Tohoku J. Exp. Med., 1998, 184, 257-266

Replacement of the Ascending Aorta and Aortic Valve with a Composite Graft: Operative and Long-Term Results

Koichi Tabayashi, Takao Fukujyu, Yusuke Turu, Mituaki Sadahiro, Toshiaki Konnai, Naoki Uchida, Mikio Ohmi and Yoshihito Sekino[1]

Department of Thoracic and Cardiovascular Surgery, Tohoku University School of Medicine, Sendai 980-8574, and [1]Saka Hospital, Shiogama 985-8506.

Tabayashi, K., Fukujyu, T., Turu, Y., Sadahiro, M., Konnai, T., Uchida, N., Ohmi, M. and Sekino, S. *Replacement of the Ascending Aorta and Aortic Valve with a Composite Graft: Operative and Long-Term Results.* Tohoku J. Exp. Med., 1998, **184** (4), 257-266 —— The purpose of this study is to analyze our treatment experience on patients with ascending aortic aneurysms, with aortic regurgitation. From January 1974 to December 1995, 49 patients underwent replacement of the aortic valve and ascending aorta with a composite graft, in which primary operation cases were 44 and reoperation ones were 5. The Bentall technique was used in 20 patients, the button technique in 11, the interposition graft technique in 11, and a combination of the interposition graft and button technique in 7. All but one reoperation cases underwent the interposition graft technique. Hospital mortality was 30% for the Bentall technique, and 9.1% for the button technique and 9.1% for the interposition graft technique; there was no hospital mortality in the combination of the interposition graft and button technique. Hospital mortality of interposition graft technique in primary operation cases was 9.1%, and that in reoperation cases was 0%. Hospital mortality in patients underwent from 1974 to 1985 was 30.8%, 27.8% from 1986 to 1991, and 0% from 1992 to 1995. Five late deaths occurred in the Bentall group (35.7%) and one late death in the button technique (9.1%). No late deaths in the other groups have occurred. In summary, operative mortality in Bentall technique group was higher than that of the other groups. Operative results were improved by the change of operative methods. The interposition graft technique is preferable for patients undergoing reoperation or when tension on the ostial anastomoses may occur. The button technique is best for patients with aortic dissection or inflamation involving the coronary ostia. ———— Bentall technique; interposition graft technique; button technique; combination of the interposition and button technique

Patients with ascending aortic aneurysms combined with aortic regurgitation

Received October 5, 1994; revision accepted for publication March 16, 1998.

Address for reprints: Koichi Tabayashi, Department of Thoracic and Cardiovascular Surgery, Tohoku Unibersity School of Medicine, 1-1 Seiryomachi, Aoba-ku, Sendai 980-8574, Japan.

(AR) are relatively uncommon, and present a challenging surgical problem. Several techniques have been described for repair of this entity (Bentall and DeBono 1968; Symbas et al. 1971; Cabrol et al. 1981; Piehler and Pluth 1982; David and Feindel 1992; Svensson 1992), but outcome after different techniques has not been critically evaluated. The main difference in these operations is the method of coronary artery reattachment to the composite vascular graft. We have utilized five of the methods: Direct reattachment to the graft, as described by Bentall and DeBono (1968), the aortic button technique reported by Symbas et al. (1971) and Zubiate and Kay (1976), reattachment of the coronary arteries with 10 mm Dacron grafts as described by Cabrol et al. (1981), reattachment with a short graft reported by Piehler and Pluth (1982), and a combination of the interposition graft and button technique (Svensson et al. 1992).

In this paper, we present an analysis of our experience in treating patients with ascending aortic aneurysms, associated with AR.

Subjects and Methods

From January 1974 to December 1995, 49 patients underwent composite valve/graft replacement of the aortic valve and ascending aorta. The method of coronary artery reattachment varied. The Bentall technique was used in 20 patients, the button technique in 11, the interposition graft technique (Cabrol technique or Piehler technique) in 11, and a combination of the interposition graft and button technique in 7. The patient mean age was 42.3 ± 13.2 years in patients undergoing the Bentall technique, 45.6 ± 8.8 for the button method, 55.2 ± 13.1 for the interposition graft technique, and 57.3 ± 5.8 for patients undergoing the combination of the interposition graft and button technique. There were no significant age differences among the four groups. Disease etiology, operative procedure and operative results are shown in Table 1. In primary operative cases, 26 patients had annuloaortic ectasia, 12 had aortic dissection, 1 had aortitis, 1 had a ventricular septal defect (VSD) and AR, and 4 had aortic sinus aneurysm. All patients had significant AR. Reoperation cases were 6, and indication were different in all cases (Table 1). One of them received Bentall technique, 4 underwent the interposition graft technique, and 1 received the combination of interposition graft and button technique. The Bentall technique was performed from 1974 to 1991 (Table 2). The button and interposition graft technique were done from 1986 to 1995. The combination of interposition graft and a button technique was performed from 1992 to 1995. Three patients had Marfan syndrom in the Bentall group (15%), 2 in the button group (14%), and 2 in the interposition graft group (18%).

Operative procedures. A median sternotomy approach was used in 47 patients. In the other two, the sternotomy was extended to a left thoracotomy in the fifth intercostal space. After systemic heparinization (3 mg/kg), an arterial

TABLE 1. *Indications for aortic root replacement, operative procedures and early mortality*

	Bentall	Button	Inter. P. Gr.	Inter. P. Gr. & Button	Total
Primary operations					
Annuloaortic ectasia	16 (4)	2 (0)	5 (0)	2 (0)	25 (4)
Dissection					
acute		1 (0)	1 (1)	1 (0)	3 (1)
chronic	2 (0)	6 (1)		1 (0)	9 (1)
Aortitis		1 (0)			1 (0)
VSD+AR	1 (1)				1 (1)
Aortic sinus aneurysm		1 (0)	1 (0)	2 (0)	4 (0)
Reoperations					
Type I dissection after Koster Collins operation for type I dissection			1 (0)		1 (0)
Type II dissection after AVR	1 (1)		1 (0)		2 (1)
Aortic sinus aneurysm after Repl of Asc aorta for type I dissection			1 (0)		1 (0)
Aortic sinus aneurysm after AVR			1 (0)		1 (0)
Aortic disruption after aortic valve resuspension				1 (0)	1 (0)
Total	20 (6)	11 (1)	11 (1)	7 (0)	49 (8)

Number in parentheses are hospital deaths.
Inter. P. Gr., interposition graft; VSD, ventricular septal defect; AR, aortic regurgitation; Repl, replacement; Asc, ascending; AVR, aortic valve replacement.

TABLE 2. *Operative time, procedures and early mortality*

	1974~1985	1986~1991	1992~1995
Bentall	13 (4)	7 (2)	0
Button		4 (1)	7 (0)
Inter. P. Gr.		6 (1)	5 (0)
Inter. P. Gr. & Button			7 (0)
Total	13 (4)	17 (4)	19 (0)

Number in parentheses are hospital deaths.
Inter. P. Gr., interposition graft.

cannula was inserted into the femoral artery and a venous cannula was inserted into the right atrium. Following institution of cardiopulmonary bypass, the pulmonary artery, left atrium or left ventricle was vented. Moderate by deep hypothermia was provided by extracorporeal circulation (ECC). Cardiac protec-

tion was performed by direct coronary perfusion in the first two patients. Since 1975, local cardiac cooling was used for myocardial protection in 6 patients. After that, cardiac protection was performed by antegrade or retrograde perfusion of crystalloid cardioplegic solution and irrigation of the pericardium with ice slush. In 14 patients in whom prolonged aortic cross-clamp (ACC) was expected, cardiac protection was achieved by combined antegrade and retrograde perfusion of cardioplegia (10 patients), or coronary perfusion by pump perfusate (4 patients). We mainly performed the Bentall technique early in the series which has been previously reported (Koizumi et al. 1978) (Table 2). The button technique was mainly used in patients with destruction or weakness of the coronary artery of which origins were due to infection or dissection. A 15- to 20-mm aortic button was reinforced with a circular patch of Teflon, and then sutured to the composite graft with a running suture of 4-0 Nespylene (Nihon Shoji, Osaka). The interposition graft technique was mainly used in patients who had previous operations. Interposition graft technique reported by Cabrol et al. (1981) was performed early in the series. An 8- or 10-mm interposition graft was sutured end to end to the left and right coronary ostia with a running suture of 4-0 Prolene (Johnson & Johnson, Somerville, NJ, USA). After seating the composite valve graft in the aortic annulus, the interposition graft was attached to the composite graft with a side to side anastomosis. The graft was placed to the right of the ascending aortic graft. Recently, interposition technique of a short graft reported by Piehler and Pluth (1982) was performed. Two 8-mm interposition grafts were sutured end to end to the left and right coronary ostia with a running 4-0 Nespylene. After seating the composite graft in the aortic annulus, both interposition grafts were attached end to end to the composite graft with a running 4-0 Nespylene. Recently, we used a combination of the interposition graft and button technique. An 8-mm interposition graft was sutured end to end to the right coronary ostium, and the left coronary artery was reattached to the composite graft using the button technique.

Statistical analysis

Values are expressed as the mean $\pm$ one standard deviation of the mean. Analysis of variance was used to determine the significance of difference among the groups. Differences were considered to be significant at a probability value less than 0.05.

Results

The durations of ECC and ACC was 231.4 ± 101.7 minutes and 135.8 ± 32.5 minutes for the Bentall procedure, 333.5 ± 91.5 minutes and 204.2 ± 64.0 minutes using the button method, 315.1 ± 144.0 minutes and 198.4 ± 61.0 minutes for the interposition graft technique, and 350.0 ± 69.0 minutes and 219.5 ± 29.4 minutes with the combination interposition graft/button procedure. There were no

significant differences of duration of ECC and ACC among the four groups. Hospital mortality was 30% for the Bentall technique, 9.1% for the button technique and 9.1% for the interposition graft technique. There was no hospital mortality in the combination interposition graft/button technique group (Table 1). There were no significant differences of hospital mortality among the four groups. Four patients with annuloaortic ectasia who underwent the Bentall procedure died; one each due to infection, respiratory failure, multisystem organ failure, and low output syndrome (LOS). One patient with VSD and AR who underwent the Bentall procedure died due to cerebral bleeding. One patient with type A dissection after aortic valve replacement who underwent the Bentall procedure died due to gastrointestinal bleeding. One patient with chronic type A dissection who underwent the button technique died due to infection. One patient with acute type A aortic dissection who underwent the Cabrol procedure died due to intractable hemorrhage from the coronary artery anastomosis (Table 1). Concomitant procedures were performed in 21 patients. Six patients underwent concurrent coronary artery bypass grafting. Two patients who underwent the Bentall technique died of LOS and infection, respectively. Nine patients underwent complete replacement of the aortic arch; seven had an aortic dissection with an intimal tear located in the transverse aortic arch, one had an entire aortic aneurysm, and one had an aortic dissection with an intimal tear located in the descending thoracic aorta. One patient who underwent the button technique died due to infection. One patient who had an aortic dissection with an intimal tear extended into the aortic arch underwent partial replacement of the proximal aortic arch. In three patients, Cabrol fistula was used, and two patient died of infection. One patient underwent closure of VSD; this patient died of cerebral bleeding. In one patient, the mitral valve was replaced due to mitral regurgitation; this patient died of LOS.

Hospital mortality was 30.8% from 1974 to 1985, 23.5% from 1986 to 1991 and 0% from 1992 to 1995 (Table 2). Early postoperative complications are listed in Table 3. Liver failure (total serum bilirubin greater than 5 mg/100ml), respiratory failure (requiring mechanical ventilation for more than 7 days), arrhythmia (requiring the use of antiarrhythmic drugs), LOS (requiring continuous infusion of dobutamine or dopamine or both $>20\ \mu g \cdot kg^{-1} \cdot min^{-1}$ for more than 24 hours), hemorrhage, and cerebral disturbances (hemiplegia or coma) were the main postoperative complications (Table 3). Complications were more frequent in patients after the Bentall technique. These included liver dysfunction in 7 of 20 patients (35%), LOS in 4 patients (20%) and cerebrovascular accident in 4 patients (20%). Follow-up ranged 2 to 225 months (mean 94.5 ± 71.0 months) in the Bentall group, from 4 to 108 months (mean 44.3 ± 39.9 months) in the button group, from 10 to 108 months (mean 62.0 ± 33.2 months) in the interposition graft group, and from 14 to 41 months (mean 30.3 ± 9.2 months) in the combination group. Five late deaths occured in the Bentall group (35.7%); three patients

TABLE 3. *Early complications*

	Bentall	Button	Inter. P. Gr.	Inter. P. Gr. & Button
Liver dysfunction	35%	36%	18%	0%
Respiratory failure	15	18	9	43
Arrhythmia	15	27	0	14
Low output syndrome	20	18	18	0
Hemorrhage	15	0	9	0
Cerebrovascular accident	20	9	0	0
Renal dysfunction	10	18	0	0
Compression of graft	15	0	0	0
Infection	10	18	0	0
Coronary ostia pseudoaneurysm	10	0	0	0
Gastrointestinal bleeding	10	0	0	0

Inter. P. Gr., interposition graft.

with annuloaortic ectasia, 2 with dissection. One patient (with dissection) died in the button group (9.1%). No late death in the interposition graft or the combination group occurred. The death in the Bentall group were due to; infection, unknown cause, fatal arrhythmia, or intractable bleeding after reoperation. The death in the button group were due to multiorgan failure after replacement of the total descending aorta.

Late postoperative complications occurred almost exclusively in the Bentall group (Table 4). These included coronary ostia pseudoaneurysms in 2 of 14 survivors (14%), distal suture line pseudoaneurysm in 1 patient (7%), aortic paravalvular leak in 1 patient (7%), and hemolytic anemia in 1 patient (7%). Three patients one each with distal suture line pseudoaneurysm, aortic paravalvular leak, and hemolytic anemia underwent reoperation at 9, 11, and 18 years after the initial procedure. The former two patients died of bleeding after

TABLE 4. *Late complications*

	Bentall	Button	Inter. P. Gr.	Inter. P. Gr. & Button
Coronary ostia pseudoaneurysm	14%	0%	0%	0%
Distal suture line pseudoaneurysm	7	0	0	0
Paravalvular leak	7	0	0	0
Hemolytic anemia	7	0	0	0
Dissection	0	0	10	0
Infection	7	0	0	0
Arrhythmia	7	0	0	0
Lung embolism	7	0	0	0

Inter. P. Gr., interposition graft.

TABLE 5. *Postoperative events in patients with Marfan and non-Marfan syndrome*

	Number of patients	Coronary ostia pseudoaneurysm	Dissection	Reoperation or secondary operation
Marfan syndrome	7	29%	29%	43%
Non-Marfan syndrome	42	0	0	12

operation. No late postoperative complications in any other group occurred, except in 1 patient in the interposition group with dissection. Postoperative events occurred frequently in patients with Marfan syndrome (Table 5). These included coronary ostia pseudoaneurysm in 2 of 7 cases (29%), and aortic dissection in 2 of 7 patients (29%). Three patients (43%) in Marfan syndrome needed reoperation or secondary operation. There were no cases complicated with coronary ostia pseudoaneurysm and aortic dissection postoperatively in patients with non-Marfan syndrome. Five patients (12%) in non-Marfan syndrome underwent reoperation or secondary operation.

DISCUSSION

Results of operative repair of ascending aortic aneurysms associated with aortic regurgitation have improved since Bentall and DeBono (1968) reported the method using a composite graft in 1968. Prior to this technique results were poor because of bleeding from anastomoses, paravalvular leakage and aneurysmal change of the residual aortic wall (Groves et al. 1964; Gott et al. 1991).

This technique, however, is not free from late complications (Kouchoukos et al. 1986; Marvasti et al. 1988). Pseudoaneurysm formation at the coronary artery anastomoses or proximal or distal suture lines and compression of the graft from to bleeding in the space between the aortic wall and the vascular graft are main complications (Kouchoukos et al. 1986; Marvasti et al. 1988). Kouchoukos et al. (1986) have reported nine cases of pseudoaneurysm occurring in their series of 103 patients. Reoperation was required in 8 patients, and 3 patients died. In our series, the Bentall technique was performed in 20 patients. Three patients had graft compression, 2 had a coronary ostia pseudoaneurysm, and 1 had distal suture line pseudoaneurysm.

It was speculated that the pseudoaneurysm caused to elevation of the interspace pressure and tension on the coronary anastomoses following blood pooling in the space between the aortic wall and the vascular graft. Kouchoukos et al. (1991) reported that development of pseudoaneurysms at the aortic and coronary ostial suture lines was observed only with the inclusion/wrap technique. It has been suggested that if the inclusion technique is used, the aorta should not be wrapped around the graft until protamine has been administered and all suture lines have been carefully examined. We concur with Marvasti et al. (1988) that the inclusion/wrap method is useful when perfect hemostasis has not been

achieved. It also may add some protection against graft infection.

The Cabrol technique (Cabrol et al. 1981) facilitates the anastomosis between the coronary ostia and the graft by using vascular graft to reconstruct the coronary arteries. This technique has redundant route for coronary circulation, but carries the risk of shower emboli into the coronary artery, and stenosis due to kinking of the limb to the right or left coronary artery (RCA, LCA) (Svensson et al. 1992). Svensson et al. (1992) have reported patients who had myocardial damage following composite graft replacement using the Cabrol technique. This complication was not observed in our series.

Recently, we used an interposition graft technique described by Piehler and Pluth (1982) in five cases, four of which were reoperative cases. The Cabrol or interposition graft techniques were useful in reoperative cases or when tension on the coronary ostial anastomoses occured (Crawford et al. 1989). One patient with acute dissection died due to bleeding from the coronary ostial anastomosis after the Cabrol technique. The cause of death was tissue fragility and extension of the dissection to the left coronary ostia which led to intractable hemorrhage. Thereafter, the coronary artery was reattached to an ostia in the composite graft using the button technique reinforced by a felt pledget. This technique facilitated the anastomosis and was stronger in fragile tissue. Ohteki et al. (1987) have found this method useful for patients with aortitis. We used this technique successfully for one patient with aortitis. It has the benefit of reinforcing the coronary ostia anastomoses in fragile tissue.

It has been reported that the button technique offers better long term survival and fewer reoperations than the Bentall or Cabrol technique (Svensson et al. 1992). One drawback is that excision of the coronary ostial buttons and mobilization of the coronary ostia are difficult and time-consuming in patients undergoing reoperation. It has been reported that tension on the ostial anastomoses caused damage or occluded the coronary artery (Svensson et al. 1992). An alternative method combining the interposition graft and button tecnhiques has several advantages, including ease in reattaching the coronary artery and good long-term patency. The risk of graft occlusion and thromboembolizm with this technique may also be lower than in the Cabrol or interposition graft method, because only one short graft is used.

Svensson (1992) has reported a straightforward technique for reattaching the coronary ostia to the ascending aortic conduit. They used an interposition graft to reattach the LCA and excised an aortic button for the RCA reattachment. This shortened interposition graft used for LCA reattachment reduces the risk of neointimal thrombosis, and neointimal proliferation has been minimal in the graft due to the high flow left maincoronary artery (Svensson 1992). More data and longer follow-up are needed to confirm these results.

We used an interposition graft to reattach the RCA, and reattached the LCA with the button technique. We felt that the risk of complication from the

interposition graft would be minimized with direct attachment of the LCA. This method would be useful in cases of small distal shift of RCA to reduce the tension on the ostial anastomosis.

To summarize, the early and late results with the Bentall technique were somewhat poor, while the button, interposition graft, and combination methods were better. It appeared that coronary artery reattachment using a graft (interposition graft technique) was easier and safer in reoperation cases. Reattachment of the coronary artery using the button technique is safer in patients with weak tissues from infection, inflammation, or acute dissection. The combination interposition graft and button technique has the advantages of technical ease in reattaching the coronary artery and of reducing the tension on the RCA ostial anastomosis, and would minimize the risk of interposition graft related complications associated with the Cabrol or interposition graft technique. It was suggested that composite valve graft replacement of the aortic valve and ascending aorta would be safe if the adequate operative method was selected for the patients with ascending aortic aneurysm with aortic regurgitation.

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