Comparison of Resection Versus Patch Aortoplasty for Repair of Coarctation in Infants and Children

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SUMMARY To evaluate two surgical techniques of treatment for coarctation of the aorta in infants and children, we retrospectively compared our long-term experience with resection and end-to-end anastomosis ("resection") vs Dacron patch aortoplasty in patients operated upon when younger than 16 years of age. Since 1967, 184 patients underwent either resection (n = 96) or patch aortoplasty (n = 88). These groups were comparable in terms of preoperative systolic blood pressure, systolic pressure gradient across the coarctation, the year of operation, age and weight at operation, prevalence of associated cardiovascular defects, and duration of postoperative clinical follow-up (1-12.3 years, median 4.3 years).

There was no statistically significant difference in operative mortality between surgical groups. Among 104 patients with follow-up longer than 1 year, there was no statistically significant difference between the two operations in the appearance of a residual gradient greater than 10 mm Hg, but for both groups this degree of residual gradient was more frequent in infants (22 of 43, 51%) than in older children (18 of 61, 31%; p < 0.025). Late postoperative systolic hypertension was noted in 20 of 104 patients (19%), divided equally between the two operative groups. Most late hypertensive patients (13 of 20, 65%) also had residual coarctation; otherwise, the occurrence of postoperative hypertension was not influenced by the type of repair or age at repair.

We conclude that resection and patch aortoplasty are equivalent operations for coarctation of the aorta in infants and children, and that long-term relief of gradient is related to age at operation rather than to technique of repair.

SINCE the natural history studies of Abbott and the pioneering surgical contributions of Crafoord and Nylin and Gross and Hufnagel, there is no question that coarctation of the aorta can and should be repaired. The original Crafoord-Gross resection-anastomosis technique, with minor modifications, is extensively used and frequently effective as the corrective procedure for this disease.

Nevertheless, the classic operation has disadvantages, technically and in long-term results. The operation requires particular skill not only of the surgeon, but also of the assistant, who must hold the clamps in precise orientation. In the classic repair, a considerable segment of aorta must be mobilized, which increases the risk of bleeding and prolongs the procedure. In up to one-third of cases, the distance between proximal and distal aortic segments or other anatomic considerations may require interposition of a tubular graft. Most important, circumferential growth of the aorta at the suture line is not uniformly adequate, and other physiologic and technical factors may intervene to cause persistence or recurrence of the intraluminal pressure gradient. This point is particularly important when considering coarctation repair in infants and young children.

Alternate procedures have been developed to avoid those technical pitfalls and to improve the long-term result of operation. Among these are variations of the prosthetic patch aortoplasty technique first proposed by Vosschulte.11 Although this approach is used in many centers, few data exist comparing the immediate and long-term surgical results with those of the resection technique.

At our institution we have debated whether the classic resection technique or the Dacron patch aortoplasty procedure offers the greater theoretical and practical advantages. Both techniques have been used with almost equal frequency since 1967. Pre- and postoperative care was provided by the same group of cardiologists, with minimal preselection of surgical candidates in most other respects. We present the results of this long-term experience.

Materials and Methods

Surgical Technique

In our hospital, classic repair of coarctation ("resection") has been performed as shown in figure 1A, with ligation of the ductus or ligamentum arteriosum and complete excision of the coarcted segment of aorta. The proximal and distal stumps are anastomosed,
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A. Resection with end-to-end repair

![Diagram of ressection with end-to-end repair](image)

B. Patch aortoplasty

**Figure 1. Surgical techniques to repair coarctation of the aorta.**

using running nonabsorbable suture material for the posterior aspect and interrupted nonabsorbable sutures anteriorly. Patch aortoplasty (fig. 1B) has been performed as described by Reul,12 with longitudinal incision of the thoracic aorta across the narrow segment and extending into the left subclavian artery. After excision of the intraluminal fibrous shelf, the vessel diameter is expanded using a large, tailored elliptical patch of woven Dacron secured with a continuous nonabsorbable stitch.

**Patients**

One hundred eighty-four patients, ages 2 days to 16 years, underwent primary repair of coarctation between January 1, 1967 and December 31, 1979 (fig. 2); 96 underwent resection and 88 underwent patch aortoplasty. Within 1 year after operation, 22 patients died (nine after resection, 13 after patch aortoplasty) and 58 were judged to have inadequate follow-up (31 resection and 27 patch aortoplasty patients), leaving 104 children in the long-term follow-up group. Duration of clinical follow-up in this group ranged from 1–12.3 years (median 4.3 years). Within this group, the number of patients who had each operation was similar (56 resection, 48 patch aortoplasty), and the proportion of patients undergoing each operation in the first year of life was comparable (24 of 56 [43%] resection, 19 of 48 [40%] patch aortoplasty).

The statistical significance (defined as $p < 0.05$) of comparisons between groups was tested by means of either the unpaired $t$ test or chi-square analysis. By this criterion, we found no significant difference between these groups in preoperative systolic blood pressure, systolic pressure gradient across the coarctation, year of repair, age and weight at the time of repair, duration of clinical follow-up (table 1), or prevalence of associated cardiovascular defects (table 2).

**Follow-up Data**

The clinical records of all 104 patients with long-term follow-up were examined, making note of all blood pressure measurements obtained with an appropriate-sized cuff and auscultation of the brachial or popliteal artery. Because of the frequent involvement of the left subclavian artery in the coarctation or the repair, right-arm cuff pressures were used to approximate the ascending aortic pressure, while the highest pressure recorded in either leg was used to approximate the descending aortic pressure. The most recently obtained values of blood pressure and arm-leg peak systolic pressure difference ("gradient") were taken to be the final values used in computations, while earlier values were used to analyze the

<table>
<thead>
<tr>
<th>Table 1. Comparison of Surgical Groups</th>
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<tr>
<td><strong>Factor</strong></td>
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<tr>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Mean preoperative systolic blood pressure (mm Hg)</td>
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<tr>
<td>Mean preoperative systolic pressure gradient (mm Hg)</td>
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<tr>
<td>Median year of repair</td>
</tr>
<tr>
<td>Mean age at repair (years)</td>
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<tr>
<td>Mean weight at repair (infants) (kg)</td>
</tr>
<tr>
<td>Mean duration of clinical follow-up* (years)</td>
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*Follow-up groups only: resection, n = 56; patch aortoplasty, n = 48.
† $p > 0.05$ (by $t$ test of independent means).
TABLE 2. Comparison of Associated Defects in Surgical Groups

<table>
<thead>
<tr>
<th>Associated defect</th>
<th>Resection group (n = 96) (% of pts)</th>
<th>Patch aortoplasty group (n = 88) (% of pts)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>32</td>
<td>39</td>
<td>NS*</td>
</tr>
<tr>
<td>PDA</td>
<td>42</td>
<td>31</td>
<td>NS</td>
</tr>
<tr>
<td>VSD</td>
<td>26</td>
<td>36</td>
<td>NS</td>
</tr>
<tr>
<td>ASD</td>
<td>9</td>
<td>9</td>
<td>NS</td>
</tr>
<tr>
<td>MS/MR</td>
<td>21</td>
<td>13</td>
<td>NS</td>
</tr>
<tr>
<td>TGA</td>
<td>5</td>
<td>5</td>
<td>NS</td>
</tr>
<tr>
<td>Other†</td>
<td>1</td>
<td>3</td>
<td>NS</td>
</tr>
</tbody>
</table>

*p > 0.05 by chi-square analysis.
†Includes tricuspid atresia, single ventricle, and double aortic arch.

Abbreviations: PDA = patent ductus arteriosus; VSD = ventricular septal defect; ASD = atrial septal defect; AS = aortic stenosis (all types); MS/MR = mitral valve stenosis or insufficiency; TGA = transposition of the great arteries.

Table 3. Classification of Surgical Results

<table>
<thead>
<tr>
<th>Classification</th>
<th>Postoperative arm-leg gradient</th>
</tr>
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<tbody>
<tr>
<td>Excellent</td>
<td>≤ 0 mm Hg</td>
</tr>
<tr>
<td>Good</td>
<td>1–10 mm Hg</td>
</tr>
<tr>
<td>Fair</td>
<td>11–20 mm Hg</td>
</tr>
<tr>
<td>Poor</td>
<td>&gt; 20 mm Hg</td>
</tr>
<tr>
<td>Persistent coarctation</td>
<td>Gradient &gt; 10 mm Hg first noted within 1 year after operation</td>
</tr>
<tr>
<td>Recurrent coarctation</td>
<td>Gradient &gt; 10 mm Hg first noted more than 1 year after operation</td>
</tr>
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</table>

The chronology of residual gradients and hypertension. In 40 patients (20 resection and 20 patch aortoplasty), at least one postoperative cardiac catheterization yielded data pertinent to this investigation. For each of these patients, the most recent direct arterial pressure gradient was averaged with the latest cuff pressure gradient to produce the value used in study calculations.

Using these data, we classified the surgical results as excellent, good, fair or poor (table 3), depending on the residual systolic pressure gradient across the site of prior coarctation. For patients who had a residual gradient greater than 10 mm Hg, we further classified the results as either persistent or recurrent, depending upon whether the gradient was first noted less than 1 year or more than 1 year after operation. Also, the final arm cuff blood pressure of each patient was compared with age- and sex-related normal values for American children as determined by the National Heart, Lung, and Blood Institute Task Force on Blood Pressure Control in Children. Any patient whose resting systolic blood pressure exceeded the normal mean value by more than 2 standard deviations was said to have arterial hypertension.

Results

Mortality and Morbidity

Figure 3 shows the immediate and long-term survival rate of our patients after coarctation repair, as determined by actuarial analysis. Among patients undergoing resection, the surgical mortality rate was 6.3%, compared with 10.7% initial mortality for those undergoing patch aortoplasty (p > 0.30). Fourteen of the 15 surgical deaths were among the 86 infants who underwent repair at younger than 1 year of age (mortality rate 16.3%). All infant surgical deaths occurred in patients with associated cardiovascular defects, and these deaths were evenly distributed over the period of this study. The one perioperative death beyond 1 year of age occurred in a 4-year-old boy with Shone's syndrome and congestive heart failure.

Late death occurred with equal frequency (six patients each) after either resection or patch aortoplasty. These deaths all involved children in whom coarctation was repaired in the first year of life. Eight of these deaths (67%) were related to later intra-cardiac operation for associated defects, although sepsis, pneumonia and persistent congestive heart failure were implicated in the remainder of the cases.

Operative morbidity was low for both groups of patients. Among those who underwent resection, two developed renal failure and one required bowel re-
section for intestinal necrosis. One patient developed renal failure after patch aortoplasty. No patient in either group had spinal paralysis, cerebral embolus, or perioperative bleeding sufficient to require reexploration of the chest. For the purpose of this study, transient arterial hypertension and abdominal pain were considered to be normal postoperative physiologic events, and were therefore excluded from morbidity calculations.

**Residual Gradient: Persistent vs Recurrent**

The surgical results are summarized in figure 4. Among infants who had resection, 10 of 24 (42%) had late systolic pressure gradients greater than 10 mm Hg, and five of these (21%) had a poor result (systolic pressure gradient greater than 20 mm Hg). By comparison, 12 of 19 infants (63%) had a pressure gradient greater than 10 mm Hg after patch aortoplasty, and eight of these 19 (42%) had a gradient greater than 20 mm Hg. This difference between result of the two operations performed in infancy was statistically insignificant ($p > 0.15$). Among patients older than 1 year at the time of repair, nine of 32 (28%) had a residual gradient greater than 10 mm Hg after resection and nine of 29 (31%) had such a gradient after patch aortoplasty, with poor results in four of 32 resection patients (12.5%) and two of 29 (6.9%) patch aortoplasty patients. These differences were not statistically significant. Residual coarctation was more common in infants than in older children ($p < 0.025$), but the results of each operation were comparable in each age group.

Figure 4 also shows the proportion of patients with residual coarctation whose gradient was classified as either persistent or recurrent. Among patients operated upon in the first year of life, most gradients exceeding 10 mm Hg (17 of 22, 77%) occurred within the first postoperative year, and were therefore classified as “persistent,” while five of 22 (23%) of these occurred after 1 year and were therefore termed “recurrent.” Among the older children, five of 18 (28%) of the residual gradients were recurrent. For all patients, the rate of persistent coarctation was greater after patch aortoplasty, and most cases of recurrence appeared after resection. This difference between procedures is significant ($p < 0.05$).

**Late Postoperative Hypertension**

The most recent arm cuff systolic blood pressure for each patient was plotted according to the type of operation and the child's age at the time of pressure determination (fig. 5). After superimposition of 95% confidence curves for normal values,$^{18}$ 10 patients in each surgical group were hypertensive on long-term follow-up. Thus, the prevalence of systolic hypertension (20 of 104, 19%) exceeds that expected in a general population ($p < 0.001$). Thirteen of 20 children with hypertension (65%) also had a residual gradient exceeding 10 mm Hg. For the seven hypertensive patients with good surgical result, the age at operation and the type of repair had no influence on the blood pressure at late follow-up.

**Figure 4.** The occurrence of persistent or recurrent coarctation. A greater proportion of infants than older children had a pressure gradient greater than 10 mm Hg on follow-up. Although there was no difference between procedures in the occurrence of residual gradient, patch aortoplasty tended more often to result in persistent stenosis, whereas resection led more often to recurrent coarctation ($p < 0.05$).

**Figure 5.** Right-arm cuff systolic blood pressure at last clinical follow-up. Solid and dashed curves represent normal age-related systolic blood pressure (mean $\pm 2$ sd).$^{18}$ Open circles represent patients with a good surgical result; solid squares, those with a residual gradient greater than 10 mm Hg. Twenty patients had systolic arterial hypertension, and 13 of these (65%) also had a residual gradient.
Discussion

In comparing the results of two techniques for repair of coarctation of the aorta, the two study groups were virtually identical in several important respects concerning age and anatomy.

Surgical and late mortality were high for infants in both groups, reflecting the compromised hemodynamic status and complicating defects in patients who required surgical repair at this age. In older, healthier patients, the risk of operation was nominal. The surgical and late mortality rates for both infants and older children in our series are similar to those published by others.1-3, 14-16

Patch aortoplasty was more likely to result in persistence of the intraaortic pressure gradient. This may be due either to incomplete excision of the fibrous shelf, intraluminal thrombosis or fibrosis, or to inadequate width of the Dacron patch. Perhaps this problem could be overcome with the use of balloononing patches or different prosthetic materials.17 However, resection was more likely to result in late recurrence of the coarctation, presumably due either to scarring, thrombosis, or lack of circumferential growth along the suture line. The long-term result of both operations was similar, and we could not confirm the advantage of patch aortoplasty reported by Sade and co-workers in their less-than-2-year follow-up of 18 infants.17

Systolic arterial hypertension was common after surgical repair regardless of the procedure. Although Nanton and Olley18 reported that 59% of their hypertensive patients had no persistence or recurrence of coarctation to explain their hypertension, 65% of our hypertensive patients had just such an anatomic basis. After successful repair of the coarctation, prevalence of resting systolic hypertension in our patients was not significantly higher than that in a general population, in agreement with the experience of Hubbell et al.19 Moreover, when the surgical result was satisfactory, the age at operation and the type of repair had no influence on the late occurrence of hypertension.

We conclude that resection and patch aortoplasty are equivalent operations for coarctation of the aorta in infants and children. In our series, poor results were related to the patient's age at the time of repair rather than to the technique of repair, emphasizing the desirability of delaying operation beyond infancy in those few patients whose response to medical treatment allows such an approach.

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