



Use Side Branch of the Aortic Graft to Facilitate Coronary Reconstruction During Complex Aortic Surgery

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The interposition graft could be used for difficult coronary reconstruction during aortic root replacement. We introduced a new technique that utilizes side branch of an aortic graft to facilitate coronary reconstruction. The present study describes this technique and its outcomes. We retrospectively reviewed 234 patient charts of those who underwent aortic root replacement between January 2013 and November 2017. Within this group, 6 patients required coronary reconstruction with branches of aortic graft and were included in this study. All patients were reoperative cases, 3 of which were for acute type A aortic dissection. The mean cardiopulmonary and aortic cross clamp times were 317.2 ± 35.1 minutes and 153.3 ± 75.4 minutes, respectively. All patients survived to discharge with a median hospital stay of 20.5 days (interquartile range: 13.75–27.75). During a median follow-up of 221 days (interquartile range: 197.78–1208), no patients experienced major adverse cardiovascular events. Four patients underwent radiographic follow-up, which confirmed patent interposition grafts (5/5). The use of branches from the aortic graft for coronary reconstruction is feasible with satisfactory outcomes.

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INTRODUCTION

Coronary reconstruction during complex aortic surgery including aortic root replacement (ARR) can be challenging due to a number of intraoperative factors such as extensive adhesions from previous surgery, space-occupying large (pseudo)aneurysm in the root, and the presence of destructive infection. These complications frequently require prolonged cardiopulmonary bypass and

Abbreviations: ARR, aortic root replacement; CABG, coronary artery bypass grafting; ECMO, extracorporeal membrane oxygenation; CTA, computed tomography angiography; MRA, magnetic resonance angiography

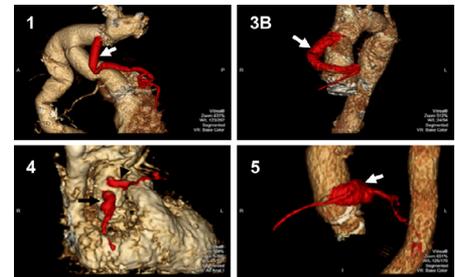
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Side branch of aortic graft facilitates coronary reconstruction with satisfactory outcomes.

Central Message

We developed a novel coronary artery reconstruction technique using the side branch of an aortic graft in complex aortic surgeries. Satisfactory clinical outcomes with patent branches were shown.

Perspective Statement

While direct coronary reimplantation with the button technique can be done in most aortic root operations, the Cabrol interposition graft technique is still needed in extreme circumstances. We modified the interposition graft by using the side branch of an aortic graft in difficult coronary reconstruction with excellent outcomes. Longer term clinical and radiographic follow-ups are needed.

operation time.^{1,2} When a coronary reimplantation directly to the aortic graft is not feasible, an interposition graft between the aortic graft and coronary ostia can be considered as an alternative (the Cabrol technique).³ Likewise, this could also be applied in proximal anastomoses of the existing coronary artery bypass conduits which can be technically challenging due to the limited mobilization.

For these complicated cases, we have developed a modified technique using side branch of an aortic graft for coronary reconstruction. This technique facilitates the proximal anastomosis of the interposition graft without compromising the procedure. In this study, we examine the outcomes of patients who underwent this procedure.

MATERIALS AND METHODS

The institutional review board of Columbia University approved this retrospective study. From January 2013 to November 2017, 234 patients who underwent ARR at Columbia University Medical Center were analyzed, including 53 reoperative ARR operations. Of these patients, 6 (2.6%) required this modified technique and were enrolled in our study.

Surgical Technique

The key to this technique is the use of branch(es) of the main aortic graft to restore the coronary perfusion when direct reimplantation is risky.

The ascending aorta is reconstructed using a graft with 1 or more branches when the use of this technique is anticipated. Otherwise, an existing side branch of the main graft can be utilized after converting the arterial perfusion line from the side branch to an alternative access. When the direct anastomosis between a coronary ostium and the root graft is not feasible, the coronary ostium is first anastomosed to another interposed graft of 6 or 8 mm, which is subsequently anastomosed to the side branch. These branches are anastomosed to the interposition grafts to the native coronary ostia and/or proximal ends of the previous coronary bypass conduits often after the aortic cross clamp is removed. This allows tension-free anastomoses of the coronary ostia under an unobstructed view in complicated cases and facilitates hemostasis of the anastomotic sites when compared to the conventional anastomoses between the coronary ostia and root graft. This technique ameliorates the known technical difficulties such as the identification of appropriate sites for coronary reimplantation during cross clamp when the main graft is decompressed, or the difficulty to obtain a blood-clear view of proximal anastomoses with a side biting clamp after the aortic cross clamp is removed.

Patient Follow-Up

All patients were followed to February 2018 either in our clinics or by phone communication. Four of them had radiographic follow-up.

RESULTS

Six patients requiring this modified technique for coronary reconstruction were identified (Table 1). All patients had 1 or more prior cardiac operations, including 3 prior coronary artery bypass graftings (CABGs) with patent bypass conduits. Stanford type A aortic dissection was a leading cause in 3 patients. The status of the operation was emergent in 2 patients and urgent in 2. Axillary artery and femoral vein cannulation was the most frequent combination to initiate cardiopulmonary bypass. Two patients required left ventricle apical venting through a small anterolateral left thoracotomy. Antegrade cerebral perfusion with deep hypothermia was required in 4 patients. The mean cardiopulmonary and aortic cross clamp times were 317.2 ± 35.1 minutes and 153.3 ± 75.4 minutes, respectively. Extracorporeal membrane oxygenation (ECMO) was needed in 2 patients postoperatively and was weaned successfully.

Table 1. Demographic Data of 6 Patients Using Side Branch(es) of the Aortic Graft to Facilitate the Coronary Reconstruction

Patient	Age	Gender	Prior Cardiac Procedure	Surgical Indication	Operation Priority	Indication for Interposition Graft Reconstruction	ECMO Support (Days)	ICU Stay (Days)	Hospital Stay (Days)	Follow-Up Time (Days)
1	45	Male	Congenital aortic coarctation s/p aortic repair and extra-anatomical bypass	Type A aortic dissection	Emergent	Fixed left coronary ostium	1	13	29	1533
2	74	Male	CABG	Type A aortic dissection	Emergent	Displaced bypass vein conduits	0	5	12	1541
3	54	Female	Congenital AS s/p aortic valve repair and ARR with Konno procedure, VSD repair and TVR	Ascending aortic pseudoaneurysm and moderate AI	Elective	Displaced right coronary ostium	0	1	6	194
4	54	Male	CABG	Critical AS with CHF	Elective	Displaced bypass vein conduits	0	15	22	209
5	78	Male	CABG	Type A aortic dissection	Urgent	Displaced bypass vein conduits	0	11	30	233
6	52	Male	IE s/p Double valve replacement	Prosthetic valve IE	Urgent	Displaced coronary ostia	1	4	19	191

AI, aortic insufficiency; ARR, aortic root replacement; AS, aortic stenosis; CABG, coronary artery bypass grafting; CHF, congestive heart failure; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; IE, infective endocarditis; s/p, status post; TVR, tricuspid valve replacement; VSD, ventricular septal defect.

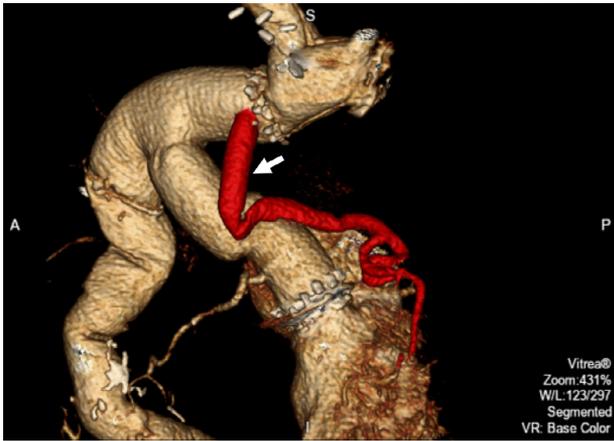


Figure 1. 3D reconstructed computed tomography angiography of patient 1 demonstrates patent interposition graft to left main coronary artery (white arrow).

All patients survived to discharge in a median hospital stay of 20.5 days (interquartile range [IQR]: 13.75–27.75) and are doing well at home as of February 2018 with a median follow-up of 221 days (IQR: 197.78–1208). Four patients had radiographic follow-up using computed tomography angiography (CTA) or magnetic resonance angiography (MRA) at a median of 143 days after surgery (IQR: 54–378.5 days). These patients comprised 5 interposed grafts, all branches were found to be patent (Figs. 1, 3B, 4, and 5). The specific information of these patients is listed:

Patient 1

A 45-year-old man with 2 previous aortic procedures for coarctation of the aorta including coarctation repair through a left thoracotomy, followed by extra-anatomical bypass through the posterior pericardial space from the ascending to suprascapular aorta with division of the proximal descending aorta, presented with an acute type A aortic dissection with severe aortic insufficiency. During a re-sternotomy, the extra-anatomical graft was injured requiring deep hypothermic cardiac arrest at 20°C. He underwent an emergent hemiarch replacement using a 1-branched 26 mm aortic graft (Gelweave Ante-flo, Vascutek, United Kingdom) and the previous extra-anatomical bypass graft was anastomosed end-to-end to this graft. The aortic root was replaced using a composite valved-conduit with a 23 mm mechanical valve. The left coronary ostium was embedded within the scar tissue precluding safe mobilization, and thus it was anastomosed to a 6 mm graft (Gelweave straight, Vascutek, United Kingdom) which was brought cephalad to anastomose the 8 mm side branch of the 26 mm aortic graft after the aortic cross clamp was removed.⁴ Cardiopulmonary and aortic cross clamp times were 364 and 127 minutes, respectively. While 2 days of ECMO support was required, he was discharged to a rehabilitation facility on postoperative day 28. Follow-up CTA found a patent-branched graft to left coronary artery (Fig. 1).

Patient 2

A 74-year-old male with previous history of CABG developed an acute type A aortic dissection. He underwent an emergent hemiarch replacement using a 1-branched 30 mm aortic graft (Gelweave Ante-flo, Vascutek, United Kingdom). The prior bypass conduits were densely adherent to the right atrium, aorta, and pulmonary artery that made the mobilization impossible. We used the side branch of the 30 mm aortic graft to reconstruct the bypass conduit to obtuse marginal artery in end-to-side fashion and bypass conduit to posterior descending artery in end-to-end fashion (Fig. 2). For this purpose, the systemic arterial perfusion line was switched from the side branch back to the right axillary arterial line, which was used for initial bypass and antegrade cerebral perfusion. Cardiopulmonary and aortic cross clamp times were 272 and 57 minutes, respectively. The patient was discharged home on postoperative day 8. Follow-up cardiac echo in 2 years found stable left ventricular function and patient was doing well at home by phone communication.

Patient 3

A 54-year-old female with an extensive cardiac surgical history presented with an enlarging 7 cm pseudoaneurysm of the aortic root as well as moderate aortic insufficiency. She had congenital aortic stenosis underwent cardiac surgery in childhood, followed by an ARR with Konno root enlargement for aortic stenosis 8 years ago. After 2 years, the patch from the Konno procedure dehiscid requiring ventricular septal defect repair and tricuspid valve replacement. Five years later (3 years before the index operation), she underwent a transcatheter valve-in-valve tricuspid replacement for bioprosthetic tricuspid stenosis. During this operation, the pseudoaneurysm was found to be originating from the prior distal anastomosis. The distal ascending aorta was reconstructed using a 1-branched 26 mm aortic graft (Gelweave Ante-flo, Vascutek, United Kingdom). After reoperative ARR

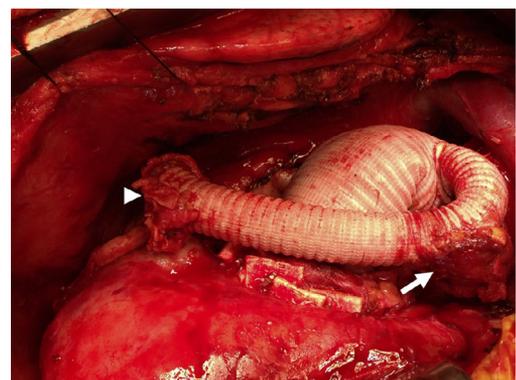


Figure 2. Intraoperative image of patient 2 demonstrates the use of side branch of the aortic graft to perfuse bypass conduit obtuse marginal artery in side-to-end fashion (white arrow) and bypass conduit to posterior descending artery in end-to-end fashion (white arrowhead).

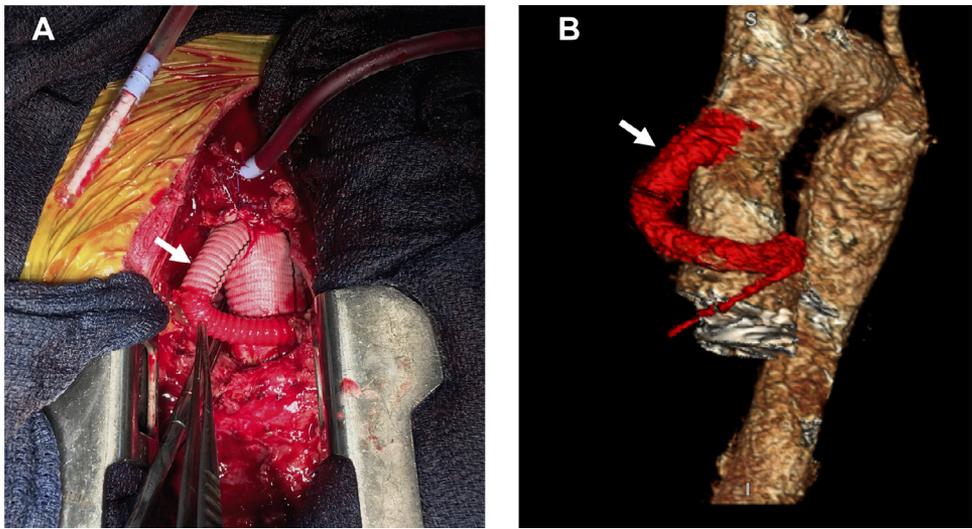


Figure 3. Intraoperative image of patient 3 demonstrates the use of side branch from the aortic graft to perfuse right coronary artery (A, white arrow); 3D reconstructed computed tomography angiography of patient 3 demonstrates patent interposition graft to right coronary artery (B, white arrow).

using a composite valved-conduit, the right coronary ostium did not reach the valved-conduit and therefore was anastomosed to the side branch of 26 mm aortic graft (Fig. 3A). Cardiopulmonary and aortic cross clamp times were 287 and 158 minutes, respectively. The patient was discharged home on postoperative day 5. Follow-up CTA showed the patent-branched graft to the right coronary artery (Fig. 3B).

Patient 4

A 54-year-old man with a history of mediastinal radiation and previous CABG presented with symptomatic severe aortic stenosis. The ascending aorta and root were significantly calcified. The aortic annulus and left ventricular outflow tract were found stenotic and did not allow a sizer for 20 mm mechanical valve even after a Manouguian root enlargement. The root was replaced with a composite valved-conduit with an 18 mm mechanical valve using coronary reimplantation. The distal aorta was anastomosed to another 26 mm 1-branched aortic graft (Gelweave Ante-flo, Vascutek, United Kingdom). Prior to the root and ascending replacement, the proximal ends of the prior bypass conduits to left anterior descending artery, obtuse marginal artery, and right coronary artery were anastomosed to an 8 mm graft (Gelweave Straight, Vascutek, United Kingdom) for delivery of cardioplegic solution, which was anastomosed to the side branch of the 26 mm aortic graft. Cardiopulmonary and aortic cross clamp times were 348 and 287 minutes, respectively. The patient was discharged to rehabilitation facility on postoperative day 22. Patient was regularly followed in cardiology clinic for permanent pacemaker, which was introduced months after index surgery.

Patient 5

A 78-year-old man had a prior CABG in 2008 and an endovascular aortic stent-graft repair for an abdominal aortic

aneurysm, complicated with stent-graft thrombosis requiring right axillo-femoro-femoral bypass, was transferred with a symptomatic large ascending aortic aneurysm with a chronic type A aortic dissection, severe aortic insufficiency, and mitral regurgitation. He underwent an urgent hemiarch replacement using a 4-branched aortic graft (Gelweave Plexus, Vascutek, United Kingdom) in anticipation of existing bypass conduits reconstruction, mitral valve replacement using a 27 mm mechanical valve, and ARR using a composite valved-conduit with native coronary reimplantation. After the aortic cross clamp was removed, the proximal ends of the previous 2 bypassed conduits to posterior descending and obtuse marginal arteries were sewn to the side branches of the aortic graft, respectively. Cardiopulmonary and aortic cross clamp times

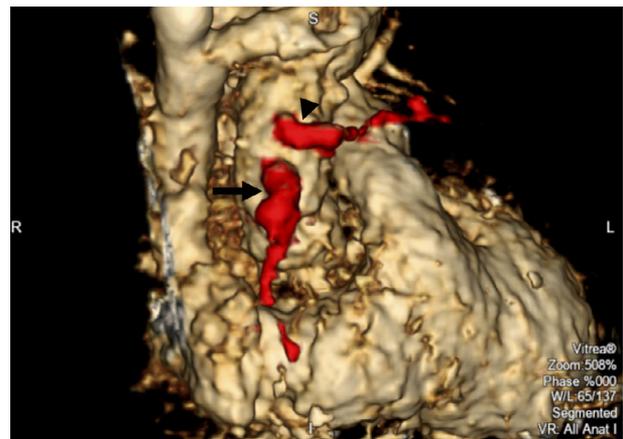


Figure 4. 3D reconstructed magnetic resonance angiography of patient 5 demonstrate patent interposition graft to bypass conduit of obtuse marginal artery (black arrowhead) and patent interposition graft to bypass conduit of posterior descending artery (black arrow).



Figure 5. 3D reconstructed computed tomography angiography of patient 6 demonstrates patent interposition graft to the large button of right and left coronary ostia (white arrow).

were 322 and 170 minutes, respectively. The patient was discharged on postoperative day 30. Follow-up MRA showed patent grafts although the image quality was suboptimal (Fig. 4).

Patient 6

A 52-year-old man with a history of aortic and mitral valve replacement for endocarditis presented with prosthetic valve endocarditis with a large root abscess. He underwent an urgent ARR using a composite valved-conduit and mitral valve replacement with reconstruction of the aortomitral fibrosa (Commando procedure). Because the coronary ostia were abnormally located close to each other, 1 large coronary button was created and sewn to an 8 mm graft (Gelweave Straight, Vascutek, United Kingdom). This 8 mm graft was then anastomosed to the side branch of a 28 mm aortic graft (Gelweave Ante-flo, Vascutek, United Kingdom) that was used for the ascending aorta reconstruction. Cardiopulmonary and aortic cross clamp times were 310 and 121 minutes, respectively. The patient required 2 days of ECMO support and was discharged to a rehabilitation facility on postoperative day 8. Follow-up CTA showed the patent-branched graft to right and left coronary arteries (Fig. 5).

DISCUSSION

The Cabrol technique during ARR was first described by Cabrol et al in 1981 as an approach to coronary reimplantation using a Dacron interposition graft to the aortic valved-conduit inside the aneurysmal pouch.³ While the interposed graft was originally described as a mustache in a side-to-side fashion, many modifications including direct implantation using short separate grafts or T-fashion grafts have been reported in order to accommodate challenging anatomy.⁵ However, direct reimplantation of the coronary ostia, the button technique, which is technically straightforward in uncomplicated cases, is considered a standard.^{6,7}

Several cases have reported regarding the interposition graft occlusion especially for grafting to the right coronary ostium, raising concern for long-term patency.^{6–9} Knight et al reported an increased spiraling flow pattern in the graft to the right coronary artery and 14% occlusion of the Cabrol grafts in a series of 7 patients and 12 interposed grafts.¹⁰ Kitamura et al also reported that 2 patients (11%) had right coronary ostium problems in their series.¹¹ On the other hand, Ziganshin et al reported satisfactory mid-term results with radiographic follow-up of a modified Cabrol technique in 40 patients out of their consecutive 348 patients who had undergone ARR.⁹ Garlicki et al reported no interposed graft issue in radiographic follow-up in a series of 25 patients.¹² Although more information is required to appropriately assess long-term patency of the interposed grafts, the Cabrol technique remained an important alternative or bailout when direct reimplantation cannot be safely performed.^{5,12} Reoperation with anatomically fixed coronary ostia, low lying position of coronary ostia (<1.5 cm from annulus), heavily calcified aortic root, and severely displaced coronary arteries from a large dissection or aneurysm are the most common indications. The anatomical and demographic diversity and high-risk nature of such a patient cohort do not allow a fair comparison of the outcomes to a standard ARR with direct coronary reimplantation.^{7,8,12,13}

In our series of 6 patients, no patients developed a clinical myocardial ischemic event during follow-up. In addition, follow-up imaging studies (3 CTA and 1 MRA) were performed, confirming the patency of all 5 branches.

Our technique is unique in that side branch of an aortic graft is used as part of the interposed graft of the Cabrol technique. This technique was introduced during the surgery for patient 1 in which we found reimplantation of the left coronary ostium to the main graft was difficult due to an impaired surgical view within the limited space from extremely dense scar and the prosthetic aortic valve.⁴ Sufficient mobilization was not possible. We then decided to interpose the left coronary ostium with a 6 mm graft. Instead of anastomosing to the root graft, we chose to anastomose it to the side branch of the aortic graft after the aortic clamp was removed. In the subsequent cases, a branched graft was used in anticipation of the use of this technique in 3 cases while it was not anticipated in 2 cases. The interposition graft anastomosed to the coronary ostium was also used to deliver the cardioplegic solution.

Although we found this technique is helpful in dealing with difficult anatomy and facilitating a prolonged procedure while yielding satisfactory clinical outcomes, longer term follow-up is warranted in order to confirm its safety. The small number of patients in our experience also limits the generalization of the described at this point.

CONCLUSIONS

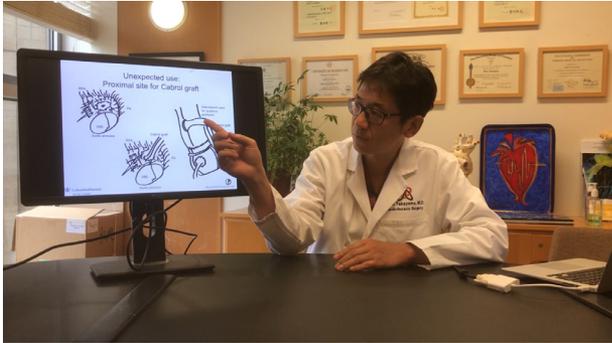
In conclusion, this new technique facilitates reconstruction of coronary arteries during complex ARR. While additional

ADULT — USE SIDE BRANCH OF THE AORTIC GRAFT

cases with longer follow-up are required to confirm the utility of the procedure, the application of this modified technique might provide an option for these difficult cases.

SUPPLEMENTARY MATERIAL

The following is the supplementary data to this article:



Video 1. Use side branch of the aortic graft in coronary reconstruction from unexpected use to expected use.

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