Editorial Comment

Stents in Treatment of Aortic Coarctation*

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Vascular stenotic lesions can be opened by balloon angioplasty techniques, but because of elastic recoil of the vessel wall, the vessel lumen returns to the predilation size after withdrawal of the balloon catheter. Such recoil and vascular dissection, if any, after balloon dilation can be circumvented by implantation of endovascular stents. Dotter (1), in the late 1960s, suggested this concept and implanted spiral coil-spring prostheses into the experimentally produced peripheral artery stenotic lesions. The stent concept and technology were dormant until the early 1980s, when the balloon-expandable and self-expanding stents were designed and used (2). Initially, stents were used in the treatment of peripheral arterial disease and coronary artery stenotic lesions in adults. The technique was then extended to the treatment of stenotic branch pulmonary arteries (3), postoperative venous obstructions (3,4) and other congenital and acquired stenotic lesions in children. To my knowledge, O'Laughlin et al. (5) were the first to report use of a stent for aortic coarctation, although the results in a 12-year-old child were marginal. Subsequently, others (6–10) reported use of stents for coarctation with encouraging results.

In this issue of the Journal, Ebeid et al. (11) present the results of stent implantation in nine patients 14 to 63 years old. Reduction in peak to peak systolic pressure gradient across the coarctation and increase in the diameter of the coarcted segment occurred immediately after stent placement. At a median follow-up of 13 months, residual peak to peak systolic pressure gradient across the stented segment remained low. One patient required redilation of the stent. Although Ebeid et al. state that they did not detect femoral artery problems, it is probably a good idea to examine physiologic effects (12) or noninvasive (13) or invasive (12) imaging of the femoral arteries used for stent implantation to detect femoral artery compromise or blockage. Despite this limitation, I believe that this report supplements the previously reported limited experience with this technique. Ebeid et al. further demonstrate the feasibility of redilation 3 years after stent placement. Finally, they show no evidence for obstruction of the left subclavian artery and left common carotid artery, even though the stent spanned the origins of these vessels from the aortic arch. The data from Ebeid et al., together with those of others (6–10), suggest that stenting of aortic coarctation in selected patients is a feasible and effective alternative to surgical or balloon therapy. Several issues with regard to aortic stents are worthy of further discussion.

Indications. The indications for stent implantation are not clearly defined at this time. On the basis of limited experience (6–11), the indications are hypoplasia of the isthmus or transverse aortic arch and tortuous coarctation with malalignment of the proximal with distal aortic segment, which are difficult to treat surgically (7). Recurrent aortic coarctation or small aneurysm after previous surgical or balloon therapy may be another indication for implantation of stents.

Technical issues. The balloon-expandable Palmaz stent (Johnson & Johnson) mounted on a balloon dilation catheter usually requires a large-diameter delivery sheath for stent implantation. Indeed, Ebeid et al. (11) used 10F to 12F sheaths, whereas Bulbul et al. (8) utilized 12F to 14F sheaths. It is generally recognized that arterial compromise or disruption, or both, may result after insertion of large sheaths. Therefore, innovative use of available technology should be incorporated into our practice such that smaller sized sheaths may be utilized for stent implantation (14,15). Stents may be mounted on an 8- or 10-mm Olbert balloon that can be introduced through an 8F or 9F sheath for initial deployment, which can be expanded to the required size with a larger balloon (15). More recently, the manufacturer of the Palmaz stent has designed balloons (up to 15-mm diameter) carried on smaller catheter shafts on which the stents could be mounted and delivered to the implantation site by 8F sheaths. It is important to seriously consider reducing the delivery sheath size because of femoral artery compromise (12); even in adults, 6F guide catheters produce less arterial damage than 7F and 8F catheters (16).

Age at implantation. Ebeid et al. (11) and Balbul et al. (8) implanted aortic stents in older children and adults, whereas other workers (6,7,10) used stents in infants and younger children. Limiting the use to older subjects is justified (8,11) because of limited evidence for the feasibility of reexpansion of the stents at a later date. However, it may be necessary to implant aortic stents in younger children. Therefore, the feasibility of such use should be explored. The feasibility of reexpansion of the stents in animal models (17–19), pulmonary artery stents in children (20) and aortic stents in adolescent and adult subjects (8,11) is encouraging, although reported aortic dissection in two of seven redilations of aortic stents in animal models (21) is of concern.

Other methods to resolve this problem should also be considered. Modification of the stent by creating an "open-ring" stent has made it possible to overdilate the stent in animal models (22). Clinical trials of this type of modification in young children are needed to demonstrate the usefulness of this technique. Another method by which this problem can be

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tackled is to use biodegradable stents (23). Several types of materials and designs are in the process of testing in animal models (23) and are soon likely to be available for clinical trials in human subjects.

Other issues. *Longitudinal rigidity.* The Palmaz stent, the most commonly used stent in the pediatric patient, is very rigid and may be difficult to implant into tortuous vessels, or the stent may cause disruption of the vessel wall (7). This problem may be circumvented by introducing a bridging articulation (24) and development of a multilink system (25). Alternatively, flexibility could be improved by using a single-filament construction of the stent.

Intimal proliferation. Varying degrees of neointimal growth have been reported and are more prevalent with self-expandable stents such as the Wallstent than the Palmaz stent (26). Therefore, it was postulated that external radial forces may contribute to the proliferative response. Intimal growth has also been observed at the ends of the stent, especially when a vessel–stent size mismatch exists and at the site of a previous stenosis. Neointimal proliferation may cause significant obstruction, especially in small vessels. Avoidance of factors likely to cause excessive neointimal growth should be undertaken. Local delivery of heparin or dexamethasone may reduce intimal proliferation but is at present not available for the clinical setting under consideration.

Obstruction of branch vessels. It is generally believed that the branch vessels that arise perpendicular to the axis of the stent (aorta) remain patent after stent deployment. In animal models, the spinal arteries were found to be patent after stent placement in the aorta (27), similar to demonstrated patency of side branches from the coronary arteries after stenting (28). Observations in human subjects confirm the patency of the side vessels after aortic stenting (7). In one of the subjects of Ebeid et al. (11), the stent covered the mouth of the left subclavian artery and part of the left common carotid artery origin at initial implantation. Angiography 3 years later showed unrestricted flow to both of these vessels. Although the available data are encouraging, because of the limited nature of observations, we should continue to gather follow-up data on the patency of branch vessels after aortic implantation of stents.

Conclusions. Although experience is limited, stents appear to be useful adjuncts to balloon angioplasty in the treatment of isthmic hypoplasia and tortuous coarcted segments. They may also have a useful role in the management of aortic disruptions or aneurysms after previous balloon or surgical therapy. Because of the need for insertion of large stent delivery sheaths into femoral artery, arterial compromise is likely to be significant. This may improve with the miniaturization of stent delivery systems, which is currently taking place. Implantation of stents in older children and adults in whom the aorta size has attained adult size is not problematic, although such may be problematic in infants and young children, whose aorta will grow with time unless the stents can be reexpanded. Alternatively, biodegradable stents, when they become available for clinical use, may help resolve this issue. Stent-deployed aortic segment is noncompliant and nonpulsatile. Whether this noncompliance adversely affects blood pressure regulation remains to be seen. With these reservations in mind, it is prudent to limit use of stents in patients with aortic coarctation for whom there are no other effective and safe alternative modes of therapy.

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