Detection of Dissection of the Aortic Intima and Media after Angioplasty of Coarctation of the Aorta

An Angiographic, Computer Tomographic, and Echocardiographic Comparative Study

R. Erbel, MD, I. Bednarczyk, cand-med, T. Pop, MD, M. Todt, MD, K.J. Henrichs, MD, A. Brunier, MD, M. Thelen, MD, and J. Meyer, MD

Balloon coarctation angioplasty (BCA) was performed in eight patients (five male and three female) who were 14–49 years old (mean, 27.3 years) with isolated discrete unoperated coarctation of the aorta (n=7) and postoperative recoarctation (n=1). BCA was successful in seven of eight patients, resulting in a decrease in the gradient (64±19 to 16±13 mm Hg, p<0.01), an increase in the diameter at the coarctation site (0.9±0.4 to 1.6±0.4 mm, p<0.01). Follow-up (6 months) has demonstrated continued gradient relief (6±9 mm Hg) and diameter increase (1.6±0.2 cm). Monitoring was performed by transesophageal echocardiography (TEE) during BCA, and before and after BCA angiography and after BCA computed tomography. In three of seven patients, immediately distal to the BCA site, intimal flaps (1–2 cm) could be detected by TEE but not by angiography or computed tomography. Follow-up TEE showed spontaneous healing in two and persistence in one patient. By TEE and computed tomography in one of eight patients during follow-up, intima and media dissection was found with pleural effusion and spontaneous healing. In one female patient, aortic dissection occurred after successful uneventful BCA, detected by TEE at the 6-month follow-up study and subsequently confirmed by biplane angiography, not detected by computed tomography and previous monoplane angiography. Because of the significant morbidity of BCA in this group of patients, its role in the management of adults with coarctation has yet to be determined. Further long-term follow-up studies will demonstrate whether the observed intima and media dissection by TEE after BCA are related to aneurysm formation. (Circulation 1990;81:805–814)

Coarctation of the aorta is usually detected during childhood, and the patient is referred for surgery. Percutaneous transluminal angioplasty (PTA), introduced by Gruentzig in 1977 for coronary arteries, was rapidly adopted as a method for treating children with pulmonary and aortic valve stenosis.1–4 Even cases of peripheral stenosis of the pulmonary artery have been successfully dilated.5 Because it was demonstrated that it is possible to perform postmortem PTA for coarctation of the thoracic aorta,6 this procedure has been successfully used in children.7–14 Reports of aneurysm formation15 related to cystic medial necrosis demonstrate the potential risks of this method.16 The mechanisms that are involved seem to be stretching of the media and rupture of the intima or media, as demonstrated in particular by Lock et al17 and confirmed by others.18 Transesophageal echocardiography has been proven a reliable method for scanning the aorta and the coarctation site by means of cross-sectional images.19 Additionally, it is possible for a dissection of the aorta to be visualized with high accuracy by transesophageal echocardiography.20,21 High-resolution tomographic images of the descending aorta in multiple planes can be obtained. Transesophageal echocardiography was, therefore, used to monitor PTA of coarctation of the aorta to provide information about morphological and functional changes of the aorta in adult patients.

Methods

Between October 1986 and March 1988, balloon coarctation angioplasty was performed in eight
patients (five male and three female) with discrete postductal coarctation who were 14–49 years old (mean, 27.3 years) and had isolated discrete unoperated coarctation of the aorta (n=7) or postoperative recoarctation after dacron interposition (n=1).

After having provided informed consent, patients in the fasting state came to the catheterization laboratory. The right femoral vein was cannulated, and right sided hemodynamics were measured with a Swan-Ganz catheter. Then, the right femoral artery was cannulated, and a pigtail catheter was inserted to measure left ventricular pressure (Statham DB, 23 i.d.). Cineventriculography was performed in biplane 30° right anterior oblique and 60° left anterior oblique projections for analysis of left ventricular function and mass; a total of 40 ml iopromid was injected at a rate of 14 ml/sec. Aortography was performed in the 40–60° left anterior oblique projection to fully visualize the aortic arch. A 7F pigtail catheter was then inserted into the opposite femoral artery using the Seldinger technique to simultaneously measure the aortic pressure proximal and distal to the coarctation. Each patient received 5,000 units heparin and 100 ml/hr low–molecular-weight dextran to inhibit platelet deposits at the dilation site and to counteract a possible decline in pressure.

A flexible-tip J guide wire was passed into the ascending aorta through the catheter. The angiographic catheter was replaced by a balloon catheter (Schneider Medintag) by means of a long wire. The size of the balloon first used in adult patients was 15 mm. A larger one was used where there was residual gradient measurement.3,10,14 The balloon was less than twofold the size of the coarctated aortic segment.22 The balloon was between 4 cm (n=4) and 6 cm (n=4) long. A balloon length of 6 cm was chosen to avoid dislodgment during inflation, which could stretch adjacent parts of the aorta. Using fluoroscopy, the position of the balloon was confirmed by its hourglass appearance during the inflation phase.22 The balloon was inflated with 1:1 with sodium chloride diluted contrast material. Air bubbles were carefully eliminated from the balloon. After the dilation, the guide wire was left in place above the coarctation, and the catheters were exchanged over the wire. Angiography was performed with the same amount of contrast material in the same projection as before. At no time was a catheter or guide wire manipulated over the area of the freshly dilated coarctation site. The catheter was withdrawn after the procedure. Heart catheterization was repeated 6 months later using angiography in the same projections. The procedure was regarded as successful if the peak gradient was less than 30 mm Hg.

Transesophageal echocardiography was performed after informed consent. Lidocaine spray was used for local anesthesia of the pharynx. Additionally, 0.324 mg bumorphine was administered intravenously 15 minutes before the procedure for better tolerance of the echoscope. Coughing is otherwise induced by examining the upper portion of the aorta and by scanning the aorta near the bifurcation of the trachea. When all preparations were finalized for the balloon dilation, the echoscope was inserted up to 44 cm to image the heart in standard positions,23 and scans of the left and right heart and the aortic and mitral valves were made. The thoracic aorta was also scanned, as previously described.20 At a depth of 20–45 cm, the descending aorta was visualized in echomorphographic slices. At a depth of 20–30 cm, the echoscope was withdrawn in 3–5-mm steps, at each of which the aorta was scanned to detect the coarctation site, which was recognized by the slightly increased distance between the aorta and the esophagus.19 The aorta was analyzed where its cross-sectional area was smallest. Because images taken during positioning of the catheter were disturbed by the multiple artifacts produced by the catheter and the balloon, the aorta was continuously imaged 1–2-cm distal to the coarctation site. To avoid aspiration, patients were asked to turn the head to the left and 0.5–1.0 mg atropine was administered intravenously before the procedure. The transesophageal echocardiographic probe was withdrawn immediately after pressure-gradient measurement and scanning of the aorta. The probe was in place for 15–20 minutes. Echoesopes (Diasonics, Palo Alto, California) or echofiberscopes (Toshiba, Osaka, Japan) with 3.5 and 3.75 MHz transducers connected to Diasonics 6400 R (Diasonics) and Toshiba SSH 65 A (Toshiba) machines, respectively, were used. For transesophageal Color Doppler echocardiography only the Toshiba SSH 65 A was used. All recordings were stored on continuous video tape (VHS). Transesophageal examinations of the aorta were repeated after 6 months. Computed tomography was performed 24–48 hours after PTA of coarctation of the aorta, with scan times of 4 seconds in four patients and 6 seconds in two patients (Somatom). Single and mean values and standard deviations are given for each measurement. The Student’s t test was used to compare data obtained before and after PTA. The level of statistical significance was set at 0.05.

Results

The results of measurements made before and after the procedure, including the angiographic measurements of the coarctation site, are given in Tables 1 and 2. Dilation was successful in seven of eight patients. It was unsuccessful in one patient who had previously undergone surgical correction (Dacron prosthesis) and had a residual stenosis. Restenosis was observed in this patient on follow-up after 6 months. No aneurysm formation was found in any of the patients. Angioplasty balloon rupture did not occur. In one patient, a balloon angiographic catheter ruptured during angiography through the distal lumen, causing the balloon to be filled at a rate of 10 ml/sec; the injection was immediately interrupted. Only one patient showed an increase in blood pressure in the ascending aorta after angioplasty but it did not exceed 160 mm Hg. No side effects occurred.
After dilation, the femoral pulse increased in all patients. No surgical intervention of the puncture site was necessary. Angiography performed immediately after dilation did not demonstrate aortic dissection in any patient. Also, the follow-up angiography in the 60° left anterior oblique projection of patient 6 was negative. Because of a suspected aortic dissection, as shown by transesophageal echocardiography, an additional biplane angiography of the descending aorta was performed in the posterior anterior and 90° left lateral projections and revealed a type III aortic dissection starting distally to the coarctation site and extending into the right femoral artery (Figure 1).

The results of echocardiography are listed in Tables 1 and 2. Immediately after angioplasty, there was a significant increase in diameter at the coarctation site, which was followed by a narrowing of the lumina in the subsequent 6 months in some patients (Table 1). There was no detectable aneurysm formation. In three patients, 0.5-1-cm long intimal flaps that extended over a length of 2-3 cm were found immediately after dilation (Figure 2). Each of these patients suffered from pain during balloon inflation, which disappeared immediately after deflation. In two of these patients, the flaps could not be visualized after 6 months. The flap persisted in only one patient (Figure 2).

In one of the other patients, pain did not disappear after deflation of the balloon and persisted for 15 minutes. Transesophageal echocardiography demonstrated medial dissection (Figure 3), thickening of the aortic wall, and entry tear. Additionally, pleural effusion developed. Six months later, the dissection had healed spontaneously and only a slight thickening of the aortic wall was present.

In patient 6, transesophageal echocardiography was not possible during the procedure because of adverse gastric reaction and the patient's anxiety. The patient suffered from severe thoracic pain 3 days after dilation, and the patient developed symptoms of intermittent claudication that persisted; digital subtraction angiography was negative. Pressure difference between arm and right leg measured 30 mm Hg. Transesophageal echocardiography 6 months later showed a type III dissection (Figure 4). Color-coded Doppler blood flow imaging showed a flow in the false and true lumen.
Table 2. Hemodynamic Data Before, Immediately After, and 6 Months After Balloon Angioplasty of Coarctation of Aorta

| Patient | Mean ±SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---------|----------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age (yr) | | 14 | 49 | 24 | 22 | 21 | 48 | 20 | 20 | | | | | |
| Sex | | M | M | F | M | F | M | M | F | | | | | |
| Pressure from ascending aortic | | | | | | | | | | | | | | |
| S A | | 168 | 180 | 176 | 140 | 132 | 170 | 192 | 130 | | | | | |
| B | | 136 | 116 | 159 | 101 | 128 | 178 | 120 | 130 | | | | | |
| C | | 110 | 140 | 168 | 128 | 128 | 133 | 128 | 133 | | | | | |
| D A | | 100 | 95 | 55 | 80 | 71 | 64 | 96 | 75 | | | | | |
| B | | 101 | 63 | 67 | 50 | 109 | 70 | 72 | 75 | | | | | |
| C | | 50 | 88 | 52 | 90 | 76 | 64 | 90 | 68 | | | | | |
| M A | | 126 | 124 | 97 | 100 | 97 | 100 | 115 | 93 | | | | | |
| B | | 117 | 84 | 102 | 61 | 139 | 103 | 91 | 94 | | | | | |
| C | | 70 | 102 | 92 | 104 | 93 | 85 | 104 | 83 | | | | | |
| Pressure from descending aortic | | | | | | | | | | | | | | |
| S A | | 87 | 95 | 109 | 92 | 66 | 100 | 120 | 100 | | | | | |
| B | | 133 | 112 | 118 | 84 | 162 | 152 | 116 | 112 | | | | | |
| C | | 105 | 140 | 144 | 126 | 128 | 128 | 130 | 112 | | | | | |
| D A | | 74 | 70 | 50 | 60 | 51 | 60 | 100 | 75 | | | | | |
| B | | 103 | 67 | 60 | 50 | 98 | 68 | 72 | 75 | | | | | |
| C | | 50 | 88 | 60 | 83 | 76 | 64 | 90 | 76 | | | | | |
| M A | | 81 | 78 | 74 | 67 | 59 | 93 | 106 | 80 | | | | | |
| B | | 117 | 86 | 83 | 75 | 124 | 95 | 87 | 79 | | | | | |
| C | | 68 | 102 | 88 | 97 | 93 | 85 | 103 | 88 | | | | | |
| Peak-to-peak gradient | | | | | | | | | | | | | | |
| A | | 81 | 85 | 67 | 48 | 66 | 70 | 32 | 30 | | | | | |
| B | | 3 | 4 | 41 | 17 | 16 | 18 | 12 | 18 | | | | | |
| C | | 5 | 0 | 24 | 7 | 0 | 0 | 3 | 12 | | | | | |
| Maximal gradient | | | | | | | | | | | | | | |
| A | | 120 | 94 | 84 | 52 | 74 | 112 | 40 | 30 | | | | | |
| B | | 12 | 16 | 44 | 40 | 20 | 12 | 12 | 20 | | | | | |
| C | | 5 | 0 | 57 | 5 | 0 | 0 | 0 | 20 | | | | | |
| Mean gradient | | | | | | | | | | | | | | |
| A | | 45 | 64 | 42 | 33 | 38 | 71 | 23 | 22 | | | | | |
| B | | 2 | 0 | 14 | 14 | 15 | 8 | 6 | 4 | | | | | |
| C | | 2 | 0 | 36 | 3 | 0 | 0 | 0 | 4 | | | | | |

M, male; F, female; S, systolic pressure; D, diastolic pressure; M, mean pressure; A, before dilatation; B, after dilatation; C, 6-month control; SD, standard deviation (all pressure data in mm Hg).

*p < 0.05, C vs. A; t < 0.05, B vs. A; tp < 0.05, C vs. B.

Transesophageal color Doppler echocardiography, in five of eight patients in whom it was performed, demonstrated a turbulent flow pattern in the whole lumen distal to the coarctation, which did not change after angioplasty. After 6 months, color Doppler demonstrated persistent turbulent flow patterns in all patients. In patient 6, entry tear at the end of the aortic arch was detected (Figure 4), and true and false lumen could be differentiated by the systolic flow in the true lumen and the jet direction of the entry site on flow patterns (Figure 4).

Computed tomography revealed typical narrowing at the coarctation site. No pathological findings were observed in six patients, including the two patients with intimal flaps. In patient 5, a short dissection with pleural effusion was visualized by computed tomography at the same part of the aorta as it was by transesophageal echocardiography (Figure 4, Top panel). Entry tear could not be seen. The 6-month follow-up revealed only a slight thickening of this part of the aorta (Figure 4, Bottom panel). Computed tomography in patient 6 was negative 1 day after dissection; no pathological findings were detected by computed tomography 6 months later. In the ascending aorta or the aortic arch, aortic dissections were not visualized by aortography or computed tomography. Also, suprasternal scanning of the aortic arch and transesophageal imaging of the ascending aorta were negative.

Discussion

This study demonstrates that balloon angioplasty can be used to treat coarctation of the aorta in adults
FIGURE 1. Angiography of aorta in left anterior oblique 60° (Panel A) and lateral projection (Panel B) 6 months after angioplasty demonstrating type III aortic dissection distal to coarctation that developed 3 days after procedure, only visible in lateral projection. It was not detected by computed tomography and intravenous digital subtraction aortography.

FIGURE 2. Transesophageal two-dimensional and M-mode echocardiograms of aorta distal to coarctation site before and immediately after procedure with formation of intimal flap.
Figure 3. Transesophageal two-dimensional echocardiographic imaging of aorta before (top panel) and after (bottom panel) angioplasty of coarctation of aorta, demonstrating medial dissection over 15 cm distally with spontaneous healing after 6 months.

younger than 50 years old. The success rate is comparable with that reported in previous studies using PTA in children and young adults. Long-term results of these studies demonstrate that patients in whom the pressure gradient could be reduced by at least 20 mm Hg did not develop restenosis. These
results are in agreement with reports that patients showing a 30% or larger increase in the diameter of the dilated segment and a 15% or larger increase across the coarctation site are likely to have a good clinical response.\(^\text{26}\) Low restenosis and redilation rates have also been reported for children.\(^\text{14,22,27}\) Restenosis occurred in our study in only one patient, that is, a patient who had undergone previous surgical repair of the aorta with interposition of a Dacron prosthesis. Despite the fact that we applied high pressures, only a minimal effect was observed in this patient. Other authors report better results from dilation in surgically repaired coarctation of the aorta.\(^\text{10,22}\)

Beekman and Roccini\(^\text{28}\) suggested that a preangioplasty gradient greater than 50 mm Hg might indicate a poor long-term result. But both our study and that by Rao et al,\(^\text{22}\) with limited numbers of patients, do not support this view.

Previous descriptions report that patients experienced pain during dilation and that morphine derivatives were sometimes necessary;\(^\text{25,26}\) in some studies general anesthesia was used.\(^\text{29}\) This seems to be related to overstretching of the aorta as indicated by dissection of the intima and media. In this study, pain was noticed only by those patients in whom dissection occurred, demonstrated by transesophageal echocardiography as intimal or medial dissection. Pain is possibly related to the distension not only of the intima and media but also of the adventitia. In PTA of coarctation of the aorta, the balloon can cause tears of the intima or media.\(^\text{17,18}\) Such dissection can be detected by transesophageal echocardiography. As differential diagnosis of the intimal flap, thrombus formation has to be considered. The free-floating dense echoes in all cases were detected immediately after deflation of the balloon and were located at the vessel wall site where the media dissection was found. The intimal flaps were found with one end at the aortic wall and not at the catheter. Thus, it seems more likely that these structures are because of intimal flaps rather than thrombus formation. These results are in contrast to previous reports of studies in which the effect of PTA of coarctation was examined by aortography. Those studies did not notice aortic dissection but described irregularities of the aorta at the dilation site.\(^\text{22,25,29}\) Aortography, as used in these studies, is only a contour method. The present study demonstrates that intimal or medial dissection after dilation of coarctation can occur, taking place in the outer contour of the aorta at the left posterior wall. Aortography in only one plane can give false-negative results but was used in some previous reports,\(^\text{11,28,29,37}\) whereas others used biplane aortography.\(^\text{14,25,26,34}\) Biplane aortography has not been recommended in all textbooks and is not performed with the current digital subtraction angiography equipment. This technique would allow only nonsimultaneous biplane angiography. Intimal flaps were very small, showed rapid movement, and
FIGURE 5. Computed tomographic imaging of thoracic aorta of patient 2 (see Figure 4) with media dissection immediately (top panel) and 6 months (bottom panel) after angioplasty of coarctation of aorta, demonstrating acute dissection with pleural effusion and spontaneous healing with residual wall thickening. Involved part of vessel wall is in agreement with transesophageal echocardiography (Figure 4).

were within the aortic lumen, so that they could not be visualized by aortography. Previous reports have documented other false-negative results of aortography.\textsuperscript{30,31} As compared with computed tomography and transesophageal echocardiography, aortography has a lower sensitivity and specificity in detecting aortic dissection.\textsuperscript{31} Similarly, computed tomography was not able to detect the small intimal flaps in three patients and the medial dissection in one of two affected patients. This might be related to the long scan times of 4 seconds, which make it impossible to demonstrate rapidly moving flaps, as previously reported.\textsuperscript{20} The specificity of computed tomography is high but its sensitivity is rather low in comparison with other methods.\textsuperscript{30} One major limitation of the presented transesophageal echocardiographic recordings is the pure resolution in the near field of the 3.5 and 3.75 MHz transducer. Newer
probes with 5 and 5.6 MHz transducers will improve resolution, which will make this technique even more important in the catheterization laboratory for this application.

Concerning the evaluation of the success of dilation, transesophageal echocardiography is not superior to pressure gradient measurement.

In previous published reports (Table 3) with detailed information on angioplasty of coarctation of the aorta in young adults, balloon size always exceeded 15 mm with coarctation diameters of 4–7 mm14,22,24–26 and a balloon coarctation ratio of 2.0–3.829 which are figures similar to those in our study. Balloon pressure was in the range of 3–9 atm,14,22,24,26,29 as in our report. Balloons were inflated for 10,14 25–60,17 and 10–60 seconds,25 which are similar to the lengths of time in our procedure. Balloon length measured 20–40,25 30,14 and 30–40 mm.22 The balloon length of 60 mm used in this study was not previously reported. The longer balloons we used cannot be ruled out as a possible cause of the observed intimal and medial tears. Tears, however, were observed in 3 of 4 patients in whom a trefoil 40-mm balloon catheter was chosen.

Because of the chance of aortic dissection during PTA, careful monitoring of blood pressure seems to be necessary. Hypertension crises are known to occur after surgical correction of aortic dissection and can be treated by β-blocking agents.31 Antihypertensive treatment should be available to treat such reactions after angioplasty of coarctation of the aorta. Previous hypertensive treatment should be reduced and careful blood pressure monitoring should be instituted. The dissection that occurred on day 3 after angioplasty in one patient might have been induced by a hypertensive crisis. No patient required antihypertensive drugs after 6 months, which emphasizes the favorable hemodynamic results.

The majority of reports12,14,22,27,28 did not detect aneurysm formation during long-term follow-up studies. Some recent studies report aneurysm formation in the region of the previously dilated coarctation segment 12 months after angioplasty, in the range of 10–20%,32–34 to 43% (three of seven patients).15 In our study, no aneurysm formation was found in adults during follow-up but the follow-up time might have been too short.

Aneurysm formation has also been found after surgery in 7% of the patients during a follow-up period of 4–16 years,36 as well as in 22% of the patients after Dacron patch angioplasty over a follow-up period of 5 years37 and 38% over a follow-up period of 14 years.38 Aneurysm formation was not observed after end-to-end anastomosis.37 Follow-up studies must determine whether patients with intimal or medial dissection, or both, as detected by transesophageal echocardiography, have a greater risk of aneurysm formation than patients without dissection.

**Clinical Implications**

Dilation of coarctation of the aorta is possible with a high rate of success even in adult patients. This eliminates the necessity for surgery and anesthesia, provides for a shorter hospital stay, and keeps costs low. Intimal or medial dissection of the aorta, or both, can occur and can be detected by transesophageal echocardiography during monitoring of the procedure. The dissection can be a major problem because the aneurysm formation can represent a contraindication to the balloon dilation of native coarctation in adult patients. Future studies must analyze whether these patients are at an increased risk of aneurysm formation at the dilation site.

**Acknowledgments**

We thank Mrs. Pahlen and Mrs. Herbrik for their secretarial assistance, Mrs. Meurer for the graphics, and Mrs. Pirch and Mrs. Sayah for the photography.
References

16. Isner JM, Donaldson RF, Fulton D, Bhan I, Payne DD, Cleveland RJ: Cystic medial necrosis in coarctation of the aorta: A potential factor contributing to adverse consequences observed after percutaneous balloon angioplasty of coarctation sites. Circulation 1987;75:689–695

KEY WORDS - aorta • aortic coarctation • aortic dissection • aortic aneurysm • angiography • echocardiography • computed tomography • transesophageal echocardiography angioplasty
Detection of dissection of the aortic intima and media after angioplasty of coarctation of the aorta. An angiographic, computer tomographic, and echocardiographic comparative study.

R Erbel, I Bednarczyk, T Pop, M Todt, K J Henrichs, A Brunier, M Thelen and J Meyer