Several techniques for repairing coarctation of the aorta in infancy have been described. There is no consensus about the preferred technique. We believe that optimally the diseased segment of the aorta should be removed and, therefore, resection and end-to-end anastomosis is our operation of choice. The surgical technique was originally described in 1945 by Crafoord and Nylin. However, because the anatomical situations vary, the technique should be suited to each individual patient.

If the aortic arch is hypoplastic, resection and repair of the coarctation alone may leave a residual gradient. The definition of aortic arch hypoplasia is difficult. In neonates, the segment of the aorta between the left carotid and the left subclavian arteries is always the narrowest part of the arch. Some surgeons use a formula to define the acceptable size of the transverse arch between the left carotid and left subclavian arteries. They suggest the dimension (mm) should be body weight \( /11001 \) 1 mm. For example, in a 3-kg baby, the transverse arch should be \( 3 + 1 = 4 \) mm. Opinions differ: some surgeons consider the use of the extended end-to-end anastomosis repair in a high proportion of patients because patients with hypoplastic arch would be considered unsuitable for coarctation repair alone. Others believe that repair of coarctation alone encourages the growth of the hypoplastic arch with better flow, and they reserve the extended repair for only very few patients. The first description of the extended repair was published by Amato and coworkers in 1977, with further modifications by Elliott in 1987. The radical approach, in principle very similar to extended end-to-end repair, involves the mobilization of the distal ascending aorta. The latter is essential in dealing with proximal arch hypoplasia.

**Operative Technique**

An arterial catheter is inserted in all infants into the radial artery on the side opposite the coarctation (usually the right side) to monitor the blood gases and arterial blood pressure in the upper body. Of equal importance is adequate venous access for transfusion if required. The patient is positioned side-lying on the table with the left side up. A lateral thoracotomy incision is made through the third or fourth intercostal space. The left lung is retracted anteriorly and inferiorly with a moist swab. A longitudinal incision is made in the mediastinal pleura over the upper descending aorta posterior to the vagus nerve and is extended superiorly over the left subclavian artery, ligating and dividing the superior intercostal vein in the process.
Figure 1 Stay sutures are placed on the anterior edge of the pleura; care must be taken not to damage the vagus nerve. The stitches are anchored to the thoracotomy retractors. The ductus arteriosus is often patent; tubular hypoplasia of the aortic isthmus is almost a constant feature in these infants.
The aorta is mobilized proximally and distally. Proximally, the left subclavian artery, the left carotid artery, and the hypoplastic aortic arch are dissected. The ductus arteriosus is then dissected without damaging the recurrent laryngeal nerve. The areolar tissue is separated from the lateral and inferior surfaces of the ductus by sharp dissection. The dissection on its medial aspect is facilitated by the use of a blunt tissue dissector to open the fibrous layer and pass a braided silk ligature around the ductus, which is then securely tied just before the vascular clamps are applied.

The descending aorta is dissected and mobilized toward the diaphragm. All the tissue between the intercostal arteries is dissected free. The first few pairs of intercostal arteries are looped; very rarely are they ligated and transected.
Figure 3  The proximal aortic dissection is carried up to and beyond the left carotid artery to provide adequate mobilization of the arch. Special care must be taken in the posterior aspect, where small branches to the viscera of the posterior mediastinum (bronchial and esophageal arteries) may be found and, if severed, can cause distressing hemorrhage. The intercostal vessels just distal to the coarctation are temporarily occluded without interfering with the approximation of the ends of the aorta while the anastomosis is being performed, because they usually run upward. The distal aortic dissection is carried to the level of the third or fourth pair of intercostal vessels, and beyond if necessary, to provide adequate mobilization.

After the ductus arteriosus is ligated, a curved neonatal vascular clamp is placed across the origin of the left subclavian artery and the left carotid artery, and catching part of the proximal arch. Care must be taken to allow adequate flow into the innominate artery. The distal clamp is placed across the descending aorta.
The coarcted segment with the ductal tissue is then resected. The incision is extended into the undersurface of the proximal aortic arch.

Various types of suture techniques and suture materials have been described. In the neonates, the author currently uses an over-and-over running stitch with 7-0 Prolene sutures mounted on a 6.5-mm semicircle needle.
The posterior suture line is placed in an open manner. The first suture is placed from inside into the medial aspect of the distal aorta and is anchored with a rubber-shod clamp. The other needle is then passed from inside to the outside of the proximal aorta. The entire posterior suture line is performed before the clamps are approximated and the two ends gently pulled together.
Clamps are approximated, and the anterior suture line is completed. The continuous circumferential suture line is hemostatic, and the subsequent growth at the repair site does not appear to be an issue. This technique achieves excellent reconstruction of the arch but requires more extensive dissection and more time. After completion of the anastomosis, the distal aortic clamp is removed to allow the excluded segment to fill with blood and expel air. The proximal aortic clamp is then slowly removed, and the systemic pressure is carefully watched. Transfusion of blood or colloids may be necessary at this time to maintain the blood pressure. An infusion of dopamine is sometimes required. The mediastinal pleura is not routinely closed, and a single pleural drain is inserted before closure of the thoracotomy.
Results

A review of 151 infants less than 3 months of age who underwent coarctation repair between 1985 and 1990 was reported from Great Ormond Street Hospital. The anatomy of the aorta was hypoplastic at the isthmus in 25% of patients and hypoplastic at the arch in 33% of patients. Established surgical procedures were used in the repair, including 77 patients who underwent an extended end-to-end anastomosis. In 30 patients, the extension was proximal to the left carotid artery (radical approach). Early mortality (8%) was related on multivariate analysis to the presence of an associated major heart defect, preoperative resuscitation, and direct postoperative gradient over the arch. This gradient was significantly lower after the radical technique if the transverse arch was hypoplastic. Actuarial freedom from recoarctation at 4 years was 57% after subclavian flap angioplasty, 77% after end-to-end anastomosis, 83% after extended end-to-end anastomosis, and 96% after radical extended end-to-end anastomosis.

Another extensive Congenital Heart Surgeons Society study by Quaegebeur and coworkers reported the results of 322 neonates with coarctation of the aorta with or without ventricular septal defect (VSD). The incidence (5%) of associated left-heart anomalies is not insignificant. The survival at 24 months was 84%. Resection and end-to-end anastomosis was the most commonly used technique. However, the operative risk was higher if the end-to-end anastomosis was extended proximal to the left common carotid artery. In patients with single moderate or large VSD, the repair of coarctation, pulmonary artery banding, and subsequent repair of the cardiac lesions were associated with the highest 2-year survival at 97%, an interesting finding which is beyond the scope of this article.

Early Complications

Bleeding

Bleeding after extensive coarctation repair must be minimized. The usual principles apply in preventing and treating the hemorrhage.

Paraplegia

Paraplegia is a very rare but serious complication after repair of coarctation of the aorta. In 1972, Brewer and coworkers reported an incidence of 0.41% of paraplegia in a collective series of 12,532 operated coarctations and recoarctations. Lerberg and coworkers observed paraplegia in 5 of 334 coarctation repairs—an incidence of 1.5%. There was a correlation between the length of aortic cross-clamping and paraplegia (mean cross-clamp time in patients who developed paraplegia was 49 minutes). There is no general agreement as to what the “safe” signs of adequate collateral circulation are in the neonatal coarctation repair. However, distal aortic pressures higher than 40 mm Hg below the clamp have been quoted as safe in children. In neonates, the measures for avoiding paraplegia are the shortest possible cross-clamp time (nowadays rarely exceed 20 minutes), avoidance of acidosis, hemorrhage, and low proximal aortic pressure. Preservation of collateral circulation is important, particularly in the setting of an extended coarctation repair. Careful technique of anastomosis should obviate the need for reapplication of cross-clamp. Mild surface hypothermia from 34°C to 35°C may also be helpful.

Paradoxical hypertension is less common in infants. Perioperative surge of catecholamine and renin production have been implicated. For severe hypertension, intravenous labetalol is given in the immediate postoperative period.

Chylothorax

Chylothorax is more likely a result of the interruption of small lymphatic vessels near the subclavian artery. If a milky drainage starts appearing from the chest drains, a conservative treatment consisting of a medium-chain triglyceride diet is started. If, however, the drainage is copious, re-operation is indicated. The site of the chylous leak is oversewn.

Late Complications

Recoarctation

Recoarctation occurs regardless of the method of surgical repair. The incidence of recoarctation is higher in patients who have undergone operation early in infancy, especially infants with low birth weight. The differences in the reported incidence may be to some extent explained by the different criteria used by different authors to define recoarctation, and the length of follow-up. The recoarctation rate was disappointingly high (40%) in a 30-year follow-up study. However, the use of an extended repair appeared to have a much lower relapse rate.

In general, intervention is indicated when a resting gradient of 20 to 30 mm Hg, in the presence of a significant narrowing on imaging, is found. With the advances in interventional cardiology, the management of recoarctation is by balloon angioplasty.

Persistent postoperative hypertension seems to be related to the age at operation. It is common in patients undergoing operation beyond infancy. Among patients observed for a long period, the incidence of hypertension is higher and life expectancy is reportedly reduced. Even in normotensive young adults after “successful” surgery for coarctation in childhood, Gardiner and coworkers demonstrated abnormal endothelial responses, emphasizing the importance of lifelong follow-up.

References

10. Quaegebeur JM, Jonas RA, Wennberg AD et al: Congenital Heart Surgeons Society outcomes in seriously ill neonates with coarctation of the


