One- to Ten-Year Follow-Up Results of Balloon Angioplasty of Native Coarctation of the Aorta in Adolescents and Adults

MOHAMED EID FAWZY, MD, FRCP(LOND), FESC, FACC, VASUDEVAN SIVANANDAM, MD, FACA, OMAR GALAL, MD, PhD, BRUCE DUNN, MD, ASHFAQ PATEL, MD, AYMAN RIFAI, MD, WALThER Von SINNER, MD, ZOHAIR Al HALEES, MD, FRCSC, FACS, FACC, BASHIR KHAN, PhD

Riyadh, Saudi Arabia

Objectives. We attempted to evaluate the role of balloon angioplasty in the treatment of discrete coarctation of the aorta in adolescents and adults, with special emphasis on long-term results.

Background. Controversy persists over the use of balloon dilation for the treatment of native coarctation of the aorta.

Methods. Between July 1986 and January 1997, 43 consecutive adolescent and adult patients with discrete coarctation of the aorta underwent balloon angioplasty. One- to 10-year follow-up data of 37 patients, including results of cardiac catheterization and magnetic resonance imaging (MRI), form the basis of this study.

Results. No early or late deaths occurred. Balloon angioplasty produced a reduction in the peak to peak coarctation gradient from a mean ± SD of 69 ± 24 mm Hg (95% confidence interval [CI] 61 to 76) to 12 ± 8 mm Hg (95% CI 10 to 14.8) (p < 0.001). Follow-up catheterization 12 months later (37 patients) revealed a residual gradient of 6.7 ± 6 mm Hg (95% CI 4.6 to 8.9); 3 (7%) of 43 patients had suboptimal results with development of recoarctation, defined as peak gradient >20 mm Hg, with successful repeat angioplasty. A small aneurysm developed at the site of dilation in 3 (7%) of the 43 patients. MRI follow-up data 1 to 10.8 years (mean 5.2 ± 2.7) after angioplasty (37 patients) revealed no new aneurysm or appreciable change in the size of the preexisting aneurysm in the three patients. The blood pressure had normalized without medication in 27 (73%) of 37 patients at follow-up examination.

Conclusions. Balloon angioplasty is safe and effective and should be considered a viable alternative to operation for treatment of discrete coarctation of the aorta in adolescents and adults.

Methods

Study subjects. Between July 1986 and January 1997, 48 adolescent and adult patients with native aortic coarctation presented at King Faisal Specialist Hospital & Research Centre. Four patients were referred to surgery: two who had tubular coarctation with severe hypoplasia of the isthmus and two in whom the wire could not cross the coarctation (interrupted aortic arch). The remaining 44 patients with discrete coarctation underwent balloon angioplasty. The indication for balloon angioplasty was systemic hypertension not controlled by medical treatment.

Balloon angioplasty technique. The technique used for balloon angioplasty has been reported previously (12,13). An angioplasty balloon is selected with a diameter equal to that of the isthmus or 1 to 2 mm smaller than the diameter of the descending thoracic aorta at the level of the diaphragm. Heparin, 2,000 U, was given intravenously before angioplasty. The angioplasty balloon was inflated by hand for 5 to 10 s until the stenotic waist disappeared. Hemodynamic measurements and biplane aortic angiography were performed immediately after the angioplasty.
before and after coarctation angioplasty. Special precaution was taken to avoid manipulating the tip of the catheter or guide wire over the area of freshly dilated coarctation.

**Follow-up evaluation.** Follow-up studies included clinical evaluation, arm blood pressure measurement in the supine position with standard spigmomanometric method and chest radiography. All antihypertensive medications were discontinued at 1 year after dilation and the blood pressure was reevaluated 1 month later. If the blood pressure remained normal, the antihypertensive medication was discontinued indefinitely. Cardiac catheterization with measurement of the gradient across the site of coarctation and aortography was performed 1 year after dilation. MRI was carried out after 1 year at the time of repeat catheterization and annually thereafter for up to 10 years after dilation to screen for aneurysm formation in 37 patients; the data were reviewed by two radiologists (A.R., W.v.S.). Thirteen of 27 patients whose blood pressure normalized without medication underwent treadmill exercise testing according to the Bruce protocol to assess the blood pressure response to exercise.

**Statistical methods.** Data are presented as mean value ± SD and 95% confidence interval (CI). The paired t test was used to compare data before and after angioplasty. Aneurysm-free survival of the patients was studied by using the Kaplan-Meier test. Statistical analyses were performed by using commercially available software (JMP v3.2, SAS).

**Results**

**Study subjects.** Forty-four adolescent and adult patients (30 male) underwent balloon angioplasty for native discrete coarctation of the aorta (Fig. 1) during a 10-year period. Their ages ranged from 15 to 55 years, (mean ± SD 23 ± 8). In one patient, dissection developed that required immediate surgical repair and was without sequelae; she was excluded from analysis. The coarctation was isolated in 38 (88%) of the 43 patients and was associated with a small ventricular septal defect in 1 patient, with an atrial septal defect in 2 patients and with a subaortic membrane in 2. Nineteen patients (44%) had a bicuspid aortic valve. All patients were hypertensive (systolic blood pressure 150 to 260 mm Hg [mean 182 ± 17]).

**Immediate results.** The peak to peak systolic gradient across the coarctation decreased from 69 ± 24 mm Hg (95% CI 61 to 76) to 12 ± 8 mm Hg (95% CI 10 to 14.8) (p < 0.001) (Fig. 2). A reduction in gradient to <20 mm Hg was achieved in 40 (93%) of the 43 patients. Neither paradoxic hypertension nor postcoarctectomy syndrome was observed after dilation of coarctation.

**Suboptimal relief of obstruction.** Suboptimal relief of obstruction, defined as immediate residual systolic gradient >20 mm Hg, was noted in 7% (3 of 43) of the patients. An undersized balloon catheter was used in these three patients because an appropriately sized balloon catheter was not available at the time of the procedure early in our experience.

**Mortality.** There were no immediate or late deaths.

**Complications.** Thrombosis of the right femoral artery developed in one patient who was not heparinized and required surgical thrombectomy.

**Follow-up results.** Two patients (living abroad) were lost to follow-up. Follow-up catheterization and angiography were performed 1 year after dilation in 37 patients. There was no significant change in gradient across the coarctation (range 0 to 20 mm Hg, mean 6.7 ± 6; 95% CI 4.6 to 8.9) (Fig. 2). Thirty-seven patients were followed up by MRI for 1 to 10.8 years (mean 5.2 ± 2.7), and 21 of this group for 5 to 10.8 years (mean 7.2 ± 1.5) (Fig. 3). No new aneurysm or recoarctation was noted (Fig. 4).

Thirty-four (92%) of 37 patients were classified as having a satisfactory outcome, defined as a residual systolic gradient ≥20 mm Hg and no aortic aneurysm.

**Recoarctation.** Recoarctation is defined as peak systolic gradient >20 mm Hg across the coarctation site. Recoarctation developed in three patients (7%). These are the same

**Figure 1.** Aortograms showing discrete coarctation (arrowhead) before dilation (A) and 1 year after dilation (B).
three who had suboptimal relief of obstruction, with a systolic gradient >20 mm Hg immediately after dilation. Successful redilation with an appropriately sized balloon catheter was carried out 6 months later, and the gradient decreased (range 5 to 15 mm Hg) in all three and remained low at restudy by catheterization 12 months later (Fig. 2).

Aneurysms. The follow-up angiogram at 12 months and the serial MRI up to 10 years after the initial dilation were scrutinized for aneurysm formation at the site of balloon angioplasty, as described previously (13). A total of three aneurysms were observed, both on angiography and MRI, giving an incidence of 7%. These aneurysms were small, measuring 2 to 2.3 cm in diameter, and could not be detected on chest X-ray film. No appreciable change in the size of the aneurysms warranting surgical intervention was noted on follow-up MRI up to 9 years later (Fig. 5).

Figure 3. Bar graph depicting the number of patients followed up for 1 to 10 years.

Figure 4. Serial MRI of the patient whose aortograms are shown in Figure 1. A, Two years after dilation. B, Ten years after dilation. C, MRI cine 10 years after dilation shows excellent results, with no aneurysm or recoarctation.

Normalization of blood pressure. The blood pressure was normal (<140/90 mm Hg) without medication in 27 (73%) of 37 patients at follow-up evaluation 1 year after angioplasty. Ten patients required treatment to control their blood pressure. Thirteen of the 27 patients with normal systolic pressure without medication underwent exercise testing during which the systolic blood pressure at peak exercise did not exceed 200 mm Hg.

Event-free survival rates. Event-free survival, defined as freedom from aneurysm, was 92% at 1 year, and this level was maintained throughout the follow-up period (Fig. 6).

Discussion

Our data are consistent with previous studies (14–17) demonstrating the efficacy of balloon angioplasty in children, adolescents and adults with discrete native coarctation of the aorta. Recently, a comparative study (17) showed that the results of balloon dilation in native and previously surgically treated coarctation are comparable. It is worth mentioning that balloon dilation for recoarctation has been regarded as a treatment of choice. In our 10-year experience at our institu-
tion, 40 (92%) of 43 patients with native coarctation had a satisfactory angioplasty result, defined as a residual gradient \( \leq 20 \) mm Hg, with no aortic aneurysms. However, we excluded four additional patients: two with a tubular type of coarctation deemed unsuitable for balloon dilation and another two in whom we could not cross the coarctation (interrupted aortic arch).

**Aneurysm formation.** Aneurysm formation at dilation sites remains a long-term concern. Aneurysm formation after coarctation angioplasty has been reported previously (7–15,18,19). In five large series (7,8,14–16), the incidence of aneurysm formation varied from 1.8% to 5.7%, a finding that is corroborated by our results. The aneurysms in the present series were small bulges, nondetectable on chest radiography and without an appreciable change in size at follow-up MRI up to 9 years later. Early reports of Brandt et al. (18) and Cooper et al. (19) noted a significant incidence of aneurysm formation during a short-term follow-up period.

It has been postulated (20) that aneurysm development may be due to the use of an oversized balloon or misinterpretation of native anatomic irregularities in the aortic contour as an aneurysm. Two of the three patients in our series who had a small aneurysm after angioplasty had been treated with a larger balloon, 2 to 3 mm greater than the size of the isthmus, used early in our experience. The importance of avoiding overdistention of the coarctation segment by careful balloon size selection is now better appreciated, and guide wire and catheter manipulation across the freshly dilated coarctation segment is known to increase the risk of aortic dissection (21).

Disruption of a part or all of the media and the presence of localized “cystic medial necrosis” have been postulated (21–23) as the underlying mechanisms of aneurysm formation after coarctation balloon angioplasty. Sohn et al. (24), using intravascular ultrasound (IVUS), demonstrated that, despite a high incidence of dissection detected by IVUS immediately after dilation of native or recurrent coarctation, many vessels re-model with a decrease in the size or disappearance of intimal flaps and dissection spaces. Even significant intimal tears after dilation have not been associated with aneurysm formation at short- or mid-term follow-up.

Although development of aneurysms after balloon angioplasty is of concern, aneurysms are also known to develop after surgical repair of coarctation, especially after patch aortoplasty, with incidence varying from 11% to 30% (2,5,25–27). The postsurgical aneurysms are defined as a ratio \( > 1.5 \) of the repair site to the descending aorta at the level of the diaphragm. Close follow-up is required for patients with or without aneurysms, and we (13) found that MRI is the best noninvasive method of following up patients who underwent coarctation balloon angioplasty. We suggest MRI in addition to annual chest radiography to be carried out after the 1st year and every 2 to 3 years thereafter. We believe that repeat catheterization and angiography after 1 year are unnecessary if MRI is available.

**Coarctation restenosis.** Restenosis is common after coarctation angioplasty in infants (8,9,15,28), as is the case with surgical repair, and it is uncommon after angioplasty in children and adults (8,12,14,15). We noted recoarctation in three patients (7%) at follow-up study after angioplasty. These three patients had suboptimal results with a residual gradient \( > 20 \) mm Hg immediately after dilation. This was encountered during our early experience, when an under-
sized balloon catheter was used in these three patients because of the unavailability of the appropriately sized balloon catheter at the time of the procedure. After all three underwent redilation with an appropriately sized balloon, results were satisfactory and have remained so.

Contrary to the findings of McCrindle et al. (17), we did not encounter a suboptimal outcome or a poor result in older patients or patients with a higher systolic pressure gradient before angioplasty.

**Normalization of blood pressure.** Blood pressure was normal (<140/90 mm Hg) at follow-up without antihypertensive medication in 27 (73%) of 37 patients. Thirteen of normal (140/90 mm Hg) at follow-up without antihypertensive medication. The incidence rate of late hypertension in 320 patients who were ≥15 years old at the time of coarctation repair. Data from another series of surgically treated patients (27) can be compared with the data of our patients. In that series, the investigators reported on the long-term results after patch aortoplasty in 68 adults aged 15 to 54 years (mean 27) at a mean follow-up interval of 8.8 years (range 2 to 14). The incidence rate of late postoperative hypertension was >50%. Wells et al. (29) reported a 46% rate of normalization of hypertension without medication after repair of coarctation in adults. Contrary to the findings of Schröder et al. (16), we found no relation between persistence of hypertension and a residual gradient ≥30 mm Hg. In our 10 patients with persistent hypertension, the residual gradient was ≤20 mm Hg.

**Conclusions.** The data presented and those reviewed from published reports show that balloon angioplasty is effective and safe in the treatment of discrete native coarctation of the aorta. When assessed with the use of historical control subjects, the results of balloon angioplasty compare favorably with the reported results of surgical repair and are associated with less morbidity and lower cost. In addition, arterial blood pressure normalized without medication in 73% of our cases. We believe that balloon angioplasty should be considered a viable alternative to surgery for treatment of discrete coarctation of the aorta in adolescents and adults.

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**References**


