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Doppler Evaluation of Femoral Arteries in Children After Aortic Balloon Valvuloplasty or Coarctation Balloon Angioplasty

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SUMMARY. **To assess long-term femoral artery complications after aortic balloon valvuloplasty or coarctation balloon angioplasty, we examined 19 children who were 3 weeks to 21 years old (mean 7.6 years) at the time of catheterization. Two-dimensional and Doppler echocardiographic examinations of the common, superficial, and deep femoral arteries were performed at an average of 2.0 years after balloon dilatation. Pulsatility index (PI) was calculated as the maximum velocity minus the minimum velocity divided by the mean velocity. No patient was suspected clinically of having peripheral arterial disease prior to the echocardiographic examination. Fourteen patients had normal femoral arteries. Of these, 10 had normal two-dimensional and Doppler echocardiographic examinations of both femoral arteries. These patients had triphasic flow patterns (forward in systole, reverse in early diastole, forward in mid-diastole) and PIs of 3.7–41.6 (mean 9.5). Four of the 14 normal patients had abnormal pulsed Doppler examinations showing continuous forward flow and low PIs (1.7–3.5) reflecting residual coarctation (10–30 mmHg gradients). Five patients had abnormal femoral arteries. Of these, two had no visible obstruction by two-dimensional echocardiography and color-flow imaging but had abnormal pulsed Doppler patterns (continuous forward flow and low PIs of 2.5 and 2.9) only on the side of the balloon catheter insertion. Three of the five abnormal patients had visible obstructions by two-dimensional echocardiography and color-flow imaging and had abnormal pulsed Doppler patterns (continuous forward flow and low PIs from 1.1–3.6). One of these three had bilateral occlusions of the common femoral arteries with multiple collateral vessels; the second had occlusion of the right common femoral artery; and the third had 1–2-cm long severely narrowed segments in both common femoral arteries. All three children were <1 year old at the time of catheterization and had balloon catheter insertions in the affected arteries.**

Echocardiography provides a useful technique for detection of clinically unsuspected but significant arterial obstruction after balloon dilatation. Thus, echocardiographic examinations of the femoral arteries should be performed on all children after balloon dilatation, particularly those <1 year old at the time of the procedure.

KEY WORDS: **Doppler echocardiography — Femoral arteries — Balloon dilatation**

The use of balloon dilatation procedures for the treatment of left heart obstructive lesions has increased in frequency over the past several years. These procedures require arterial entry with large balloon catheters of irregular contours. Several studies of arterial complications following percutaneous cardiac catheterization have reported a variable incidence of femoral artery injury depending on the ages of the patients studied and the techniques used [3, 6, 7, 10, 12–14]. These reviews of femoral artery complications from percutaneous cardiac catheterization in children were performed before the advent of left heart balloon dilatation procedures. Little information is available concerning the occurrence of femoral artery injury or obstruction with these procedures [1]. The objective

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Table 1. Demographic, catheterization, and echocardiographic data for each patient

Patient	Age (yr)	Treated lesion	F/U interval	Balloon size used		Abnormal echo exam		PI	
				RFA	LFA	RFA	LFA	RFA	LFA
1	0.06	AS	1.6	5 mm	6 & 8 mm	Total	Total	2.1	1.1
2	0.08	AS	0.4	7 mm	NE	Total	No	2.5	5.5
3	0.5	Coarc	4.8	5 mm	4 pig	No	No	3.3	2.7
4	0.7	AS	1.1	6 mm	6 mm	Partial	Partial	3.5	3.6
5	1.2	AS	1.9	6 & 8 mm	6 mm	No	No	4.5	4.3
6	1.8	Coarc	3.9	10 mm	4 pig	Partial	No	2.9	5.8
7	3.0	Coarc	1.8	8 mm	NE	No	No	2.9	2.2
8	4.3	Coarc	1.7	10 mm	NE	No	No	2.7	3.5
9	4.8	AS	1.2	8 mm	8 mm	No	No	5.7	3.7
10	5.7	AS	3.7	12 mm	5 pig	Partial	No	2.5	6.6
11	6.6	AS	1.5	10 mm	10 mm	No	No	8.4	5.8
12	7.0	AS	2.9	12 & 15 mm	5 pig	No	No	6.0	6.3
13	9.2	AS	3.4	18 mm	18 mm	No	No	6.5	6.6
14	12.3	AS	1.7	18 & 20 mm	18 & 20 mm	No	No	10.1	8.9
15	13.0	AS	0.5	12 mm	12 mm	No	No	2.0	1.7
16	15.6	AS	2.0	20 mm	20 mm	No	No	8.4	7.7
17	17.9	AS	1.3	20 mm	20 mm	No	No	8.8	8.4
18	20.1	AS	1.2	15 mm	15 mm	No	No	6.3	8.0
19	20.8	AS	1.3	18 mm	15 mm	No	No	41.6	23.2

AS, aortic stenosis; Coarc, coarctation of the aorta; F/U, follow-up; LFA, left femoral artery; NE, not entered; PI, pulsatility index; RFA, right femoral artery.

of this study was to assess the intermediate- and long-term femoral artery complications in children who had undergone aortic balloon valvuloplasty or coarctation balloon angioplasty.

Methods

Patients

The study patients were randomly selected from all children who had previously undergone aortic balloon valvuloplasty or coarctation balloon angioplasty and who were being seen in the outpatient clinic for routine evaluation between October 1988 and May 1990. Patients were excluded from the study who (1) had placement of a femoral artery catheter in the interval between balloon dilatation and the echocardiographic examination or (2) had prior cardiac surgery and placement of femoral artery cannulae. Using these criteria, the study group included 19 children (14 with aortic stenosis, three with coarctation of the aorta, and two with both aortic stenosis and coarctation of the aorta). Fifteen patients had prior aortic balloon valvuloplasty and four patients had prior coarctation balloon angioplasty. The majority of dilatations were performed using Meditech balloon dilatation catheters. No sheath was placed in the femoral artery for any patient. At the time of interventional catheterization, the patients' ages were from 3 weeks to 21 years (mean 7.6 years). The mean interval from the catheterization to the follow-up echocardiographic evaluation was 2 years (range 0.4–4.8 years). Prior to the echocardiographic examination, no patient was clinically suspected of having femoral artery obstruction.

Echocardiographic Examination

All patients underwent two-dimensional echocardiographic, pulsed Doppler, and color Doppler examinations of the common, superficial, and deep femoral arteries using a 128-element, phased linear array system with 7.5- and 5-MHz transducers (Acuson, Mountain View, CA, USA). Two-dimensional images were evaluated for evidence of anatomic narrowing. Color Doppler images were utilized to detect disturbed flow at narrowed regions or to confirm the absence of flow at imaged sites of obstruction. The pattern of flow was evaluated with pulsed Doppler echocardiography. Recordings were corrected for intercept angle when necessary, but no angle correction greater than 60° was used. The pulsatility index (PI) was calculated for each common femoral artery as the maximum velocity minus the minimum velocity divided by the mean velocity [4, 5, 8, 9]. Normal values for the PI in the femoral artery are age-dependent and have been reported to range from 3.7 ± 0.9 in premature infants to 8.4 ± 3.1 in adults [2, 8]. When adequate tracings from the common femoral artery could not be obtained, the superficial or deep femoral artery was used for calculation of the PI. For each patient, three cardiac cycles were measured and averaged.

Results

The pertinent demographic, catheterization, and echocardiographic data for each patient are summarized in Table 1.

Normal Femoral Arteries

Fourteen patients had normal femoral arteries. Ten of the 14 patients had normal two-dimensional echocardiographic, pulsed Doppler, and color Doppler examinations of both femoral arteries. These patients ranged in age from 1.2–20.8 years at the time of catheterization. On the Doppler examinations, these patients had triphasic flow patterns and PIs of 3.7–41.6 (mean 9.5). One patient had a PI of 41.6 due to severe aortic insufficiency. All others had PIs <10.6 (mean 5.9). Figure 1A shows a color Doppler image from a normal patient illustrating nondisturbed flow in the common, superficial, and proximal deep femoral arteries. The pulsed Doppler recording from this patient (Fig. 1B) shows a typical normal triphasic flow pattern (forward in systole, reverse in early diastole, forward in mid-diastole).

Four of the 14 patients with normal femoral arteries had normal two-dimensional echocardiographic and color Doppler examinations, but their pulsed Doppler examinations showed continuous forward flow and low PIs (range 1.7–3.5) reflecting residual coarctation gradients of 10–30 mmHg. These patients were 0.5, 3.0, 4.3, and 13 years old at the time of catheterization.

Abnormal Femoral Arteries

Five patients had abnormal femoral arteries. Two of the five patients with abnormal femoral arteries had no visible arterial obstruction by two-dimensional echocardiography and color-flow imaging; however, these patients had abnormal pulsed Doppler patterns with continuous forward flow and low PIs of 2.5 and 2.9 only on the side of previous balloon catheter insertion. These patients were 1.8 and 5.7 years old at the time of catheterization. Figure 2A shows an abnormal pulsed Doppler recording from the right common femoral artery of one of these two patients. Note the continuous forward flow throughout diastole. The normal pulsed Doppler recording obtained from the left common femoral artery of the same patient is shown for comparison (Fig. 2B).

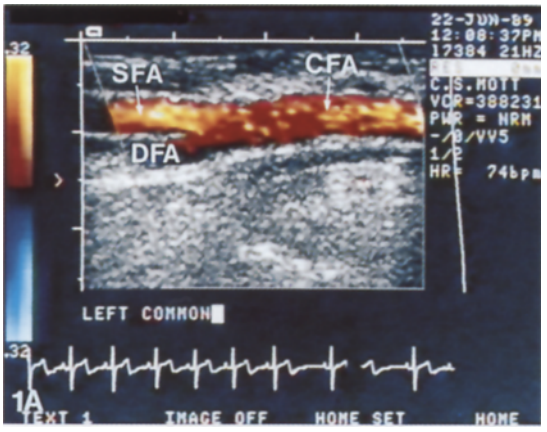
Three of the five abnormal patients had visible obstructions by two-dimensional echocardiography and color-flow imaging with abnormal pulsed Doppler patterns showing continuous forward flow and low PIs of 1.1–3.6. All three patients were <1 year old at the time of catheterization and had balloon catheter insertions in the affected arteries. One patient with aortic stenosis underwent balloon valvuloplasty using a double balloon technique at 8 months of age. Long, narrowed segments were seen in both common femoral arteries. Figure 3 shows a two-dimensional image of the right common femoral artery of this patient illustrating the narrowed region. One patient with aortic stenosis underwent balloon valvuloplasty using a single balloon technique at 1 month of age. Figure 4A shows a color Doppler image with a region of complete obstruction in the right femoral artery. Note the disturbed flow (indicated by the mosaic flow signals) beyond the obstruction. The pulsed Doppler recording obtained downstream from the obstruction in the deep femoral artery (Fig. 4B) illustrates abnormal continuous flow distal to the obstruction. One patient with aortic stenosis underwent balloon valvuloplasty at age 3 weeks (via the right femoral artery) and again at 3 months (via the left femoral artery). In this patient, echocardiography revealed complete obstruction of both common femoral arteries with multiple collateral vessels. This was confirmed by angiography at the time of a follow-up catheterization.

None of these five patients with abnormal femoral arteries had a cardiac catheterization prior to the interventional procedure.

Discussion

Femoral artery injury is an important potential complication of aortic balloon valvuloplasty or coarctation balloon angioplasty. Sahn et al. first reported the usefulness of two-dimensional echocardiography as a technique for assessment of femoral artery complications in children post catheterization [12]. Subsequently, several studies showed the value of pulsed and color-flow Doppler for detection of peripheral vascular flow abnormalities [4, 5, 8, 9, 11, 13]. In this study, these noninvasive methods were used to investigate the occurrence of femoral artery complications in children following aortic balloon valvuloplasty or coarctation balloon angioplasty.

In most patients, abnormalities in the femoral arteries were identified with two-dimensional imaging. However, color-flow mapping was extremely helpful for the detection of disturbed flow in narrowed regions of the femoral vessels and the absence of flow in completely obstructed vessels [11, 13]. In addition, color-flow imaging allowed the identification of small collateral vessels surrounding regions of obstruction. Pulsed Doppler echocardiography provided a useful means for quantification of the severity of the flow disturbances within the femoral vessels. In addition, pulsed Doppler echocardiography provided a technique for detection of partial obstructions not well imaged with two-di-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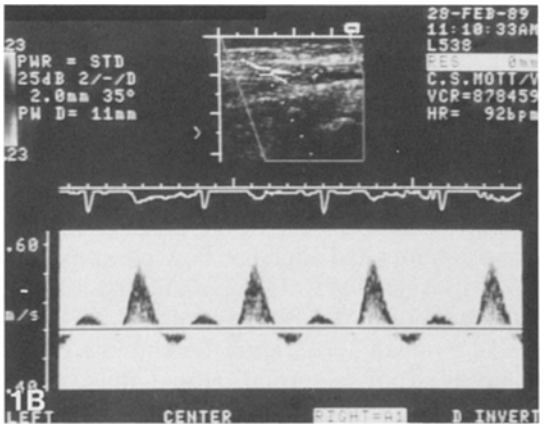
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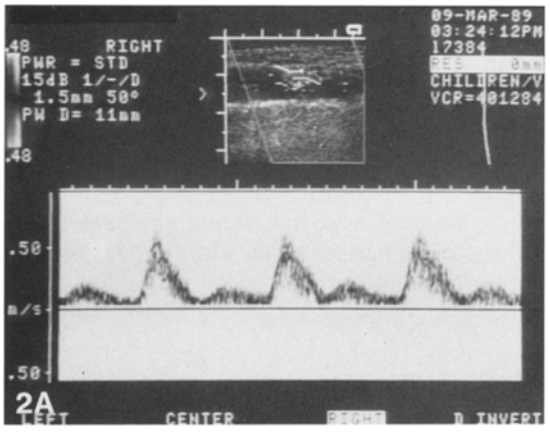
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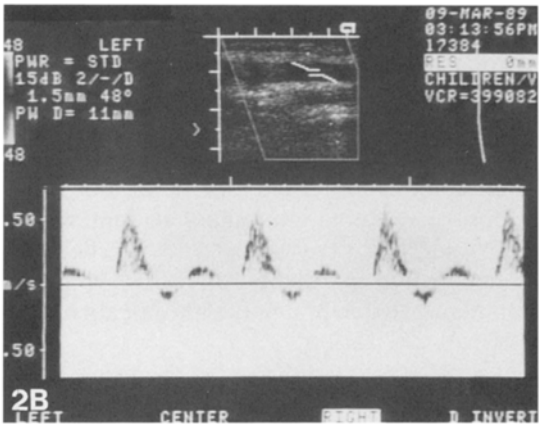
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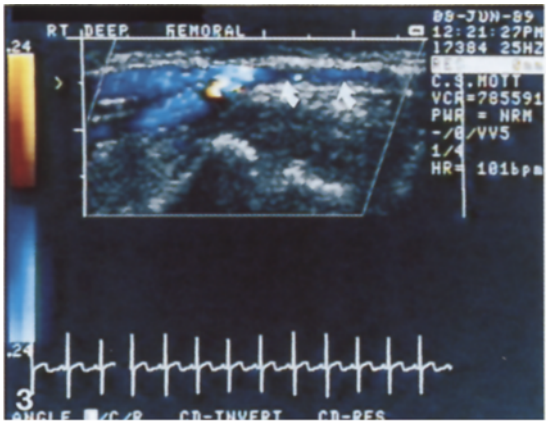
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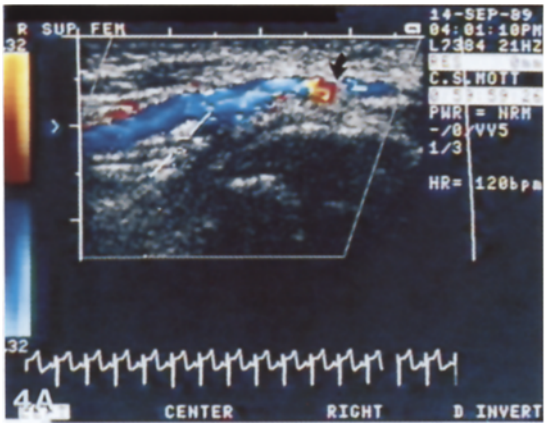
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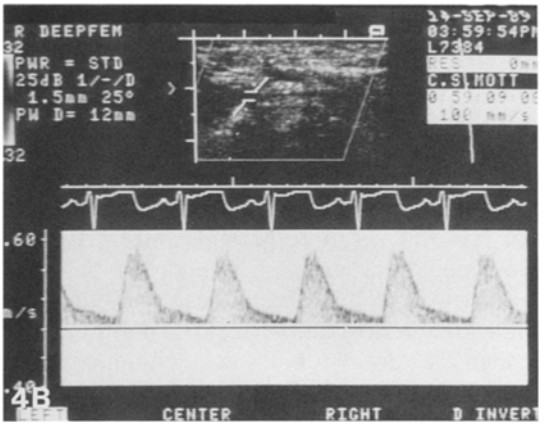
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mensional echocardiography. However, more proximal arterial obstruction (e.g., coarctation of the aorta) can result in a femoral artery Doppler pattern identical to that found in patients with distal obstruction. Usually, distal obstruction is suspected when an abnormal femoral artery Doppler pattern is found in one leg only. If both femoral artery Doppler examinations are abnormal, proximal and distal obstructions can usually be distinguished by examination of the ascending and descending aorta and by direct visualization of the narrowed site using two-dimensional and color-flow imaging.

This study suggests that children less than 1 year of age have a higher risk for development of arterial obstructions after balloon dilatation of left heart obstructive lesions. Of the four children who underwent interventional procedures prior to 1 year of age, three had severe narrowing or complete obstruction of at least one femoral vessel. We speculate that the high rate of femoral injury in small children relates to the relatively large size of the balloon catheters used in this age group compared to the size of the femoral vessels. In our institution, the femoral artery approach for aortic balloon valvuloplasty or coarctation balloon angioplasty is not currently utilized in neonates. Neonates undergo interventional procedures utilizing the umbilical vessels if available. In neonates and older infants in whom the umbilical vessels are not available, a surgical approach is currently utilized to preserve the femoral vessels. Due to the risk of clinically unsuspected femoral artery injury, we recommend that all children who have had balloon dilatation procedures using an arterial approach undergo an echocardiographic evaluation of their femoral arteries.

In conclusion, femoral artery injury can occur after introduction of balloon dilatation catheters, especially in very young children. The long-term significance of these injuries is uncertain and needs further investigation. The potential effect on growth of the extremity and possible symptoms of arterial insufficiency are of particular importance.

Fig. 1. (**A**) Color Doppler examination of the left femoral arteries. This, and all subsequent figures, are oriented with the patient's head to the right. The red flow area represents systolic flow toward the transducer. *CFA*, common femoral artery; *SFA*, superficial femoral artery; *DFA*, deep femoral artery. (**B**) Pulsed Doppler recording from a normal superficial femoral artery. Note the typical triphasic flow pattern (forward in systole, reverse in early diastole, and forward in mid-diastole).

Fig. 2. (**A**) Pulsed Doppler recording from the right common femoral artery illustrating an abnormal pattern of continuous forward flow throughout diastole. (**B**) Pulsed Doppler recording from the left common femoral artery of the same patient as in (**A**). Note the normal triphasic flow pattern.

Fig. 3. Color Doppler examination of the right femoral arteries showing a long segment narrowing of the right common femoral artery (*arrows*). The blue flow area indicates flow away from the transducer (toward the left).

Fig. 4. (**A**) Color Doppler examination of the right femoral arteries showing a discrete area of complete obstruction (*arrow*) in the right common femoral artery. Note the mosiac color pattern indicating disturbed collateral flow distal to the obstruction. (**B**) Pulsed Doppler recording from the right deep femoral artery distal to the obstruction illustrated in (**A**). Note the abnormal pattern of continuous forward flow throughout diastole.

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