Coarctation: The search for the Holy Grail

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One of the Holy Grails of pediatric cardiac surgeons is an operation for coarctation of the aorta that results in no postoperative recoarctation or hypertension. Five decades have gone by since the first coarctation repair by Crafoord in 1944. The results of coarctation repair during that time have been steadily improving. Mortality is now almost exclusively related to associated cardiac anomalies. The greatly feared complications of paraplegia and mesenteric ischemia have been nearly eliminated. Now we are focused on trying to perfect the techniques of coarctation repair to eliminate recoarctation and minimize postoperative hypertension.

Walhout and colleagues¹ have reviewed the outcomes of 262 children undergoing repair of coarctation of the aorta between 1973 and 2000. They compared the results of patients who had a polytetrafluoroethylene (PTFE) patch aortoplasty versus those of patients who had resection of the coarctation with an end-to-end anastomosis (REEA). There was no mortality from isolated coarctation repair. There were no patients with postoperative paraplegia. The techniques (REEA vs PTFE patch aortoplasty) did not differ in the incidence of recoarctation. PTFE patch repair that included coarctation ridge resection was found to be a risk factor for late aneurysm formation. PTFE patch repair was associated with increased late hypertension compared with results in those patients who had REEA. Arch hypoplasia and young age (<1 month) were found to be risk factors for recoarctation. The authors recommend REEA when it is anatomically possible because of the favorable results, especially the lower incidence of late hypertension.

The authors are to be congratulated for their extensive review of one of the largest series of coarctation repairs reported and carefully followed up over a long period of time. Their careful analysis gives a slight edge to REEA over PTFE patch aortoplasty. The main limitations of this review are that it was a nonrandomized retrospective review, and there is no group of patients undergoing resection with *extended* end-to-end anastomosis. Nonrandomization means that the surgeon made a decision in the operating room as to whether a resection with end-to-end anastomosis was possible or decided perhaps because a resection could not be performed safely that a patch aortoplasty should be performed. This intraoperative decision, based on a variety of variables, would tend to stratify the outcome of the patients.

The other limitation of this study is partly historical, but even in the recent patients in this series, apparently none had resection and *extended* end-to-end anastomosis. This has been our procedure of choice at Children's Memorial Hospital for infants with coarctation since 1991.² This procedure includes resection of the coarctation and an incision in the undersurface of the transverse arch with a mirror counterincision in the descending thoracic aorta. This leads to a long oblique anastomosis that crosses potential sites for recoarctation. The technique of resection with *extended* end-to-end anastomosis addresses many of the anatomic features that have been associated with recoarctation. All ductal tissue is resected, the anastomosis augments a hypoplastic transverse aortic arch or isthmus, and the use of autologous tissue allows for growth of the anastomosis. The operation specifically addresses arch hypoplasia and young age, 2 risk factors for recoarctation identified in this study. A meta-analysis reviewing 6 institutions' incidences of recoarctation with the technique of resection with *extended* end-to-end anastomosis revealed a recoarctation rate of 7% in 507 patients.³ This is less than the recoarctation rate of 21% reported in the current review.

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PTFE patch repair in this series was noted to have a high incidence of aneurysm formation when the coarctation ridge was excised, with no aneurysms observed when the coarctation ridge was not excised. Late aneurysms occurred in 8 patients in this series when the coarctation ridge was excised and in no patient when ridge resection was not performed. This outcome is similar to the findings in our review of the PTFE patch aortoplasty, in which we noted no true aneurysm formation in over 125 patients undergoing PTFE patch aortoplasty (none of our patients had coarctation ridge resection).⁴ This I believe to be an important finding because it helps confirm the safety of PTFE patch aortoplasty. It also emphasizes that resection of the coarctation ridge should not be performed when a patient is undergoing PTFE patch aortoplasty.

The authors of the current study¹ found that the PTFE patch repair had a higher incidence of late hypertension than REEA. Late hypertension (defined as blood pressure >150/90 mm Hg in the right arm) occurred in 3 patients undergoing REEA and 8 patients undergoing PTFE patch aortoplasty. We found a high incidence of recoarctation (and hence hypertension) in our PTFE patch aortoplasty series if the patch technique was used in patients less than 1 month of age.⁴ In our series, if the patch repair was performed at less than 1 month of age, recoarctation occurred in 6 of 12 patients. That is part of what prompted us to abandon the PTFE patch aortoplasty in favor of resection with *extended* end-to-end anastomosis for infants with coarctation of the aorta.

The following question arises: In which patients should a PTFE patch aortoplasty technique be used? One particular subgroup identified in this series that I believe is of concern are those patients who had an attempted resection with end-to-end anastomosis that was then converted to a PTFE patch aortoplasty. I believe the occurrence of that intraoperative complication should be avoided whenever possible, and those patients should probably have had a primary PTFE patch aortoplasty. Patients who have a primary repair with one crossclamp application followed by a second crossclamp application shortly afterward during the same procedure to address the continuing coarctation are at increased risk for paraplegia.³ Before performing a resection and end-to-end anastomosis, the surgeon should take all possible precautions to ensure that the 2 ends will be able to come together. This might require extensive mobilization of the descending thoracic aorta, including ligating and dividing multiple sets of collateral vessels and full mobilization of the transverse aortic arch, including the left subclavian artery, the left carotid artery, and the innominate artery, with division of their pericardial attachments. Another group of patients for whom PTFE patch aortoplasty might be the technique of choice are those with extensive collaterals who are at risk of intraoperative hemorrhage. These collaterals

can be very large, tortuous, and fragile. Attempts to ligate and divide them in an effort to mobilize the aorta might lead to catastrophic hemorrhage. Obversely, the older child (>1 to 2 years of age) who has very few collaterals is also well suited to a PTFE patch repair. These patients without collateral formation are at risk for paraplegia if the aortic clamp time is prolonged. One advantage of the patch aortoplasty technique is the relatively short aortic clamp time (mean of 26 minutes in our series). A fourth indication for PTFE patch aortoplasty is a reoperation after previous repair (most commonly REEA). In the series of Walhout and colleagues,¹ 18 of the patients who had a reoperation had a PTFE patch aortoplasty versus only 2 undergoing a repeat REEA. In our review PTFE patch aortoplasty was the most common technique used for a recoarctation repair.³ Finally, PTFE patch aortoplasty is indicated for older patients with arch hypoplasia in whom the patch is brought up into the transverse arch either through a left thoracotomy or from a median sternotomy approach. We are currently not using PTFE patch aortoplasty in infants less than 1 year of age or for patients greater than 18 years of age. In the younger age group, as mentioned earlier, we demonstrated a high incidence of recoarctation. In the older age group we avoid this technique because of the prolonged abnormal physiology resulting in poststenotic dilatation and thinning of the descending thoracic aorta that puts the patient at increased risk for aneurysm formation. Adult patients with coarctation should have a resection of the coarctation with placement of an interposition graft.

The timing of the operation with regard to the risk of recoarctation in this review was an interesting and very relevant finding. Age at operation of less than 1 month was a risk factor for recoarctation. Of course, many of the patients less than 1 month of age are receiving alprostadil (prostaglandin E₁), and repair cannot be delayed. However, there was no difference in the incidence of late recoarctation in patients operated on from 1 month of age to 1 year of age compared with patients greater than 1 year of age. There was no benefit to waiting for patients over 1 month of age to be older to decrease the risk of recoarctation. This corresponds with our philosophy that coarctation should be repaired at the time of diagnosis.

We might be at a point at which it is not technical-surgical advances but rather modulation of the healing process that will lead to the desired Holy Grail of no recoarctation and no late hypertension. To this end, we have been studying the effect of vascular endothelial growth factor on the healing of a vascular anastomosis in a coarctation model.⁵ We found that the topical application of vascular endothelial growth factor to the anastomotic site results in enhanced healing with less fibrosis, less cellular infiltrate, and no focal dystrophic medial calcification.

What does the review by Walhout and colleagues¹ tell us? First, when possible, REEA might be superior to PTFE patch aortoplasty, with a slightly lower incidence of recoarctation and a significantly lower incidence of late hypertension. However, these conclusions must be tempered given the fact that this was not a randomized prospective study. Second, the incidence of aneurysm formation after PTFE patch aortoplasty is very low when the coarctation ridge is not resected. Third, patch aortoplasty is an effective bail-out procedure when resection with end-to-end anastomosis fails in the operating room. Finally, both arch hypoplasia and age of less than 1 month are independent risk factors for recoarctation.

I believe infants with coarctation of the aorta should be treated with resection and *extended* end-to-end anastomosis, and older children (>1-2 years of age) can be treated with either resection and *extended* end-to-end anastomosis (if technically feasible) or with PTFE patch aortoplasty. Adults with coarctation should have an interposition graft. We as surgeons must strive to analyze our results by using differ-

ent surgical techniques and attempt to use this information to generate the optimum outcome for patients with coarctation of the aorta. It might take more research at an endothelial cell-molecular level to fully achieve this Holy Grail of no recoarctation and no residual hypertension.

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