E/e′ is ≥15. It has been reported that significantly more postoperative cardiovascular events occur in cases with E/e′ ≥15 compared to E/e′ ≤8. Mortality is also significantly higher in the former case [13]. Intraoperative declines in cardiac output require more time to return to baseline in patients with E/e′ ≥15. In hearts with diastolic dysfunction, both intraoperative and postoperative management are often difficult.

6.2.5 Management of Patients Who Have an Intra-aortic Balloon Pump

Patients with acute coronary syndrome and unstable cardiovascular hemodynamics or severe heart failure with very low cardiac output often have an intra-aortic balloon pump (IABP) placed preoperatively. An increase in diastolic blood pressure due to IABP support has a positive effect on coronary blood flow. The elevation of systemic mean arterial pressure is effective for stabilizing cardiovascular hemodynamics when the heart is reversed and vertically positioned. Since higher systemic blood pressures and increased cardiac output are appropriately maintained, no additional transfusion is needed in many cases [14].

IABP is usually operated to assist with every heartbeat (1:1) counter pulsation. As electric cautery is performed in surgery, IABP is often used with an arterial pressure trigger mode. The beating position of the IABP balloon is confirmed intraoperatively using TEE. The optimal position is 2–3 cm distal to the origin of the left subclavian artery. In cases where thrombi adhere to the intimal vessel in atherosclerotic lesions, postoperative renal failure and embolic events in the lower extremities are potential complications. Heparin may cause hemorrhage at the IABP insertion site.

6.2.6 Conversion to On-Pump CABG

The prognosis for patients with cardiovascular hemodynamic collapse during anastomosis and thus requiring an extracorporeal circulation is sevenfold worse compared to patients without such hemodynamic deterioration. Intraoperative conversion to the use of an extracorporeal circulation consists of two types: elective conversion and emergency conversion due to hemodynamic compromise. Between 2000 and 2005 when OPCAB became popular, the conversion rate to on-pump CABG due to hemodynamic collapse was 6–8 %, and the emergency conversion rate was 3 %. Recent advancements in devices used in OPCAB along with improvements of surgical skill contributed to a reduction in the conversion rate; however, approximately 2 % of cases are still converted to on-pump CABG, and the emergency conversion rate is approximately 1 %.

Elective conversion to on-pump CABG is more common with moderate to severe mitral regurgitation or organic problems such as the presence of a patent foramen ovale. In addition, electively converted cases include the following scenarios: arterial dissection, the coronary arteries to be anastomosed are buried, and cases in which OPCAB was determined to be impossible due to very low right ventricular function or diastolic function [15]. A stiff heart or a heart with a thickened wall is also likely to collapse. Patients with left main coronary artery stenosis, heart failure with diastolic dysfunction, or cases of repeat CABG or semi-emergency nature are also likely to be converted to on-pump CABG.

The use of intraluminal coronary shunting during LAD anastomosis is useful for preventing conversion. Additionally, IABP use can prevent conversion, and the temporary application of percutaneous cardiopulmonary support and ventricular assist devices is helpful.

Emergency conversion occurs most frequently during Cx anastomosis, most commonly due to severe mitral regurgitation when the heart is in a reversed, vertical position, leading to low cardiac output and hemodynamic collapse [16]. However, recent advancements in devices such as stabilizers and positioners have improved cardiovascular hemodynamics in the reversed, vertically positioned heart, thereby reducing the rate of hemodynamic compromise. On the other hand, compression with a stabilizer in patients with diastolic dysfunction or decreased right ventricular function is associated with hemodynamic collapse and conversion to on-pump CABG during LAD anastomosis.

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