A Stepwise Aortic Clamp Procedure to Treat Porcelain Aorta Associated with Aortic Valve Stenosis and Hemodialysis

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A 62-year-old man was referred for an aortic-valve surgery because of severe aortic stenosis. Thirty years ago, he had undergone a mitral valve commissurotomy and after 9 years, the valve had been replaced by a mechanical valve. He had been undergoing hemodialysis for the past 8 years. A computed tomographic (CT) scan of the chest and abdomen showed a dense circumferential calcification in the wall of the entire thoracic and abdominal aorta, pulmonary artery, and left and right atrium. A conventional aortic-valve replacement was performed. To avoid an embolic event, a “stepwise aortic clamp” procedure was attempted and involved the following: (1) brief circulatory arrest and aortotomy during moderate hypothermia; (2) balloon occlusion at the ascending aorta during low-flow cardiopulmonary bypass (CPB); (3) endoarterectomy by using an ultrasonic surgical aspirator to enable aortic cross-clamping; and (4) a cross-clamp reinforced with felt and full-flow CPB. The patient recovered without any thromboembolic events. Using this procedure to treat a porcelain aorta seemed to reduce the time limit and reduced the risk of brain injury during cardiac surgery.

Keywords: aortic stenosis, balloon occlusion, endoarterectomy, hemodialysis, porcelain aorta

Introduction

Aortic valve surgery of a patient with a porcelain aorta can be problematic because of the increased risk of perioperative atheroembolism. The current strategies for aortic valve surgery of patients with a porcelain aorta are deep hypothermic circulatory arrest, graft replacement, balloon occlusion, endoarterectomy, apico-aortic valved conduit, and transcatheter aortic valve implantation. Since each modality has its unique problems and limitations, the porcelain aorta is a challenge for the cardiac surgeon. The case of the replacement of an aortic valve in a patient with a porcelain aorta is presented here. He was successfully treated with a stepwise aortic clamp procedure that combined circulatory arrest, endoarterectomy, balloon occlusion, and sequential normal cardiopulmonary bypass (CPB) perfusion under a cross-clamp.

Case Report

A 62-year-old man had undergone mitral valve commissurotomy 30 years back. 9 years ago, the valve had been replaced by a 27-mm mechanical valve (St. Jude Medical, Inc., St. Paul, Minnesota, USA). He was admitted to our hospital because of orthopnea. He had been undergoing hemodialysis for 8 years, diagnosed as having...
Fig. 1  Computed tomographic (CT) scans of the patient’s chest and abdomen. (A) The ascending aorta, pulmonary artery, and descending aorta show dense circumferential calcification. The frontal section view shows that (B) the entire ascending aorta wall is calcified; (C) the pulmonary artery and atrium are calcified; and (D) the abdominal aorta is heavily calcified.

Fig. 2  Schematic of the stepwise cross-clamp procedure. (A) During 8 minutes of circulatory arrest, an aortotomy is performed and a Foley catheter is inserted and inflated. (B) During 16 minutes of low-flow perfusion, endoarterectomy at the aortic clamp site is performed by using an ultrasonic surgical aspirator. (C) The ascending aorta is cross-clamped by using a Fogarty atraumatic clamp. Conventional cardiopulmonary bypass (CPB) is then restarted. The aortic wall is sandwiched by Teflon felt to minimize damage and to secure clamping. Before closing the aortotomy site, the edge is decalcified by using an ultrasonic surgical aspirator. (D) The aortotomy site is closed by using a set of Teflon felt strips on the outside of the aortic wall.
aortic regurgitation. The aortic valve area was 0.5 cm² (calculated by the pressure half time) and the peak/mean pressure gradient was 65 mmHg/35 mmHg. The surgical annular diameter of the aortic valve was 18 mm. The estimated pulmonary artery systolic pressure was 81 mmHg. Chest radiography revealed calcification along the ascending aorta; the cardio-thoracic-ratio was 66%. A computed tomographic (CT) scan of the chest and abdomen showed dense circumferential calcification in the wall of the entire thoracic and abdominal aorta, the pulmonary artery, and the left and right atrium (Fig. 1A–1D). A CT scan obtained 9 years ago had not shown any significant calcification. The transcatheter aortic valve implantation (TAVI) was not available then in Japan since it had been undergoing clinical trials. It was judged that the severity of the patient’s condition did not allow time to wait for TAVI approval. Conventional aortic valve replacement surgery was therefore planned.

Operation

The Epiaortic echography revealed a narrow window of calcification at the ascending aorta and this area was used for the aortotomy. An appropriate inflow site or cross-clamp site was not present at the ascending aorta and arch. The right subclavian artery was heavily calcified and hence the right axillary artery and right femoral artery, both of which had some calcification, were used as the inflow site. Since the axillary and femoral artery both had a risk of embolic event, these arteries were used simultaneously to reduce the speed of blood flow.

A two-stage venous cannula, left ventricular vent, and retrograde cardioplegic line were inserted. When the patient was cooled down to 27°C, the extracorporeal circulation was arrested for 8 minutes, and an aortotomy was performed. A Foley catheter (24 Fr) was inserted through the aortotomy and inflated as an endo-clamp balloon. The low-flow perfusion (0.8 L/min) was initiated and did not dislodge the catheter. Simultaneous perfusion from the right axillary artery and the right femoral artery decreased the risk of neck vessel malperfusion in the event of Foley catheter dislodgement and innominate artery occlusion (Fig. 2A). During 16 minutes of low perfusion, endoarterectomy and decalcification were performed by using an ultrasonic surgical aspirator (SonoSurg, Olympus Medical Systems Corp., Tokyo, Japan) to enable aortic cross-clamping (Fig. 2B). The ascending aorta was softened sufficiently for clamping. The strength of the wall seemed to be preserved well. After performing the endoarterectomy, the ascending aorta was cross-clamped by using a Fogarty atraumatic clamp and Teflon felt, which sandwiched the aortic wall on the outside (Fig. 2C). Total perfusion was restarted (3 L/min) and the aortic valve was replaced by a 19-mm Regent prosthetic valve (St. Jude Medical, Inc., USA). After the edge of aortotomy was decalcified (Fig. 2C), aortotomy was closed with Teflon felt reinforcement (Fig. 2D). Thromboembolic events were not noted postoperatively.

Discussion

Approximately 2% of the patients requiring cardiac surgery will have extreme calcification of the ascending aorta and aortic arch, a phenomenon called a “porcelain aorta”. An off-pump coronary artery bypass, proximal graft connectors, and alternative sites for proximal graft inflow have somewhat solved the problem of a porcelain aorta in patients undergoing isolated coronary surgery. However, aortic valve surgery of a patient with a porcelain aorta can be problematic because of the increased risk of perioperative atheroembolism.

A deep hypothermic circulatory arrest seems to provide a safe procedure during the surgical time limit in which an arrest greater than 40 minutes may increase the risk of brain damage. Aortic valve replacement, endoarterectomy, and ascending aortic replacement with a graft can be performed within the time limit. A selective cerebral perfusion under deep hypothermia may provide more time than that provided by a simple circulatory arrest.

An endoarterectomy makes suturing possible at the sites of the cross-clamp, graft anastomosis, or aortotomy closure. However, potential aneurysmal degeneration of the endoarterectomized aortic wall needs to be monitored. An ultrasonic surgical aspirator is useful for decalcifying and softening an anastomotic site during surgery in a calcified valve.
Cosgrove\(^1\) and other researchers\(^3,6\) report that inflating the occluding balloon at the distal ascending aorta after circulatory arrest, reinstating circulation, and replacing the aortic valve during rewarming are useful in shortening the circulatory arrest time. A risk of the procedure is dislodgement of the balloon, which may necessitate reduced pressure and cause low-flow perfusion and neck vessel malperfusion.

Ascending aorta replacement during deep hypothermic circulatory arrest is also a strategy for establishing conventional cross-clamping and full-flow perfusion. The operative mortality ranges from 6.8% to 10%\(^5\) and this procedure may increase the surgical invasiveness for patients.

The apico-aortic valved conduit is a solution for treating a porcelain aorta.\(^8\) It may be suitable for patients who have undergone multiple median sternotomies and have a patent bypass graft. However, patients with aortic valve regurgitation are not good candidates.

Transcatheter aortic valve implantation TAVI has been established as a safe and effective alternative for treating severe symptomatic aortic stenosis in high-risk patients.\(^9,15\) The incidence of porcelain aorta can be as high as 18% in patients with aortic stenosis who are treated by TAVI.\(^6\) Few data have been published on the course of patients with a porcelain aorta who were treated by TAVI, but the limited available information appears to be favorable.\(^7\) Our concern with using TAVI for our patient was the durability of the valve since our patient was young and the expected 5-year survival is 59% (based on a 2010 report from the Japanese Society for Dialysis Therapy).\(^8\)

The mechanism of calcification in atherosclerosis seems to differ from the mechanism of calcification that occurs in patients undergoing hemodialysis. The calcification in atherosclerosis is primarily caused by a plaque formation at the intimal layer. The endarterectomy and decalcification seem to remove a certain amount of inner thickness from the aortic wall in patients with atherosclerosis. On the other hand, chronic renal failure causes vitamin D activation failure, and a low calcium level consequently results in secondary hyperparathyroidism and a high blood calcium level.\(^9\) High calcium and phosphate levels cause the sedimentation of phosphate calcium in the arterial wall. For this patient, the ultrasonic surgical aspirator was quite effective for decalcifying the aorta. After the decalcification, weakness of the aortic wall did not occur. We believe sediment calcification resulting from hemodialysis occurs at the inner surface of the aorta and is easily removed by an ultrasonic surgical aspirator. In Japan, the number of patients undergoing chronic hemodialysis has been constantly increasing during the past 20 years.\(^18\) In 2008, there were 283,000 patients. Cardiac surgery on patients with a porcelain aorta will increase due to an increase in the number of hemodialysis patients. A strategy needs to be developed to prepare for this eventuality.

**Conclusion**

To avoid embolic events and reduce the risk of brain ischemia, a stepwise aortic clamp procedure was attempted as the third cardiac surgery for a patient who had aortic valve stenosis, who was on hemodialysis due to chronic renal failure, and with a porcelain aorta.

**Disclosure Statement**

Susumu Isoda and other authors have no conflict of interest.

**References**