Magnetic Resonance Imaging of the Iliofemoral Arteries After Balloon Dilation Angioplasty of Aortic Arch Obstructions in Children

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Background We wished to determine the nature and incidence of changes in the iliofemoral arteries after balloon dilation angioplasty (BDA) for aortic arch obstruction in children and to determine the reliability of gradient magnetic resonance imaging (MRI) in their detection.

Methods and Results Sixty-three children, including 62 with and 1 without arch obstruction, underwent MRI of the iliofemoral vessels. Of these, 36 patients had undergone transfemoral BDA (7 after previous transfemoral diagnostic catheterization), 12 had undergone diagnostic transfemoral catheterization but not BDA, and 15 had no history of femoral arterial catheterization. The iliofemoral arteries were normal on MRI in all 15 children without catheterization. Among the 36 children who had undergone BDA, the ipsilateral iliofemoral artery was normal in 15, mildly narrowed in 7, and severely stenotic or occluded in 14 (39%), including 6 of 9 patients treated for acute femoral artery thrombosis and 8 with no history of femoral artery thrombosis. Two patients had documentation of progressive obstruction. Six patients had concordant conventional angiography. There was a significant correlation between the number of balloon catheters used for the angioplasty and severe occlusive changes. Nine of 19 patients who had undergone diagnostic transfemoral catheterization had severe obstructive changes on MRI; 8 of 9 weighed <10 kg at catheterization.

Conclusions Obstructive lesions of the iliofemoral arteries are common after transfemoral BDA of arch obstructions (58%) and can be reliably evaluated with gradient MRI. Catheter size and manipulation are the main contributing factors. (Circulation. 1994;90:915-920.)

Key Words • thrombosis • balloon • angioplasty • coarctation • magnetic resonance imaging

Balloon dilation angioplasty has become the treatment of choice for residual or recurrent aortic arch obstruction in children after surgical repair and is also being used as an alternative treatment for primary coarctation of the aorta.1 Because of the large size of the balloons necessary to dilate the thoracic aorta, some of these procedures require the insertion of relatively large catheters into the pediatric femoral artery. We previously reported a high incidence of acute iliofemoral complications after systemic transfemoral arterial balloon angioplasty techniques.2 Many of the patients with acute complications, especially thrombosis, were treated successfully with thrombolytic agents.3-5 However, the long-term effects of passing these large catheters through the femoral arteries of growing children has not been determined. It is the purpose of this study to determine the nature and incidence of changes in the iliac and femoral arteries after balloon catheter insertion and to determine the usefulness of gradient magnetic resonance imaging (MRI) in detecting these changes.

Methods

During a 4-year period between August 1988 and November 1992, 36 patients undergoing MRI examination of the thoracic aorta as a follow-up after balloon dilation angioplasty for aortic arch obstruction had additional fast-scan (gradient) imaging of the pelvic vessels at the end of the procedure. Among 41 consecutive balloon angioplasty patients undergoing MRI follow-up, only 5 did not undergo MRI of the pelvic vessels, because of lack of cooperation or arousal from sedation. To determine the reliability of the MRI technique in detecting iliofemoral arterial obstructive lesions, an additional 26 patients with a clinical diagnosis of aortic arch obstruction who were referred for MRI examination and 1 normal volunteer also had gradient imaging of the pelvic vessels.

MRI Technique

The pelvic vessel studies were performed after the necessary imaging of the thorax had been carried out. Examinations were conducted in a 1.5-T superconducting magnetic resonance scanner, with a body coil, echo time (ET) of 35 milliseconds, repetition time (TR) of 15 milliseconds, flip angle of 15°, and two averages. Scan thickness was 5 mm, and scans were obtained from the level of the anterior iliac crests superiorly to the inguinal crease inferiorly.

MRI Interpretation

The MRI studies were interpreted by a radiologist blind to the history of previous arterial cannulation or balloon dilation angioplasty. The patency of each iliofemoral artery was graded as (1) patent and normal in size; if asymmetrical, the difference in diameter was <25%; (2) stenotic: the diameter of the smaller vessel was between 25% and 75% less than that of the contralateral vessel; or (3) severely stenotic or occluded: the abnormal vessel demonstrated absent signal or an extremely small lumen on at least one image level.

The vessels were evaluated at three levels: the common iliac artery, the external iliac to common femoral artery, and the superficial and profunda femoral arteries.
Medical Record Review

The clinical charts were reviewed for the following information: history of previous femoral arterial catheterization, age and weight at catheterization, size of catheters used, presence or absence of recognized acute complications after the procedure, and nature and result of treatment of the complications. In patients undergoing balloon dilation angioplasty procedures, the balloon diameter and the number of balloon catheters used were noted. The time interval between the catheterization procedures and the MRI study was determined.

Catheterization Technique

Before 1990, both the diagnostic and therapeutic parts of the balloon dilation angioplasty procedure were performed through the same vascular access. The common femoral artery was catheterized percutaneously with an arterial sheath, usually 6F. Hemodynamics studies and angiography were performed. Through an end-hole catheter in the ascending aorta, an exchange-length guide wire was positioned, and the sheath and catheter were exchanged for a balloon angioplasty catheter. After balloon inflation, the catheter was exchanged for another sheath and multi-side-hole angiographic catheter, and postangioplasty angiography was performed. If the increase in the size of the aortic lumen was felt to be inadequate, the procedure was repeated with a larger balloon. Each balloon angioplasty was followed by aortography.

Since early 1990, the diagnostic portion of the procedure has been performed in most patients with a balloon-tipped angiographic catheter introduced transeptally from the femoral vein and maneuvered into the ascending aorta. Hemodynamics were monitored continuously, and repeat aortography was obtained through this catheter, reducing catheter exchanges through the femoral artery.

A low-profile 5F catheter (Meditech) was used for patients requiring a balloon diameter of 8 mm or less. This catheter was inserted through a 6F sheath. In patients requiring angioplasty with balloons larger than 8 mm, low-profile, 3-cm balloon catheters (Opti-plast, Vas-Cath) or low-profile, 5.5-cm balloon catheters (Mansfield), with shafts of 8F and 9F, were used. The combined catheter shaft and deflated balloon of the larger catheters resulted in profiles from 10F to 12F. These catheters were inserted into the femoral artery over a guide wire, without an arterial sheath.

All the balloon angioplasty procedures were performed under general anesthesia with systemic heparinization (150 U/kg to a maximum of 5000 U). Activated clotting times were not measured. If the procedure was completed within 1 hour of heparin administration, heparin was reversed with protamine after the catheters were removed. The patients were observed in hospital for at least 24 hours after the procedure, with frequent monitoring of pedal and femoral pulses. If lower-extremity pulses were not palpable within 1 to 2 hours after the procedure, full systemic heparinization was instituted. If the pulses did not return after 24 hours, intravenous infusion of a thrombolytic agent or surgical thrombectomy was considered.

Statistical Methods

Numerical data are presented as range and mean±1 SD. Statistical significance of results was determined by a non-paired Student's t test.

Results

A total of 63 children underwent MRI of the pelvic vessels, including 36 patients who had undergone transfemoral balloon dilation angioplasty, 12 patients with arch obstruction who had undergone transfemoral catheterization for diagnosis (7 had undergone both diagnostic catheterization and transfemoral balloon dilation angioplasty), 14 patients with arch obstructions and no history of previous femoral arterial catheterization, and 1 normal volunteer without arch obstruction.

Patency of the iliac and femoral arteries with <25% diameter asymmetry between the two sides was demonstrated in the normal volunteer and in all patients who had not undergone transfemoral catheterization (Fig 1). In 1 patient without prior catheterization but with severe coarctation, there was a slight reduction in signal intensity within the femoral arteries bilaterally, but the lumen was symmetrical and of normal size. The common iliac artery and the superficial and profunda femoral arteries were patent and symmetrical in all patients,
including those who had undergone prior transfemoral catheterization.

Among the 36 children who had undergone transfemoral balloon dilation angioplasty, the ipsilateral iliofemoral artery was patent and normal in size in 15 (Figs 2 and 3), patent but stenotic in 7, and occluded or severely stenotic in 14 patients (Fig 4). The balloon angioplasty patients were 6.8±5.18 years old (range, 3 months to 18.2 years) at the time of catheterization and weighed 21.46±13.97 kg (range, 4 to 55.5 kg). The mean weight of the patients with ipsilateral iliofemoral artery occlusion or severe stenosis was 18±14.83 kg (range, 4.1 to 55.5 kg), and the group with normal ipsilateral iliofemoral arteries weighed 16.17±13.1 kg (range, 4 to 54.1 kg). The difference in weight is not statistically significant (P=.74). Likewise, there is no statistical difference between the weights of the patients with normal ipsilateral iliofemoral arteries and the total group of patients with abnormal ipsilateral arteries, including occluded and stenotic arteries (P=.390).

The number of balloon catheters used per patient was compared for the group with normal ipsilateral iliofemoral arteries and the group with occluded or severely stenotic ipsilateral iliofemoral arteries. In the former group, 5 of 15 patients had two balloon catheters inserted, and no patients had more than two catheters. In the group with ipsilateral occlusion, 8 of 14 patients had two or more catheters, and 2 patients had three catheters. The group with iliofemoral arterial occlusion had significantly more balloon catheter exchanges than the group with normal vessels (P=.03). The maximum balloon diameter used in each patient was studied as an indicator of the deflated balloon profile but was not significantly different between the two groups (P=.12).

The data were further analyzed according to the year in which the angioplasty procedure was performed. Twenty-two procedures were performed before 1990; in this group, the ipsilateral iliofemoral arteries were normal in 8 patients, occluded or severely stenotic in 11, and stenotic in 2. Among 16 patients who underwent balloon angioplasty during or after 1990, the ipsilateral iliofemoral artery was normal in 7 patients, occluded or severely stenotic in 3, and stenotic in 5.

The mean time between the balloon angioplasty procedure and the MRI examination was 17.9±19.1 months (1 to 67 months). The mean time between angioplasty and MRI was longer in the patient group treated before 1990 (25.2 versus 9.6 months; P=.02).

Among the 36 patients who underwent transfemoral balloon angioplasty, 10 were recognized as having an acute iliofemoral complication after the procedure, 9 had femoral artery thrombosis, and 1 had bleeding requiring surgical attention. Among the 9 patients with acute femoral artery thrombosis after the procedure, follow-up MRI showed iliofemoral arterial occlusion or severe stenosis in 6 and stenosis in 1; 2 had normal vessels. Treatment for the acute thrombosis had included intravenous streptokinase infusion in the 2 patients with normal vessels, heparin in the 1 patient with a stenotic vessel on follow-up MRI, and surgical thrombectomy (4 patients), intravenous streptokinase (1 patient), and intravenous heparin (1 patient) in the group with iliofemoral occlusion. Eight additional patients with severe obstructive changes of the ipsilateral iliofemoral artery on MRI did not have evidence of acute femoral artery thrombosis by routine clinical examination before hospital discharge.

Two patients had documentation of progressive obstruction on MRI (1 day after and 6 months after...
Six-year-old girl with right iliofemoral arterial occlusion and patent left iliofemoral artery after neonatal diagnostic catheterization via the right femoral artery and balloon dilation angioplasty via the left femoral artery. A, Axial gradient magnetic resonance image (MRI) at the level of the common femoral artery shows occlusion of the right and patency of the left femoral artery and vein. B, Axial gradient MRI at the level of the superficial femoral artery demonstrates arterial patency bilaterally. C, Conventional right iliac arteriogram confirms thrombosis of the right external iliac and common femoral arteries with opacification of the superficial femoral artery through anterior iliac arterial collaterals. IIA indicates internal iliac artery; SFA, superficial femoral artery.

balloon dilation angioplasty; in both, the initial MRI showed patent and normal-size iliofemoral arteries, whereas repeat pelvic MRI 6 months later showed occlusion of the ipsilateral iliofemoral artery. Four other patients had repeated pelvic MRI examinations that showed no significant change.

Among the 19 patients who underwent diagnostic transfemoral arterial catheterization before MRI, the ipsilateral iliofemoral artery was normal in 7, occluded or severely stenotic in 9, and stenotic in 3 patients. Eight of the 9 patients with occlusion or severe stenosis weighed <10 kg at the time of cardiac catheterization (mean weight, 5.54 kg). This group included 12 patients who underwent only diagnostic catheterization and 7 patients who underwent balloon dilation angioplasty through the contralateral femoral artery.

Six patients in this series had angiographic correlation with the MRI findings. In all cases, femoral angiography was performed at the time of a later catheterization, after the MRI but before further transfemoral intervention. There was complete correlation between the angiographic and MRI findings in all patients, including 3 with normal iliofemoral vessels, 2 with iliofemoral arterial occlusion after balloon dilation angioplasty, and 1 with a normal iliofemoral artery after balloon dilation angioplasty and contralateral iliofemoral arterial occlusion related to previous diagnostic catheterization.

Discussion

Infants and children, especially those weighing <20 kg, have an increased incidence of femoral arterial thrombosis after cardiac catheterization. Contributing factors include femoral arterial spasm, intimal injury at the puncture site, shearing injury due to catheter friction, and changes in the blood viscosity, coagulability, and cardiac output related to the congenital cardiac defects. Technical factors that have led to a reduction in femoral arterial complications include systemic heparinization and the use of small catheters and arterial sheaths. The application of balloon dilation angioplasty techniques to pediatric cardiovascular dis-
ease reversed the trend toward smaller catheters and again resulted in an increased incidence of femoral arterial injuries. In a report of the experience from this institution between 1984 and 1987, 29 of 64 patients (45%) undergoing balloon aortic valvuloplasty or balloon dilation angioplasty of coarctation restenosis had clinical evidence of femoral arterial injury.\textsuperscript{2} Despite aggressive medical and surgical management, 38% of symptomatic patients and 17% of all patients had clinical findings of iliofemoral arterial obstruction at the time of hospital discharge. Others have reported a higher success rate for medical therapy of femoral arterial thrombosis.\textsuperscript{4,3} The incidence of clinical sequelae, including leg length discrepancy and claudication after cardiac catheterization, is disputed.\textsuperscript{15,19,20}

There is still no long-term follow-up of patients who have undergone transfemoral balloon angioplasty to determine either the incidence of iliofemoral arterial occlusive changes or the clinical effects. A recent study using two-dimensional and Doppler ultrasound examination of the femoral artery in 19 unselected asymptomatic patients who had previously undergone transfemoral balloon angioplasty demonstrated abnormal femoral arteries or femoral arterial Doppler signals in 5 (26%).\textsuperscript{21}

These authors also found a relation with patient age at the time of intervention, since all patients with documented arterial narrowing were <1 year old at the time of catheterization. Their study differed from the present one in that, according to their described methods, they did not examine the iliac arteries.

The present series of patients examined by MRI is not ideal, since not all patients who underwent balloon dilation angioplasty were included in the study. However, since patients who underwent MRI were selected only according to their need for imaging of the aortic arch and not by any issues related to the femoral artery, they are a nonbiased sample and can be assumed to be representative of the entire group.

The MRI examination used in this study has an important advantage over the previously described ultrasound study because it included the length of the iliofemoral artery from the common iliac artery to below the femoral bifurcation. It is important for those involved in imaging the femoral artery to be aware that catheter-related complications usually involve the external iliac artery.\textsuperscript{2,9} The distal common femoral artery and the superficial femoral artery are always patent, even in the presence of complete obstruction of the external iliac artery, because of the presence of collateral vessels.\textsuperscript{9}

This series of pediatric patients demonstrates that, even in the presence of altered hemodynamics as a result of aortic coarctation, MRI reliably demonstrates patency and obstruction of the external iliac and femoral arteries. There were no instances of false-positive interpretations in patients with coarctation who had not undergone femoral arterial catheterization, and in each instance in which the study was interpreted as showing iliofemoral asymmetry, the smaller vessel was on the same side that had been catheterized. More importantly, this study demonstrates a much higher incidence of arterial occlusive changes than was suspected clinically, either acutely after the catheter procedure or on clinical follow-up. Whereas 21 of 36 patients (58%) who had undergone balloon dilation angioplasty had obstructive iliofemoral arterial changes on MRI, only 7 of the 21 (33%) had a clinically recognized acute complication of the procedure, despite routine postprocedure monitoring of lower-extremity circulation. In addition, the documented progression in 2 patients of iliofemoral arterial occlusion is convincing evidence of a progressive process, possibly related to damage of the vessel intima.

The findings of lower incidence and severity of arterial occlusive changes in the patients who underwent balloon dilation angioplasty after as opposed to before the beginning of 1990 are encouraging. Before 1990, the ipsilateral iliofemoral artery was abnormal in 13 of 21 (62%), with 11 (52%) having severe changes (occlusion or severe stenosis). Since the beginning of 1990, 9 of 15 patients (60%) have had iliofemoral arterial abnormalities, but only 3 (20%) had severe changes. A possible contributing factor for this difference in incidence is the longer interval between the date of the intervention and the date of the MRI in the earlier group. Alternatively, the later group had fewer catheter exchanges because of the use of the transvenous transseptal approach for the diagnostic hemodynamic and angiographic studies. The correlation be-

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**Fig 4.** Progressive right iliofemoral arterial obstruction after balloon dilation angioplasty (BDA) via the right femoral artery at 12 years of age. A, Axial gradient magnetic resonance image (MRI) at the level of the external iliac arteries 6 months after BDA demonstrates patent external iliac arteries (arrowheads) bilaterally. B, Gradient MRI at a similar level obtained 12 months after BDA demonstrates severe narrowing of the right external iliac artery (arrowhead).
between the number of balloon catheters used and the absence or presence of arterial obstruction also supports the importance of reducing the number of catheter exchanges in the femoral artery. The lack of correlation between occlusive changes and patient age at the time of intervention may be related to the fact that the younger patients required smaller balloon diameters and the smaller catheters were usually used through arterial sheaths. The use of an arterial sheath is probably important in minimizing the trauma to the iliac and femoral arterial wall.

Previous reports have documented relatively poor results of surgical repair in patients weighing <12 kg.1,2,13 The present study confirms this finding. Among 4 patients who had undergone surgical thrombectomy and arterial repair for acute femoral arterial thrombosis, none had patent iliofemoral arteries on MRI follow-up.

The following conclusions may be drawn from this study.

1) Gradient MRI is a useful technique for evaluating iliofemoral vascular complications of catheter procedures.

2) Transfemoral diagnostic catheterization in infants with coarctation has a high incidence of arterial occlusive complications.

3) The incidence of abnormal iliofemoral arteries after transfemoral balloon dilation angioplasty of arch obstructions is high (58%)—higher than predicted by clinical examination immediately after the procedure—suggesting a progressive pathogenesis.

4) Catheter manipulation (ie, the number of catheter exchanges) in the femoral artery plays the most significant role in the late finding of arterial occlusion.

5) Further research is needed to monitor patency of the femoral arteries and lower-extremity development to identify factors that influence the incidence of arterial complications.

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