Aortic root replacement with coronary button re-implantation: low risk and predictable outcome

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Abstract

Objective: Cardiac morbidity in aortic root replacement often occurs through myocardial ischaemia. We analyzed a 10 year experience of all root replacement operations by one surgeon to determine the incidence of coronary complications and risk factors for early mortality.

Methods: The study included 140 aortic root replacement patients (aged from 2 to 77 years; median 53 years) operated between 1988 and 1999. Thirty-four had Marfan’s syndrome. Eleven had root infection requiring homograft replacement. Nineteen were reoperations (14%). Concomitant procedures were arch replacement (16), mitral replacement (five), and coronary bypass (22). Mobilization and reimplantation of the coronary ostia was performed in 139 patients. We performed the distal graft anastomosis before right coronary reimplantation.

Results: There were eight hospital deaths (5.7%). Risk factors for hospital mortality were: preoperative NYHA class IV, shock, LVEF ≤30%, acute dissection, concomitant mitral valve replacement, pump time ≥160 min, reentry for bleeding, and postoperative renal failure. Neither myocardial ischaemia nor right ventricular dysfunction contribute to mortality. There were 18 late deaths with an actuarial survival of 79% at 5 years. There were no late coronary false aneurysms.

Conclusions: Button reimplantation with the sequence described is predictable and safe. Wrap-around is unnecessary. Coronary aneurysms have been eliminated. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Aorta; Coronary; Replacement; Root; Technique; Valve

1. Introduction

Aortic valve replacement now carries a very low hospital mortality (<5%) [1]. Besides duration of operation the only important difference between isolated valve and aortic root replacement is the management of the coronary arteries.

The original Bentall method employed an in situ circumferential suture line around the coronary ostia then complete aortic wrap around to control bleeding. Tension within the perigraft space conveyed the significant risk of coronary separation, false aneurysm formation and re-operation [2]. To avoid this problem Cabrol used a fistula to the right atrial appendage and subsequently adopted inter position dacron conduits to the coronary ostia with the new risk of graft thrombosis [3,4]. Currently these methods are superceded by coronary button mobilization from the native aortic wall and direct reimplantation into the valved conduit [2,5–8]. We have used this method routinely for 10 years but recognize technical pitfalls which can be avoided by appropriate surgical methods. This study describes one surgeon’s experience of aortic root replacement in a 10 year period and provides an analysis of strategies to avoid morbidity.

2. Patients and methods

From our thoracic aortic database we reviewed 140 consecutive aortic root replacement patient operated between October 1988 and January 1999. All types of aortic root and ascending aortic pathology were included. Excluded were patients who underwent the Ross procedure for isolated aortic valve disease and those undergoing a valve sparing root repair or valve replacement and separate supra coronary graft. There were 93 males two of which were infants, and 47 females. Ages ranged from 2 to 77 years (median 53 years). Marfan’s syndrome was present in 34 (24%) and the Ehlers–Danlos syndrome in one.

The patient and surgical data are shown in Table 1. Coronary artery disease requiring coronary bypass was present in 22 patients (16%). In 16 (11%) patients the aneurysm or dissection extended into the aortic arch. Nineteen
(14%) had undergone previous cardiac surgery. This included acute type A dissection repair with valve replacement in five, elective aortic root repair in three, aortic valve replacement in nine and coronary bypass surgery in two. In three patients the root replacement we report was their third cardiac operation. All eighteen candidates for emergency surgery were NYHA IV. Of the 132 elective procedures 39 patients were in NYHA I or II, 47 in NYHA III and 36 in NYHA IV.

Eighty-three patients (59%) had annulo-aortic ectasia restricted to the root and proximal ascending aorta. In one patient the aneurysm extended into the proximal arch and required hemiarch replacement. The morphology of the root was the same for both phenotypically Marfan and non-Marfan patients.

The 16 ascending aortic aneurysms were predominantly atherosclerotic and half extended into the aortic arch. Five required complete arch and three hemiarch replacement, two with coronary bypass grafts.

Of the 14 aortic dissection patients seven were acute and seven chronic. All seven acute patients had Marfan’s syndrome. All seven chronic dissection patients underwent hemiarch replacement with fenestration between the true and false aortic lumen to prevent visceral malperfusion.

All 11 endocarditis patients had excavating aortic root sepsis and abscess or fistula formation. Nine had prosthetic valve endocarditis and two native valve endocarditis. Three had left ventriculoaortic discontinuity.

Five patients had aortitis and an inflammatory ascending aneurysm with aortic regurgitation. One of these had previously undergone aortic valve replacement and suffered prosthetic dehiscence during steroid and cytotoxic treatment. Full root replacement was then performed with a bileaflet valved conduit after which prosthetic valve endocarditis necessitated homograft root replacement. The sixth patient in this category, a 52-year-old female, had burnt out aortitis with a porcelain aorta, tight aortic stenosis and bilateral coronary ostial stenosis.

The remaining patients included five males with congenital bicuspid valves and ascending aortic aneurysms who were treated by root replacement, as were two with infected dacron grafts and three with mediastinal false aneurysms. Two of the false aneurysms occurred after repair of acute Type A dissection and one after bioprosthetic aortic valve replacement for endocarditis. Lastly two male infants presented with congenital aortic root anomalies. One had previously undergone repair of aorto left ventricular tunnel and had a structurally abnormal valve and ascending aorta. The second had aortic stenosis and a massively dilated ascending aorta.

2.1. Surgical methods

The conduct of each procedure was dictated by the pathological process, the need for concomitant procedures and in the light of increasing experience. Coronary ostial mobilization and direct button re-implantation was the procedure of choice throughout.

Cardiopulmonary bypass was undertaken at a perfusion temperature of 32°C unless hypothermic circulatory arrest was required for aortic arch replacement (n = 9) or the open anastomosis in acute type A dissection (n = 7). In this case systemic temperature was reduced to 18°C. Retrograde cerebral venous perfusion was employed in five total arch replacement patients but not for hemiarch repair or the open ended anastomosis in acute type A dissection. Femoral arterial cannulation was employed for all dissection and circulatory arrest patients and those whose aneurysm extended to within 2 cm of the innominate artery. Direct arch cannulation was used where pathology was restricted to the root and proximal ascending aorta. Venous return to the pump oxygenator was by a two-stage cannula inserted into the right atrial appendage. For the three patients with mediastinal false aneurysms femoral arteriovenous cannulation and systemic cooling were established before resternotomy since we anticipated entry into the aneurysm with the potential for exsanguinating haemorrhage or air embolism. For re-warming in these patients new cannulae were inserted into the ascending aortic graft and right atrium.

Myocardial protection was by cold antegrade crystalloid cardioplegia in every case. The heart was vented via the apex of the left ventricle or the right superior pulmonary vein. Aprotinin was not used in those undergoing hypothermic circulatory arrest or coronary bypass [9–11].

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Table 1
Indications for aortic root replacement and operative data

<table>
<thead>
<tr>
<th>Pathology</th>
<th>n</th>
<th>Emergency</th>
<th>Redo</th>
<th>Valved conduit</th>
<th>Allograft</th>
<th>Tube + stentless</th>
<th>Early death</th>
</tr>
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<tbody>
<tr>
<td>Annular ectasia</td>
<td>83</td>
<td>3</td>
<td>2</td>
<td>81</td>
<td>0</td>
<td>2</td>
<td>2</td>
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<td>Atherosclerosis</td>
<td>16</td>
<td>1</td>
<td>2</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>14</td>
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<td>1</td>
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<tr>
<td>Aortic stenosis</td>
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<td>0</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pseudoaneurysm</td>
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<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>Infected graft</td>
<td>2</td>
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<td>2</td>
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<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>140</td>
<td>18</td>
<td>19</td>
<td>125</td>
<td>13</td>
<td>2</td>
<td>8 (5.7%)</td>
</tr>
</tbody>
</table>
2.2. Conduct of aortic root replacement

The aorta was then completely transected at the sino-tubular junction and distally between 1 and 2 cm before the cross clamp. The coronary buttons were excised with a 1.5 cm diameter cuff of aortic wall and mobilized over a short length to facilitate re-implantation. The root was then replaced with an appropriate valved conduit. A bileaflet valved conduit was used in 125 patients whilst two received a stentless porcine root bioprosthesis sewn onto a dacron conduit. In 11 patients with active root or graft infection an aortic allograft was employed. The two infants also received an aortic allograft.

The mechanical or bioprosthetic valve was first sewn into the annulus. Aortic allografts in infected roots were secured with interrupted 2/0 simple monofilament sutures situated in the left ventricular outflow tract beneath the infected annular tissue. The left coronary button was then implanted with continuous 5/0 polypropylene. Gelatin resorcinol formol (GRF) glue was also used to repair an acutely dissected distal aorta before the open distal anastomosis. For chronic dissection patients the open anastomosis was performed after excising the whole aneurysm and fenestrating the septum between true and false lumen.

For mechanical valved conduits the distal anastomosis was then performed to the transected aorta. Only after completing the distal anastomosis was the site of right coronary re-implantation determined with the graft distended with blood. This manoeuvre avoids kinking or tension as may occur if the distal anastomosis is performed last. The sequence was different for aortic allografts and stentless xenograft valves where it is necessary to scrutinize the inside of the conduit to avoid injuring the valve.

For complete arch replacement total circulatory arrest was undertaken after the left coronary anastomosis. The aneurysm was excised and replaced with a separate graft.

In addition to direct coronary re-implantation 22 patients underwent coronary artery bypass for occlusive disease.

In three patients including one infant tension on the right coronary implant was relieved by inserting a pericardial hood [12].

2.3. Follow-up

Details of each operation were obtained from the medical records where the operation note contained a drawing of the procedure. All patients were followed by telephone interview and discussion with the General Practitioner, Cardiologist or both. In the event of late mortality a death certificate was obtained.

2.4. Statistical analysis

Long term survival in months was ascertained from the time of operation to the end point of February 1999 using Kaplan–Meier curves. Risk factors considered for early mortality were: operation during the first 5 years, sex, age >70, hypertension, smoking, NYHA IV, LVEF <30%, preoperative shock, Marfan’s syndrome, annuloaortic ectasia, degenerative aneurysm, acute dissection, endocarditis, reoperation, concomitant procedures: aortic arch replacement, mitral valve replacement, coronary artery bypass grafting, pump time >160 min, postoperative complications including reentry for bleeding, arrhythmias, neurologic deficit, renal failure, and sternal infection. Differences between categorical data were tested using a Fisher’s exact test. Results with P-values less than 0.05 were considered statistically significant.

3. Results

3.1. Intra-operative events

The Cabrol procedure was undertaken in only one patient where previous surgery had resulted in peri aortic fibrosis and calcification which rendered coronary mobilization unsafe. Coronary mobilization and re-implantation into the valved conduit proved feasible in all other patients although a pericardial hood was necessary to prevent tension in three cases. The first was a re-operation and the second a female patient with prosthetic valve endocarditis where the right coronary ostium was very close to the prosthesis. The third was the infant with previous aorto left ventricular tunnel. The right coronary was in proximity to the previous repair and was difficult to mobilize adequately for appropriate implantation into the allograft. On discontining cardiopulmonary bypass one patient in whom right coronary re-implantation appeared satisfactory developed right ventricular dysfunction. This was first attributed to air embolism but when supportive perfusion failed to improve the electrocardiogram a saphenous vein coronary bypass graft was undertaken. After this recovery was uneventful. This was the only patient where supplemental coronary bypass was required.

For the patient with porcelain aorta root replacement was performed using hypothermic circulatory arrest and retrograde cerebral perfusion. The obliterated right coronary was bypassed. The left coronary artery had an ostial stenosis but was mobilized and re-implantated. Coronary bypass grafts were performed to the three major vessels.

3.2. Post operative complications

Fourteen patients required surgical re-entry for excessive bleeding. In one patient this was from the valve annulus and in two patients from the distal graft anastomosis. No bleeding was coronary-related and there were no late coronary false aneurysms. Diffuse bleeding was noted in 11 patients who had undergone surgery for aortic dissection, root sepsis or re-operation. Early in the series we noted a bleeding tendency in hypothermic circulatory arrest patients who received aprotinin before it was understood that both cooling and aprotinin prolonged the activated clotting time.
Abnormal bleeding contributed to three of eight postoperative deaths, one from mediastinitis and two from multiple organ failure.

All hospital deaths (eight patients) occurred in patients who were pre-operatively NYHA IV. Four of the patients were in cardiogenic shock pre-operatively. Three died following complex re-operations and three after root replacement with concomitant procedures. Two had undergone combined aortic root replacement, mitral valve replacement and coronary bypass. The third with severe diffuse coronary disease underwent coronary bypass alone.

The causes of hospital death in eight patients are shown in Table 2.

Two deaths were in the acute type A dissection group. One died as a consequence of mediastinitis and the other through multiorgan failure after prolonged diffuse abnormal bleeding. A re-operation patient who underwent hypothermic circulatory arrest and suffered diffuse abnormal bleeding also died from multiple organ failure. Dysrhythmia accounted for two sudden hospital deaths and were thought to be due to complete heart block. Non-ischaemic left ventricular failure was the mode of death for another two patients who underwent combined aortic root and coronary procedures.

Results of risk factor analysis for the hospital mortality is shown in Table 3.

Twenty-one patients (15%) suffered dysrhythmic events other than atrial fibrillation. Conduction disturbances predominated with periods of pacemaker dependency. Two patients with excavating aortic root sepsis required a permanent pacemaker. Transient neurological events occurred in ten patients (6%). These were identified in the recovery area and were attributed to intra-operative thromboembolism. None of these patients were left with permanent neurological disability and there were no documented valve-related thromboembolic events in the recovery period. In addition to the two patients who died from multiple organ failure two others suffered transient renal failure one of which required dialysis. One patient suffered gastrointestinal haemorrhage.

![Fig. 1. Actuarial survival rate after aortic root replacement.](image-url)
through acute duodenal ulceration. This responded to medical treatment.

3.3. Late outcome

Follow up was completed in 113 patients (86% of hospital survivors). The mean follow-up period was 33.8 months, ranging from 1 to 108 months.

There were 18 late deaths with an actuarial survival of 94% at 1 year, 79% at 5 years and 64% at the end point (Fig. 1). Nine patients died suddenly. Two who remained in NYHA III with congestive cardiac failure, died at 4 and 9 months postoperatively. Five who were NYHA I died in syncopal mode from either ventricular fibrillation or complete heart block. Three of these had been treated for ventricular dysrhythmia in the early post operative period. Of the remaining nine patients, one anticoagulated patient died from cerebral haemorrhage, one from cancer and two from prosthetic valve endocarditis, (15 and 52 months after root replacement). The others were found after death and did not undergo autopsy.

There have been no false aneurysms from a coronary ostial suture line. Three mechanical prosthesis patients sustained late cerebral thromboembolic events and were found to be inadequately anticoagulated.

4. Discussion

Despite the potential difficulties in this varied group direct button re-implantation of the coronaries proved feasible in all but one patient. There was no coronary related morbidity or false aneurysm formation in the whole group and 80 patients (57%) had elective root replacement (±CABG) for annulo aortic ectasia without mortality.

Whilst specialist aortic centres report hospital mortalities between 4 and 10% for aortic root replacement more general national audit figures suggest less satisfactory outcomes [5,7,8,13–20]. Technical problems still cause mortality from perioperative myocardial infarction, right ventricular

Table 4
Aortic root replacement in large series

<table>
<thead>
<tr>
<th>Authors</th>
<th>n</th>
<th>Acute dissection (%)</th>
<th>Bentalla</th>
<th>Buttona</th>
<th>Cabrola</th>
<th>Early mortality (%)</th>
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<tr>
<td>Cabrol [13]</td>
<td>100</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>4</td>
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<tr>
<td>Lytle [14]</td>
<td>123</td>
<td>20</td>
<td>123</td>
<td>0</td>
<td>0</td>
<td>5.6</td>
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<tr>
<td>Kouchoukos [15]</td>
<td>172</td>
<td>10</td>
<td>105</td>
<td>51</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Lewis [16]</td>
<td>280</td>
<td>8</td>
<td>267</td>
<td>0</td>
<td>12</td>
<td>5</td>
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<td>Svensson [5]</td>
<td>348</td>
<td>10</td>
<td>137</td>
<td>43</td>
<td>157</td>
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<td>Aoyagi [17]</td>
<td>66</td>
<td>0</td>
<td>36</td>
<td>3</td>
<td>21</td>
<td>10.6</td>
</tr>
<tr>
<td>Gott [18]</td>
<td>270</td>
<td>7</td>
<td>250</td>
<td>0</td>
<td>0</td>
<td>4.8</td>
</tr>
<tr>
<td>Borst [7]</td>
<td>335</td>
<td>17</td>
<td>253</td>
<td>51</td>
<td>1</td>
<td>6.6</td>
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<tr>
<td>Hilgenberg [19]</td>
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<td>24</td>
<td>0</td>
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<tr>
<td>Girardi [20]</td>
<td>52</td>
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<td>0</td>
<td>30</td>
<td>22</td>
<td>3.8</td>
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<tr>
<td>Dossche [8]</td>
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<td>13</td>
<td>178</td>
<td>65</td>
<td>1</td>
<td>7.8</td>
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<td>Westaby</td>
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<td>0</td>
<td>139</td>
<td>1</td>
<td>5.7</td>
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a It does not include the technique with separately interposed coronary grafts.
dysfunction and bleeding. With impervious vascular grafts wrap around of the native aorta is a redundant and potentially troublesome manoeuvre. We achieve better access to potential bleeding sites by complete transection of the aorta both proximally and distally. This allows gentle traction on a mobile repair to rule out surgical bleeding.

We consider the sequence of the different stages in aortic root replacement to be important. In particular, right ventricular dysfunction and perioperative myocardial infarction usually occur through technical difficulties with right coronary re-implantation. We suggest that the site of right coronary re-implantation should be determined only after anastomosis of the distal dacron graft to the native aorta or arch graft. Even then the precise site is determined by temporarily filling the graft. Tension or kinking of the anastomosis can then be predicted and avoided with an appropriate extension technique. In this event our preference is to suture only the inferior lip of the coronary button to the dacron graft and then roof two-thirds of the superior circumference with a wedge of pericardium [12]. Others prefer a dacron inter-position graft [21]. If the right coronary is implanted before the distal graft anastomosis this may cause traction on the coronary button in a cranial direction (Fig. 2). This tendency is greater with the button technique than in the classical Bentall operation where the right coronary remains an integral part of the native aorta.

Gott reported 270 aortic root replacements, many in Marfan’s syndrome, where the classical Bentall technique was used [18]. They reported only six (2.5%) coronary false aneurysms. Other series of root replacements are recorded in Table 4 to provide comparable hospital mortality data between the classical Bentall, Cabrol and button re-implantation methods. Most series include patients with acute type A dissection but not excavating root sepsis or re-operations for mediastinal false aneurysm. The outcomes appear similar though Svensson and colleagues suggest that the button technique has better long term survival with a lower re-operation rate [5]. Hilgenberg’s report of 110 consecutive root replacements with prosthetic valved conduits provides data similar to our own, but particularly a very low incidence of re-operation for false aneurysm [19]. Others are less enthusiastic about direct coronary reimplantation for re-operative surgery. Kouchoukos, a proponent of the button technique reported a series of re-operative root operations where 19% of the patients had a Cabrol coronary conduit [22].

In summary, we favour the button technique for all aortic root replacements and have eliminated coronary false aneurysm. We consider the pericardial hood extension to be preferable to coronary bypass or dacron conduit coronary extension though these methods work well for other surgeons. Very low hospital mortality can be achieved for both elective and re-operative cases in high volume centres.

References

[19] Hilgenberg AD, Akins CW, Logan LD, Vlhaikes GJ, Buckley MJ,

