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ANGIOGRAPHY

Clinical Utility of Rapid Prescreening Magnetic Resonance Angiography of Peripheral Vascular Disease Prior to Cardiac Catheterization

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ABSTRACT

Purpose. The presence of peripheral vascular disease, in particular iliofemoral disease, is responsible in part for vascular complications from femoral artery cannulation. We investigated whether prescreening for vascular obstructions with magnetic resonance angiography (MRA) in high-risk patients with peripheral vascular disease (PVD) would provide useful information to angiographers seeking to improve the safety and efficiency of femoral artery access at cardiac catheterization. *Methods*. Twelve consecutive patients with known or suspected PVD underwent contrast-enhanced, aorto-iliofemoral MRA using a real-time BolusTrak technique. Contrast-to-noise ratios for each patient were calculated. The cardiac angiographer reviewed the MRA prior to catheterization and selected an access site. The patients' subsequent clinical course was evaluated, and a postprocedure questionnaire was completed by the angiographer to define the value of the prescreening MRA. *Results*. No significant vascular complications occurred in these patients as defined by failure of initially chosen access site, arterial dissection, limb ischemia, pseudoaneurysm formation, hemorrhage (including retroperitoneal hematoma), or need for blood transfusion or emergency vascular surgical repair. Statistical frequency analysis of the responses in the postprocedure questionnaire demonstrated that the MR data were clinically valuable in (1) influencing the initial choice of access site; (2) influencing technical alterations to the standard access; and, (3) enhancing confidence in the selection of access site. *Conclusions*. MRA prescreening in patients with PVD is an effective, novel adjunct to cardiac catheterization in selected patients

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that improves physician confidence and influences technical choices during coronary angiography from the femoral artery approach.

Key Words: Peripheral vascular disease; Magnetic resonance angiography; Coronary angiography; Cardiac catheterization; Complications; Procedural safety.

INTRODUCTION

Complications of femoral artery access are frequently encountered while performing percutaneous diagnostic and interventional cardiac procedures. These complications may increase morbidity and patient discomfort, and lead to prolonged hospitalization and resource utilization including blood transfusion, additional guide wire exchanges, or even surgical repair (Khoury et al., 1992; Lewis et al., 1999; Spies and Berlin, 1998). The presence of peripheral vascular disease, in particular iliofemoral disease (PVD), is responsible in part for vascular complications from femoral artery cannulation. Based on the current literature, we estimate that at least 20% of patients scheduled for cardiac catheterization with clinical, Doppler, or angiographic evidence of aorto-iliofemoral disease could benefit from an iliofemoral prescreening protocol for selection of an access site if it were safe, inexpensive, rapid, and effective (Bogart et al., 1995; Hildick-Smith et al., 2000).

It has been reported that brachial or radial artery approaches may be attempted in patients with peripheral vascular disease with a high success and low complication rate (Kiemeneij et al., 1997). However, these approaches are used infrequently by the majority of angiographers. Cardiologists are not routinely trained in these approaches in most fellowship programs, and technical failure rates are high with inexperienced angiographers (Heuser, 2000). It might be beneficial to determine which patients with peripheral vascular disease would be candidates for the standard femoral artery approach before committing them to a nonstandard approach. Accordingly, we conducted the present pilot study to determine whether prescreening of patients with peripheral vascular disease with magnetic resonance angiography (MRA) could provide data that might enhance the clinician's confidence and ability to obtain arterial access.

CASE REPORT

A 43-year-old woman with a history of hypertension, hypercholesterolemia, tobacco use, coronary artery disease, and prior rotational atherectomy and percutaneous transluminal coronary angioplasty (PTCA) of her left anterior descending coronary artery was admitted with crescendo angina. She complained of severe claudication that limited her from walking more than half a block due to discomfort in both lower extremities. The patient underwent an adenosine thallium/sestamibi stress test that revealed anteroseptal ischemia. She was referred for cardiac catheterization. On physical examination, diminished bilateral femoral pulsations and bilateral femoral bruits were present. Her distal lower extremities demonstrated pulses detectable only by Doppler ultrasonic examination.

Because of the presence of PVD by history and physical exam, the patient underwent magnetic resonance angiography of her aorto-iliofemoral vasculature prior to cardiac catheterization. This revealed complete occlusion of the right external iliac artery at its origin with no visible flow in the right common femoral artery, which is the customary site of arterial access (Fig. 1A). Accordingly, left femoral artery access was obtained using the modified Seldinger technique. Catheters were advanced without difficulty through the left common iliac artery using a Wholey (soft-tipped) guide wire.

Contrast angiography confirmed total occlusion of the right external iliac artery at its origin with late, faint reconstitution of the right common femoral artery by collaterals (Fig. 1B). Subsequent coronary angiography was well tolerated without complication. Because the right femoral artery is the standard, preferred, initial site of arterial access due to its proximity to the angiographer, initial arterial access would have been unsuccessful in this patient. The MRA prescreening correctly directed the angiographer to the left femoral artery where the procedure was feasible, and ultimately successful.

METHODS

Informed consent was obtained according to Washington University Institutional Review Board guidelines, the purpose of which is to protect the rights and welfare of participants in human subjects

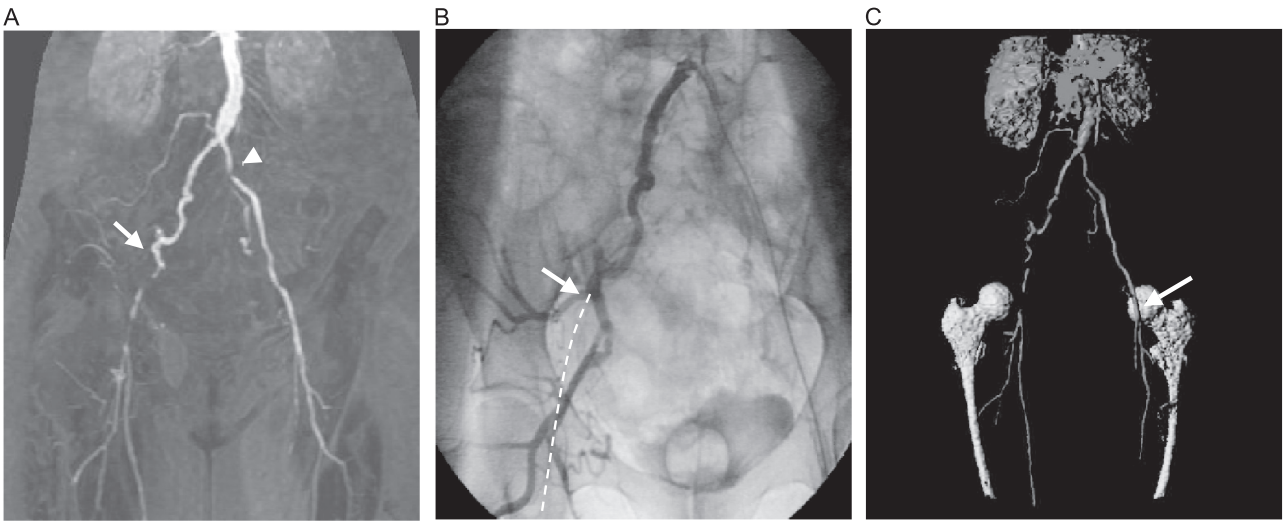

Figure 1. (A) Antero-posterior maximum intensity projection (MIP) showing chronic occlusion of the right external iliac artery at its origin (arrow). Note also mild-moderate stenosis in the left common iliac artery (arrowhead). (B) Invasive contrast angiography confirms total occlusion of the right external iliac artery at its origin (arrow). Dashed line denotes true course of external iliac artery and common femoral artery (the customary vessel used for vascular access), which fills late by collaterals. (C) Surface rendered MRA in the same patient demonstrating relationship of common femoral arteries to the femoral heads. Arrow denotes usual access site as determined by fluoroscopy of the femoral head.

research http://medicine.wustl.edu/~hsc/). Twelve consecutive patients with known or suspected peripheral vascular disease based on history (claudication), physical exam (diminished femoral/lower extremity pulses or the presence of femoral bruits), prior angiographic documentation, or lower extremity arterial bypass surgery (i.e., aorto-bifemoral bypass) who were scheduled for clinically indicated cardiac catheterization were enrolled. If there was no contraindication, these patients underwent an aorto-iliofemoral MRA at 1.5 T (Philips Medical Systems, Bothell, WA) using a real-time bolus tracking technique as described below. The contrast-enhanced (Gadolinium-DTPA @ 0.2 mL/kg) 3D gradient echo MRA was acquired in 17 seconds using a randomly-segmented, centrically ordered, k-space filling sequence (TE/TR/α=1.4/5.1/40, resolution of $2.9 \times 0.9 \times 1.8$ mm^3) (Lee and Wang, 1998; Willinek et al., 2002). Prior to contrast injection, the high resolution 3D scan was prepared (i.e., scanning parameters were initialized and stored in the scanner's memory for rapid recall after contrast agent arrival). Timing of the MR acquisition to the arrival of contrast agent was achieved using a large field-of-view, real-time digital subtraction ''MR fluoroscopy'' technique (*i.e.*, BolusTrak) (Ho et al., 1998). When the contrast bolus—injected at 2 cc/sec by an MR-compatible power injector (Spectris; MedRad, Inc., Indianola, PA)—was seen to arrive in the descending aorta, the high-resolution, 3D MRA sequence was immediately commenced by the operator. The sequence was automatically repeated sequentially four times to visualize arterial and venous phases and to permit assessment of peripheral vasculature having severely impeded flow. The total MR exam time, including the survey scans, was less than 20 minutes.

Postprocessing was performed with maximum intensity projections (MIPs) from multiple angles. Because the optimal site of common femoral artery cannulation is over the lower one-third of the femoral head and superior to common femoral artery bifurcation, 3D surface renderings were also generated (Fig. 1C). Since the femoral head may be visualized by fluoroscopy, the surface renderings and MIPs together clearly define the arterial to femoral head relationships prior to arterial puncture.

For an objective quantification of contrast-enhanced image quality, contrast to noise ratio (CNR) was calculated for each patient. On the raw, contrast-enhanced dataset, regions of interest were analyzed in the common femoral artery plane in which they were best visualized and patent, along with the surrounding tissue (which included the subcutaneous fat and muscle), and mean background signal as an estimate of noise. The CNR was calculated as the difference in intensity

between the common femoral artery and its surrounding tissue, divided by the background noise intensity.

The angiographer of record reviewed both the MIPs and the 3D surface images prior to performing the cardiac catheterization, and completed a postprocedure questionnaire to assess the clinical value of the MR angiogram. The survey questions were categorized as either ''valuable'' or ''not valuable'': 1) Did the MR data influence your initial choice of access site? 2) Did the MR data result in technical alterations to the standard access procedure such as choice of wire, sheath selection, *etc*.? 3) Did the MR data enhance confidence in your selection of the access site? 4) Do you feel that the time or difficulty gaining access was reduced?

Fisher's exact test was used for analysis of the survey responses with a null hypothesis that each survey question was ''not valuable.'' A *P* value less than 0.05 was considered to be statistically significant.

RESULTS

Baseline clinical characteristics of the 12 subjects are described in Table 1, and reflect the high-risk nature of this population. Indeed, after MR prescreening, one patient was discovered to have a previously undiagnosed, 5-cm, abdominal aortic aneurysm. Due to the rapid access to information from prescreening MRAs, patients were able to undergo MRA and still proceed to catheterization on the same hospital day. During their hospitalization, no major vascular complications occurred in these patients as defined by failure of initial chosen access site, arterial dissection, limb ischemia, hemorrhage including retroperitoneal bleeding or need for blood transfusion, pseudoaneurysm formation, or need for emergency, vascular surgical repair.

Table 1. Baseline characteristics of high-risk patients with peripheral vascular disease undergoing MR prescreening.

Baseline patient characteristic (n=12)	
Age (years ± SD)	62±13
Male sex	42% (5)
Hypertension	100% (12)
Diabetes mellitus	42% (5)
Hypercholesterolemia	83% (10)
Prior coronary artery bypass (CABG)	25% (3)
Smoking history	92% (11)
Claudication	42% (5)
Abdominal aortic aneurysm	8% (1)
Prior vascular bypass grafting	25% (3)
Presence of femoral artery bruit	58% (7)
Diminished femoral artery pulses	25% (3)

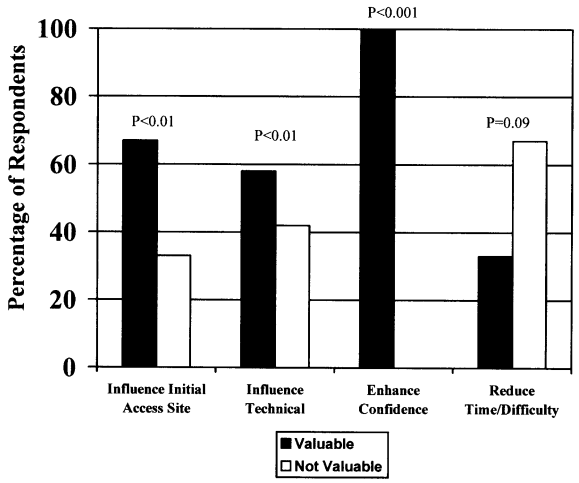

Figure 2. Statistical frequency analysis of postcardiac catheterization questionnaire demonstrating perceived clinical benefit to angiographers of rapid prescreening with MRA. Note P values reported for statistical significance in relation to the null hypothesis of ''not valuable'' for each question.

Contrast-to-noise ratios were calculated from regions of interest as described above. The average areas analyzed were: 1) common femoral artery, 330 mm^2; 2) surrounding tissue, 971 mm^2; and 3) background, 2,213 mm^2. The average CNR was 22 ± 12.

The results of the postprocedure questionnaire are shown in Fig. 2 and demonstrate the potential value of MRA prescreening in this population. Analysis of the questionnaire suggests that the MR data were clinically valuable in 1) influencing the initial choice of access site: 67% of respondents (P<0.01); 2) influencing technical alterations to the standard access technique: 58% (P<0.01); 3) enhancing confidence in the selection of access site: 100% (P<0.001). The MR data were perceived as less valuable in impacting the time or difficulty in gaining access, once the site of access choice was made after reviewing the MRA: 33% (P=0.09).

DISCUSSION

Magnetic resonance angiography is increasingly utilized in the clinical assessment of patients with peripheral vascular disease. The sensitivity and specificity of contrast-enhanced, three-dimensional MR angiography for the demonstration of vascular occlusions has been reported to be as high as 94% and 97%,

respectively (Meaney et al., 1999; Swan et al., 2002). Three-dimensional MR angiography has also been shown to be well suited for the characterization of lower extremity bypass grafts (Bertschinger et al., 2001). It is rapidly performed, well tolerated, and its safety is well established (Goyen et al., 2001; Koelemay et al., 2001; Rofsky and Adelman, 2000; Westenberg et al., 1999). This study was undertaken to determine if MR angiographic prescreening would improve the clinician's ability to select and access the optimal arterial site for left heart catheterization.

Several clinically relevant observations are apparent from this study. First, MR angiography can be performed rapidly and is well tolerated in a population of high-risk patients with known or suspected peripheral vascular disease and stable coronary syndromes who are about to undergo catheterization. During their hospitalization, no major vascular complications occurred in these patients as defined above. This favorable outcome contrasts with literature-based estimates of a one-in-five risk of procedural failure in patients with peripheral vascular disease who undergo coronary angiography from the femoral artery approach (Hildick-Smith et al., 2000). Contrast to noise ratios for the MRAs obtained were well above established thresholds for the arterial segments analyzed to be visually apparent. A CNR ≥ 5 has been shown to be visually conspicuous (Ahrens et al., 1998). Length of hospital stay did not appear to be affected by the MRA prescreening procedure as patients were able to undergo MR angiography and cardiac catheterization on the same hospital day without difficulty. In addition to the postprocessed MIPs, surface rendered images appeared to be particularly useful in defining the vascular anatomy in relation to the femoral head landmark, which can be visualized by fluoroscopy. This relationship may be especially valuable when gaining arterial access in patients with prior aorto-bifemoral bypass grafting, where the bypass graft frequently inserts into the common femoral artery over the femoral head. By reviewing the MR images, one can avoid inadvertent cannulation of the native femoral artery, which is often occluded, potentially leading to procedural failure (Fig. 3).

We also have demonstrated that MR angiographic prescreening in patients with peripheral vascular disease is an effective method for enhancing confidence, influencing technical considerations, and improving the initial choice for femoral artery access site. It is also helpful in defining the optimal site for femoral artery puncture once a site is chosen for access.

Figure 3. Oblique maximum intensity projection showing the native common femoral artery (arrow) and synthetic aorto-femoral bypass graft (arrowheads, note smooth appearance). After reviewing these images, the operator was able to direct the guide wire superiorly into the bypass graft and avoid the chronically occluded native vessel.

This point is of particular relevance because the incidence of pseudoaneurysm formation is known to be increased due to inadvertent puncture of the superficial femoral artery, which can be the result of an anatomically high, common femoral artery bifurcation. As with iliofemoral occlusive disease, no routine method exists for elucidating these complicating factors prior to catheterization.

In conclusion, based on our findings, we believe that MRA prescreening will be useful to the clinician in evaluating patients for femoral arterial access who have prior aortofemoral bypass grafting or diminished femoral pulses, suggesting a high-grade stenosis. Magnetic resonance angiography prescreening in patients with PVD improves physician confidence and influences technical choices during coronary angiography from the femoral artery approach. This novel application of MR angiography may have benefits beyond immediate procedural success, such as reductions in fluoroscopy exposure time, hemorrhage, need for blood transfusion, length of hospital stay, or cost of hospitalization. Future, double-blinded studies in larger patient populations are warranted to address these questions.

ABBREVIATIONS

MRA	magnetic resonance angiography
PVD	peripheral vascular disease
PTCA	percutaneous transluminal coronary angioplasty
MIP	maximum intensity projection
CNR	contrast-to-noise ratio

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