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Anesthetic management of apicoaortic bypass in patients with severe aortic stenosis

Satoru Ogawa[1], Ryu Okutani[1], Tatsuhiro Shigemoto[1], Koji Hattori[2], Toshihiko Shibata[2], and Masahiro Ide[3]

[1] Department of Anesthesiology, Osaka City General Hospital, 2-13-22 Miyakojima-hondori, Miyakojima-ku, Osaka 534-0021, Japan
[2] Department of Cardiothoracic Vascular Surgery, Osaka City General Hospital, Osaka, Japan
[3] Anesthesia Associates of KOBE, Hyogo, Japan

Abstract
Apicoaortic bypass (AAB), or apicoaortic conduit insertion, is a conventional surgical method that has been regaining attention due to the aging population and the increasing number of repeat surgeries. The indication for the procedure has been extended as an alternative for aortic stenosis when the usual sternotomy or aortic clamping is considered to be difficult, e.g., in patients with severe calcification of the ascending aorta (porcelain aorta), or in patients with a patent coronary artery bypass graft located adjacent to the posterior surface of the sternum. Herein, we report our recent anesthetic management of three patients undergoing AAB. Once the apicoaortic conduit is inserted, blood from the left ventricle is ejected via two routes, the narrowed native aortic valve and the apicoaortic conduit. Thus, it is necessary to elucidate any change in blood flow after the withdrawal of the extracorporeal circulation, by using intraoperative transesophageal echocardiography. Furthermore, if a rigid apical connector is not used, anastomosis of the cardiac apex and conduit is conducted under ventricular fibrillation without the infusion of cardioplegic solution; thus, patients are deemed likely to suffer increased myocardial damage. As a rigid apical connector was not used in the three present patients, the administraction of adequate catecholamines was needed for the withdrawal of the extracorporeal circulation. In addition, because those undergoing AAB often have extremely poor cardiac reserve preoperatively owing to the administration of adequate catecholamines was needed for the withdrawal of the extracorporeal circulation. In the three present patients, anesthetic management was successful, and there were no intraoperative or immediate postoperative complications.

Key words Apicoaortic bypass · Apicoaortic conduit · Severe aortic stenosis · Porcelain aorta

Address correspondence to: S. Ogawa
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Introduction

Apicoaortic bypass (AAB), or apicoaortic conduit (AAC) insertion, is a surgical procedure conducted conventionally for congenital aortic stenosis and severe left ventricular (LV) outflow stenosis. The method has been regaining attention due to the aging population and the increased number of repeat surgeries. The indication for the procedure has been extended as an alternative treatment of aortic stenosis (AS) when standard sternotomy or aortic clamping is anticipated to be difficult in certain cases, such as in patients with severe calcification of the ascending aorta (porcelain aorta) or those with a patent coronary artery bypass graft located adjacent to the posterior surface of the sternum [1–3]. Herein, we report our recent experience with the anesthetic management of three patients undergoing AAB.

Case reports

Case 1

We treated a 75-year-old woman who had undergone triple-vessel coronary artery bypass grafting (CABG) 15 years previously for angina pectoris; this had been followed by percutaneous transluminal coronary angioplasty, performed on two occasions. Subsequently, the patient experienced gradual progression of the AS, and likely associated episodic chest pain, without significant occlusion by coronary lesions being seen at subsequent follow-up examinations, and she was scheduled to undergo surgery for AS. An AAB procedure was selected, as this was repeat surgery, the left internal thoracic artery used in the previous surgery was adjacent to the sternum, and a porcelain aorta was present (Table 1). Preoperative transthoracic echocardiography (TTE) showed severe AS, with a left ventricular-to-

Table 1. Patient characteristics, pre- and postoperative data and results

Case no.	Age (years)	Sex	Diagnosis	Past op.	LVEF (%)	AVA (cm^2)	LV-Ao peak gradient (mmHg) Pre	Post[a]	Pre/Post-NHYA status	Outcome
1	75	F	AS, porcelain Ao, IHD	CABG	70	0.51	82	—	4/1	Well at 10 months
2	60	M	AS, AR, MR, IHD, porcelain Ao, RF	CABG	25	0.60	66	—	4/1	Well at 9 months
3	79	F	AS, porcelain Ao	—	62	0.41	164	—	3/1	Well at 8 months

AS, aortic stenosis; AR, aortic regurgitation; MR, mitral regurgitation; porcelain Ao, porcelain aorta; RF, renal failure; IHD, ischemic heart disease; CABG, coronary artery bypass grafting; AVA, aovtic valve area

[a]The flow in the aortic valve was confirmed by TTE after the operation in all patients; however, the pressure gradients were scarcely detected because of the low pressure in each patient

aortic (LV-Ao) systolic gradient of 82 mmHg, and an aortic valve area of 0.51 cm^2 with mild aortic regurgitation (AR), LV end-diastolic diameter (LVDd) of 45 mm, and LV ejection fraction (LVEF) of 70%.

After the induction of general anesthesia, endotracheal intubation was performed, followed by differential lung ventilation using a 7-Fr bronchial blocker. A left anterolateral thoracotomy was performed with the patient in the right lateral decubitus position, and then arterial and venous cannulae were inserted from the right external iliac artery and vein for partial extracorporeal circulation (ECC). After the descending aorta was totally clamped, an artificial vascular graft (Gelseal, 24 mm; Sulzer Vascutek, Glasgow, UK) was anastomosed to the descending aorta, and the clamping was released. Next, the heart was forced into ventricular fibrillation using an appropriate device, and a 7-cm graft was sutured (Gelseal, 24 mm; no apical connector), where the apical myocardium had been resected. A defibrillator was then used to restore spontaneous heartbeat (duration of ventricular fibrillation, 80 min; lowest body temperature, 32°C). Subsequently, another composite graft (Gelseal, 24 mm + Carpentier Edwords Pericard valve, 19 mm; Edwards Lifesciences LLC, Irvine, CA, USA) was sutured between the two sutured grafts to construct the AAB (Fig. 1). After air in the graft was completely eliminated, the graft was released, and the patient was weaned from the ECC under continuous infusion of milrinone to complete the surgery. Postoperative chest computed tomography (CT) demonstrated favorable contrast enhancement of the AAC without any compression or stenosis (Fig. 2).

Case 2

A 60-year-old man with diabetic nephropathy who was on dialysis had undergone quadruple-vessel CABG 4 years previously for angina pectoris. At subsequent follow-up examinations, the patient was observed to have gradual progression of AS with onset of anginal pain and episodic syncope, and he was scheduled to undergo surgery. AAB was selected for the procedure, as this was a repeat surgery and a porcelain aorta was present (Table 1). Preoperative coronary angiography (CAG) demonstrated patency of all grafts. TTE showed severe AS with an LV-Ao systolic gradient of 66 mmHg and an aortic valve area of 0.6 cm^2 with moderate AR. Moderate mitral regurgitation (MR) was also present. The LVDd was 58 mm, and LVEF was 25%, with diffuse severe hypokinesis of LV wall motion.

The procedures for ECC and surgery were similar to those used in case 1. There was significant backflow into the left ventricle due to AR, despite the use of a suction tube inserted through the site of myocardial resection in an attempt to remove blood from the left ventricle. Therefore, a lower body temperature and reduced flow of blood returning to the patient were employed (duration of ventricular fibrillation, 65 min; lowest body temperature, 28°C) to maintain sufficient exposure of the operative field. After spontaneous heartbeat was restored, transesophageal echocardiography (TEE) confirmed favorable intragraft blood flow. However, the patient required norepinephrine, epinephrine, and milrinone for circulatory support to maintain adequate hemodynamics. Postoperatively, the patient was weaned from continuous catecholamine infusion; he was extubated the following day, and then transferred out of the intensive care unit (ICU).

Case 3

A 79-year-old woman with a history of hypertension and hyperlipidemia who was on oral medication and had no surgical history came to us with a 2-month history of chest pain at rest and was diagnosed with severe AS after detailed examinations. Chest CT indicated a porcelain aorta (Table 1); thus, AAB was selected as the surgical procedure. Preoperative TTE

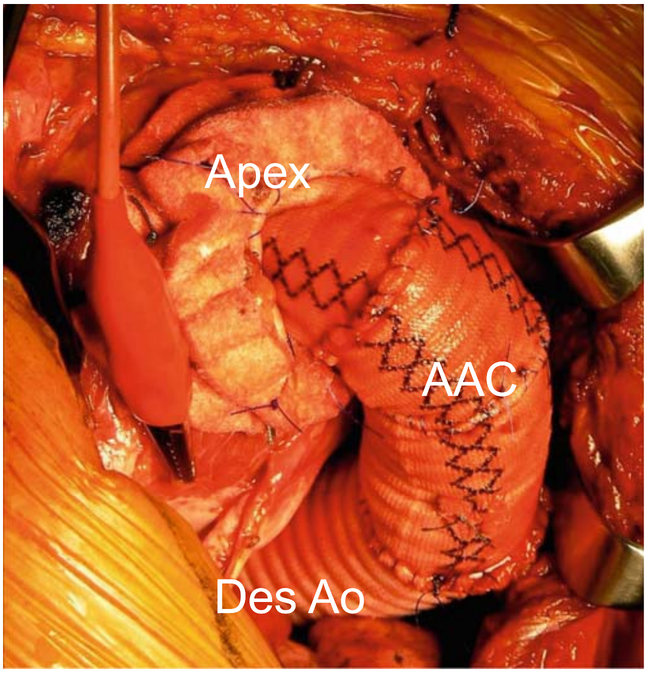
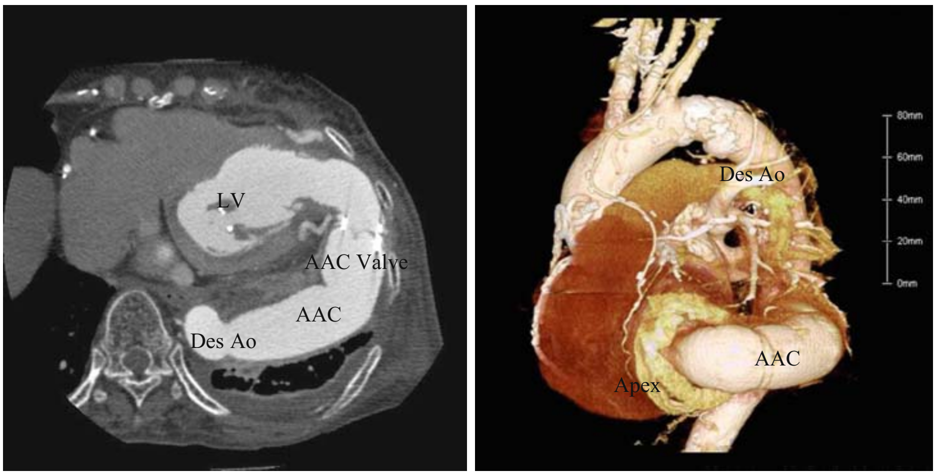


Fig. 1. Operative view of apicoaortic bypass in case 1. *Apex*, apex of heart; *AAC*, apicoaortic conduit; *Des Ao*, descending aorta

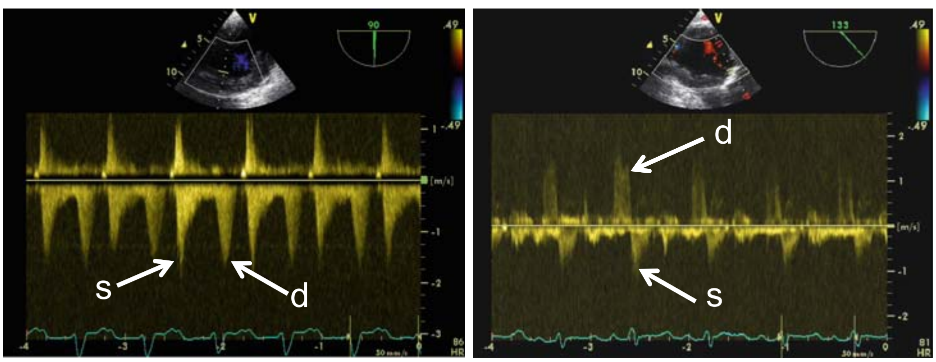
A



B

Fig. 2A,B. Postoperative computed tomography (CT) images from case 1 showing no compression or stenosis in the AAC. **A** Enhanced CT. **B** Three-dimensional (3D)-CT. *LV*, Left ventricle; *AAC*, apicoaortic conduit; *Apex*, apex of heart; *Des Ao*, descending aorta

A



B

Fig. 3A,B. Intraoperative transthoracic echocardiography (TEE) after bypass in case 2 (transgastric left-ventricular long-axis view). **A** Continuous-wave Doppler across apical outflow showing conduit flow during systole (←*s*) and mitral flow during diastole (←*d*). **B** Continuous-wave Doppler across native aortic valve showing native flow during systole (←*s*) and aortic regurgitation during diastole (←*d*). Ratio of blood flow in the AAC to that in the native aortic valve = SV_{AAB} (=$CSA_{AAB} \times VTI_{AAB}$): SV_{AV} (= $CSA_{AV} \times VTI_{AV}$) = 4.5×22: 0.6×24 = 7: 1, where *SV*, is the stroke volume; *CSA* is the cross-sectional area, and *VTI* is the velocity-time integral showed an LV-Ao systolic gradient of 164 mmHg and aortic valve area of 0.41 cm^2, with severe AS and mild AR. Preoperative CAG demonstrated no significant coronary stenosis and no abnormality in LV wall motion.

The procedures used for ECC and surgery were similar to those used in case 1 (duration of ventricular fibrillation, 88 min; lowest body temperature, 32°C). After being weaned from ECC, the patient required norepinephrine and milrinone for circulatory support to maintain adequate hemodynamics. Postoperatively, the patient was weaned from continuous infusion of catecholamine; she was extubated the following day, and then transferred out of the ICU.

Discussion

AAB, or apicoaortic conduit (AAC) insertion, was first reported in 1975 by Cooley and colleagues [4] as a radical surgical method for patients with LV outflow stenosis. The procedure was later conducted for congenital aortic stenosis (AS), though recently it has been used as an alternative procedure for AS in patients with severe calcification of the ascending aorta or in post-CABG patients [1–3].

TEE was performed intraoperatively in the three patients in the present study for the evaluation of cardiac function (systolic and diastolic functions), valvular disease, any patent foramen ovale, and atherosclerosis and calcification of the thoracic aorta with a sewn graft, as well as for adjustment of the location of the venous cannula in the right atrium for extracorporeal circulation (ECC) and the evaluation of AAB. All of our patients had severe AS with multiple complications, including ischemic heart disease; thus, hemodynamic management from anesthesia induction to the start of ECC was targeted to maintain a heart rate of 60 bpm and mean arterial pressure of approximately 60–70 mmHg.

In this procedure, once the AAC is inserted, blood from the left ventricle is ejected via two routes, the narrowed native aortic valve and the AAC. Thus, it is necessary to elucidate changes in blood flow after withdrawal of the ECC [5,6]. Contrary to the anticipated complex hemodynamics after AAC insertion, intraoperative TEE Doppler analysis in the present patients indicated that blood flow up to the ascending aorta was ejected through the native aortic valve even after AAC insertion. The amount of blood flowing through the native aortic valve is thought to depend on peripheral vascular resistance, the degree of stenosis of the native aortic valve, the valvular area of the artificial valve in the conduit, and the degree of mitral regurgitation. The ratio of blood flow in the AAB to that in the native aortic valve can be calculated as the stroke volume (SV) through the AAB [SV_{AAB} = cross-sectional area (CSA_{AAB}) × velocity-time integral (VTI_{AA})] divided by SV through the native aortic valve [SV_{AV} = cross-sectional area (CSA_{AV}) × velocity-time integral (VTI_{AV})] (Fig. 3). However, many cases are difficult to evaluate sufficiently with TEE performed in a lateral position, and a satisfactory blood-flow ratio was not detected in our cases 1 and 3. It is not known how much blood flow through the conduit regurgitated to the descending aorta; however, postoperative angiography demonstrated perfusion in the ascending aorta and aortic arch from both routes, rather than just one. Moreover, determination of the existence of apical stenosis can be done by specifying the pressure gradient, thus enabling the detection of complications associated with AAC obstruction or AAC valve dysfunction.

In the present patients, anastomoses of the cardiac apex and conduit were conducted under ventricular fibrillation without the infusion of a cardioplegic solution. Although the procedure was performed under induced hypothermia, the patients were deemed likely to suffer increased myocardial damage; thus, an appropriate selection of cardiotonic drugs was required at the withdrawal of the ECC. Each patient had severely impaired diastolic function (diastolic mitral annular velocity: $e' < 5$; diastolic mitral inflow velocity / annular velocity: $E/e' > 15$); thus, ECC was withdrawn under hemodynamic management with the use of milrinone in addition to noradrenaline.

The present case 2 had moderate AR in addition to low cardiac performance and high pulmonary arterial pressure preoperatively, and TEE after construction of the AAB confirmed severe AR. This patient also had underlying moderate MR; thus, a reduction in the severity of MR after construction of the AAB was theoretically expected [7]. However, because of the remaining AR, the severity of the MR seemed unlikely to be alleviated, due to limited remodeling of the LV. A previous report noted that AAB was contraindicated in patients with moderate or severe AR [7]. In the present case 2 with moderate AR, AAB was selected, as we expected that other procedures would be difficult to perform. With this patient, we had some trouble with the operative field and withdrawal of the EEC. Nevertheless, improvement of performance status was satisfactory. We consider that AAB is not contraindicated for patients with moderate AR whose main pathogenesis is AS.

A conventional conduit will be crushed in ventricle systole; thus, in many countries, a rigid connector is generally used for the insertion of the conduit. In the patients in the present study, AAB was performed without the use of a rigid apical connector [8, 9]. The presence or absence of a lesion indicating apical LV

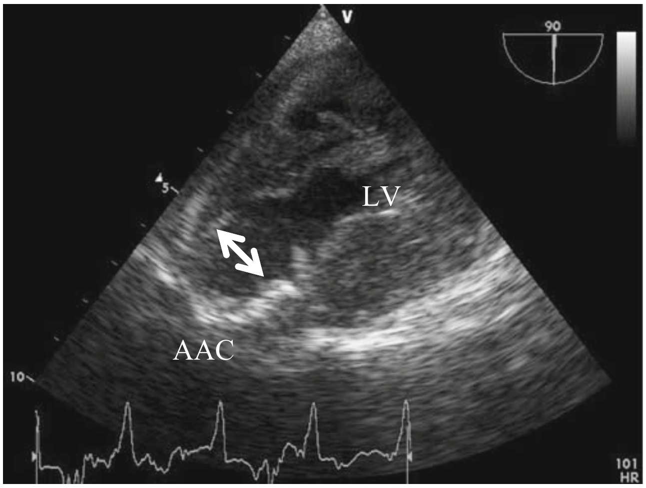


Fig. 4. Intraoperative TEE after bypass in case 2. Two-dimensional transgastric left-ventricular long-axis view at 90° showing no apical stenosis. *AAC*, apicoaortic conduit; *LV*, left ventricle

outflow tract restriction in systole was evaluated by two-dimensional studies (Fig. 4). The performance of AAB with a rigid apical connector is simple, enabling the anastomosis to be conducted without ECC at room temperature [10]. However, because of the limited availability of rigid apical connectors in Japan, ECC was used in all of the present patients, and apical anastomosis was conducted under moderate hypothermia and ventricular fibrillation, with satisfactory results attained.

Specific complications can be encountered with AAB, such as coronary ischemia and cerebral emboli due to retrograde perfusion; AAC obstruction; AAC valve dysfunction; infective endocarditis; thrombosis in the AAC; and arrhythmia, in which LV resection is causative [6, 11]. The postoperative course was favorable in all three patients in the present study (Table 1) without any complications. Although additional studies are required for the evaluation of the long-term prognosis of patients who undergo AAB [2,8,12], the procedure may be conducted as an alternative to aortic valve replacement, which is difficult to perform in an increasing number of patients.

Patients undergoing AAB often have extremely poor cardiac reserve preoperatively because of the indication for the procedure, or because of other illness; thus, careful hemodynamic management under general anesthesia is required. Intraoperative TEE was useful for anesthetic management in the patients in the present study, in whom AAB was completed successfully without intraoperative or immediate postoperative complications.

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