

EDITORIAL COMMENT

Stents in the Management of Aortic Coarctation in Young Children*

P. Syamasundar Rao, MD

Houston, Texas

Stents were initially used in adult subjects for treatment of obstructive lesions of iliac, coronary, and renal arteries. This was then followed by application of stent technology to the pediatric population (1,2). The technique was initially used to treat branch pulmonary artery and systemic venous stenoses but then was extended to the treatment of aortic coarctation. The indications used for implanting stents for aortic coarctation are generally taken to be the following: 1) long segment coarctation; 2) associated hypoplasia of the isthmus or aortic arch; 3) tortuous coarctation with malalignment of proximal with distal aortic segment; and 4) recurrent aortic coarctation or an aneurysm after prior surgical or balloon therapy (3,4). Immediate reduction of

See page 877

peak systolic pressure gradient and increase in the diameter of the coarcted segment have been demonstrated after stent implantation. The ratio of diameters of coarcted segment to the descending aorta at the level of the diaphragm increased to unity in many patients who underwent aortic stenting. Improvement in the size of hypoplastic isthmus or transverse aortic arch and exclusion of the aneurysm, if present, also occurred after stent placement. Stent therapy was found to be effective in post-surgical and -balloon recoarctations as well as in native coarctations (3–6). On the basis of the available data, stent therapy seems to be an attractive and preferred alternative to balloon (7–9) or surgical (10,11) therapy for treatment of aortic coarctation, especially in the adolescent and young adult. Most cardiologists use stents in adolescents and adults, although a few have advocated their use in younger children.

In this issue of *JACC: Cardiovascular Interventions*, Mohan et al. (12) evaluate the feasibility and effectiveness of

stent implantation to treat aortic coarctation in young children and compare the results with those in older children. The study group consisted of 22 patients ages 1 to 10 years (mean, 5.6 years) with weights ranging from 9.7 kg to 27 kg (mean, 19.8 kg), all <30 kg. The results demonstrate increase in the diameter of the coarcted segment, fall in peak systolic pressure gradient, and improvement in ratio of aortic coarctation segment/descending aorta at the level of diaphragm. These results were similar to those seen in patients weighing >30 kg. The authors conclude that stent therapy for treatment of aortic coarctation in young children is effective and safe and is similar to that seen in older patients, although stent redilation will be required. The manuscript is well written, and examining the issue of stents in the treatment of aortic coarctation in young children is of importance. But, use of stents in young children has been reported by a number of cardiologists in the past. Several patients that Mohan et al. (12) included in the study group had discrete coarctation (e.g., see Fig. 3 in Mohan et al. [12]), and these patients might easily be treated successfully with much simpler balloon angioplasty. Therefore, therapy should be individualized depending upon the anatomic substrate. The authors report only immediate results. Although these results are not too dissimilar to those reported by others, it is more important to examine long-term efficacy and safety of stents in young children. Despite these limitations, the authors' data are of value and supplement the previously reported experience with stent therapy in young children and gives us the opportunity to discuss the use of stents in young children.

The major use of stents is to address aortic recoarctation after surgical or balloon therapy. Recoarctation after both surgical correction (13–15) and balloon angioplasty (16–19) has been described. Renarrowing after surgery does not depend on the type of surgical repair, but depends upon the age at surgery; the younger the child at surgery, the higher the chance for recoarctation (13–15). Factors predictive of restenosis after balloon angioplasty include young age and severely narrowed isthmus and coarcted segment (16–19). Although biophysical characteristics of the coarcted aortic segment have been implicated (20) in the causation of recoarctation, true cellular pathophysiologic mechanisms responsible for recoarctation have not been identified. Once they are identified, appropriate treatment algorithms to prevent recoarctation could be developed to address the pathophysiology. Therefore, keeping coarcted segments open with stents is an attractive option, as proposed by Mohan et al. (12). Unfortunately the metallic stents do not grow with the child, and their implantation routinely in neonates, infants, and young children is predicated on the assumption that these stents can be re-expanded and such re-expansion will eventually achieve diameters of adult-sized (21) aortas. It has been stated (22) that even when large stents (e.g., Palmaz P-8 series, Genesis XD [Cordis, Bridgewater, New

*Editorials published in *JACC: Cardiovascular Interventions* reflect the views of the authors and do not necessarily represent the views of *JACC: Cardiovascular Interventions* or the American College of Cardiology.

From the Division of Pediatric Cardiology, The University of Texas/Houston Medical School, Houston, Texas.

Jersey] and ev3 LD [St. Paul, Minnesota]) are used, they might not be dilatable to adult-sized aorta.

Re-expansion of the stents used to treat residual or recoarctation and growth-related narrowing seems feasible, relatively safe, and largely effective (5,6), although such conclusions are based on limited experience. In the study by Duke et al. (23), although repeat dilation achieved improved stent diameter and peak pressure gradient, much of the re-expansion was necessary simply to restore the original lumen size, which was reduced between the times of implantation and restudy. Stents in their series (23) were on average re-expanded to only a maximum of 86% of the size of the distal vessel and to approximately 80% of the size of the balloon used for redilation. In their discussion, Duke et al. (23) expressed their concern that it is still uncertain whether redilation will be successful many years after stent deployment, whether multiple sequential (repeat) dilations will be effective, and whether such re-expansions will ultimately achieve a vessel lumen of adult size. Mullins (22) states: "In most infants or small children, a surgical coarctation repair, even with an arch advancement or a simple balloon dilation as a temporizing treatment, would be preferable to the implantation of a stent, which would obligate the patient to later and usually much more complicated surgical procedures." And I agree. If the stents could eventually be expanded to adult size with little or no complications, stents would be a good option; however, this did not seem to be the case. Consequently, alternative considerations for treatment of coarctations in young children should be explored.

Balloon angioplasty. Patients who have discrete aortic coarctation should undergo balloon angioplasty. The probability for development of recoarctation in this subset is low (24,25), and if recoarctation develops at a later age, it could be addressed at that time with stents, if necessary.

Biodegradable stents. Stents constructed with biodegradable materials (polymers) that subsequently get resorbed into the circulation have been used in the treatment of coronary and peripheral artery disease. Use of such stents in treatment of aortic coarctation might keep the coarcted aortic segment open for a 3- to 6-month period, after which the stents dissolve. By then, the ratio of the normal aortic tissue to abnormal tissue might be in favor of the infant, thus preventing recurrence of significant narrowing. Report of successful use of a bioabsorbable metal stent in a neonate with critical recoarctation (26) is encouraging, but testing in appropriate animal models, miniaturizing stent delivery systems, and clinical trials in large groups of young patients are needed.

Growth stents. Modification of the stent by creating an "open-ring" stent has made it possible to overdilate the stent in animal models (27). Ewert et al. (28) and Sigler et al. (29) extended this concept, where they cut open the stent longitudinally and reconnected the stent halves with bioab-

sorbable surgical sutures to form a circular stent. Feasibility, effectiveness, and biocompatibility in animal models were demonstrated. However, thinning of the vessel wall with partial rupture of the media was observed at the site of stent breakage (29). Clinical application of this concept was reported by Ewert et al. (30). Pressure gradients decreased from 30 mm Hg to 8 mm Hg immediately after stent implantation. During follow-up for 24 months (range 11 to 51 months), 5 patients required repeat dilation and 4 of these required larger stents implanted at a later date. One patient had simple redilation, and another had a larger stent implanted. Four patients did not require re-intervention during the follow-up period. The overall results, requiring multiple interventions, might be considered unsatisfactory. Larger clinical trials of this type of modification of stents in young children are needed to demonstrate the usefulness of this concept.

Summary and conclusions. Stent therapy seems to be an attractive and preferred alternative to surgical or balloon therapy for treatment of aortic coarctation in the adolescent and young adult. Although Mohan et al. demonstrated feasibility and effectiveness of stent implantation to treat aortic coarctation in young children, concerns regarding high probability of not achieving adult sizes when stents are implanted in young children should lead us to investigate alternative options, including not using stents in discrete coarctations and exploring further research on biodegradable and growth stents.

Reprint requests and correspondence: Dr. P. Syamasundar Rao, Professor and Director, Division of Pediatric Cardiology, The University of Texas/Houston Medical School, 6410 Fannin Street, UTPB Suite # 425, Houston, Texas 77030. E-mail: P.Syamasundar.Rao@uth.tmc.edu.

REFERENCES

1. Mullins CE, O'Laughlin MP, Vick GW III, et al. Implantation of balloon expandable intravascular grafts by catheterization in pulmonary arteries and systemic veins. *Circulation* 1988;77:189-99.
2. O'Laughlin MP, Perry SB, Lock JE, et al. Use of endovascular stents in congenital heart disease. *Circulation* 1991;83:1923-39.
3. Rao PS. Stents in treatment of aortic coarctation. *J Am Coll Cardiol* 1997;30:1853-5.
4. Rao PS. Stents in the management of congenital heart disease in pediatric and adult patients. *Indian Heart J* 2001;53:714-30.
5. Rao PS. Coarctation of the aorta. *Curr Cardiol Rep* 2005;7:425-34.
6. Rao PS, Seib PM. Coarctation of the aorta. eMedicine from WebMD. Updated July 20, 2009. Available at: <http://emedicine.medscape.com/article/895502-overview>. Accessed July 27, 2009.
7. Zabal C, Attie F, Rosas M, et al. The adult patient with native coarctation of the aorta: balloon angioplasty or primary stenting? *Heart* 2003;89:77-83.
8. Macdonald S, Thomas SM, Cleveland TJ, et al. Angioplasty or stenting in adult coarctation of the aorta? A retrospective single center analysis over a decade. *Cardiovasc Intervent Radiol* 2003;26:357-64.
9. Pedra CA, Fontes VF, Esteves CA, et al. Stenting vs. balloon angioplasty for discrete unoperated coarctation of the aorta in adolescents and adults. *Cath Cardiovasc Interv* 2005;64:495-506.

10. Anagnostopoulos-Tzifa A. Management of aortic coarctation in adults: endovascular versus surgical therapy. *Hellenic J Cardiol* 2007;48:290-5.
11. Weber HS, Cyran SE. Endovascular stenting for native coarctation of the aorta is an effective alternative to surgical intervention in older children. *Congenit Heart Dis* 2008;3:54-9.
12. Mohan UR, Danon S, Levi D, Connolly D, Moore JW. Stent implantation for coarctation of the aorta in children <30 kg. *J Am Coll Cardiol Intv* 2009;2:877-83.
13. Pinzon JL, Burrows PE, Benson LN, et al. Repair of coarctation of the aorta in children: postoperative morphology. *Radiology* 1991;180:199-203.
14. Rao PS. Balloon angioplasty for aortic recoarctation following previous surgery. In: Rao PS, editor. *Transcatheter Therapy in Pediatric Cardiology*. New York, NY: Wiley-Liss, 1993:197-212.
15. Hager A, Schreiber C, Nutzl S, Hess J. Mortality and restenosis rate of surgical coarctation repair in infancy: a study of 191 patients. *Cardiology* 2009;112:36-41.
16. Rao PS, Thapar MK, Kutayli F, et al. Causes of recoarctation after balloon angioplasty of unoperated aortic coarctation. *J Am Coll Cardiol* 1989;13:109-15.
17. Rao PS, Galal O, Smith PA, et al. Five- to nine-year follow-up results of balloon angioplasty of native aortic coarctation in infants and children. *J Am Coll Cardiol* 1996;27:462-70.
18. Kaine SF, Smith EO, Mott AR, et al. Quantitative echocardiographic analysis of the aortic arch predicts outcome of balloon angioplasty of native coarctation of the aorta. *Circulation* 1996;94:1056-62.
19. Rao PS, Koscik R. Validation of risk factors in predicting recoarctation following initially successful balloon angioplasty of native aortic coarctations. *Am Heart J* 1995;130:116-21.
20. Rao PS, Waterman B. Relation of biophysical response of coarcted aortic segment to balloon dilatation with development of recoarctation following balloon angioplasty of native coarctation. *Heart* 1998;79:407-11.
21. Garcier JM, Petilacolin V, Filaire M, et al. Normal diameter of the thoracic aorta in adults: a magnetic resonance imaging study. *Surg Radiol Anat* 2003;35:322-9.
22. Mullins CE. Inappropriate stents: primary cause of failure of stent redilation in coarctation of the aorta. *Cath Cardiovasc Interv* 2008;72:557-8.
23. Duke C, Rosenthal E, Qureshi SA. The efficacy and safety of stent redilatation in congenital heart disease. *Heart* 2003;89:905-12.
24. Hassan W, Awad M, Fawzy ME, et al. Long-term effects of balloon angioplasty on left ventricular hypertrophy in adolescent and adult patients with native coarctation of the aorta: up to 18 years follow-up results. *Cath Cardiovasc Interv* 2007;70:881-6.
25. Mullins CE. A revisit: balloon dilation versus stents for treatment of coarctation of aorta. *Cath Cardiovasc Interv* 2007;70:887.
26. Schranz D, Zartner P, Michel-Behnke I, Akinturk H. Bioabsorbable metal stents for percutaneous treatment of critical recoarctation of the aorta in a newborn. *Cath Cardiovasc Interv* 2006;67:671-3.
27. Ing FF, Fagan TE, Kearney DL, et al. A new "open-ring" stent (abstr). *Circulation* 1996;94:I-57.
28. Ewert P, Riesenkampff E, Neuss M, et al. Novel growth stent for the permanent treatment of vessel stenosis in growing children: an experimental study. *Cath Cardiovasc Interv* 2004;62:506-10.
29. Sigler M, Schneider K, Meissler M, et al. Breakable stent for interventions in infants and neonates: an animal study and histopathological findings. *Heart* 2006;92:245-8.
30. Ewert P, Peters B, Nagdyman N, et al. Early and mid-term results with the growth stent: a possible concept for transcatheter treatment of aortic coarctation from infancy to adulthood by stent implantation? *Cath Cardiovasc Interv* 2008;71:120-6.

Key Words: adolescent ■ aortic coarctation ■ aortic recoarctation ■ pediatric ■ stents.