Utility of Color Doppler Ultrasonography and MRA in the Evaluation of Patients with Leg Ulcers

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Abstract

Purpose: The aim of the study is to evaluate the role of color Doppler ultrasonography and MRA in the evaluation of the normal and abnormal vascular supply to the leg which may lead to leg ulcers.

Material and methods: Between October 2011 and May 2012, our study included fifty patients complaining from leg ulcers, they were 36 males and 14 females with age ranging from 29-75 years and mean of 52 years. Color Doppler Sonography (CDS) and Contrast Enhanced MRA (CE-MRA) examinations were done to evaluate normal and abnormal vascular supply to the leg which may lead to leg ulcers. CDS was done using combination of real time B-mode imaging system with pulsed and continuous wave Doppler facilities and the availability of color coding of signals. CE-MRA with bolus chase technique was performed for all patients.

Results: MRA study proved to be 100% sensitive, 80% specificity positive predictive of 90% and negative predictive of 50% with 90% accuracy compared to Doppler which proved to be 80% sensitive with 60% specificity, positive predictive 85.7% and negative predictive 50% with accuracy 75%.

Conclusion: The findings of this study indicate that contrast-enhanced MR angiography is highly accurate for the detection of peripheral arterial diseases which lead to leg ulcers. Contrast-enhanced MR angiography has significantly and clinically important higher sensitivity compared with duplex US and is slightly more effective for diagnosing disease because of its higher specificity.

Key Words: Leg ulcers – Doppler – MRA.

Introduction

CHRONIC leg or vascular ulcers typically manifest as arterial, neurotrophic, diabetic, or venous ulcers. They are distinct with regard to their location, appearance, bleeding, and associated pain and findings [1].

Duplex ultrasonic imaging provides a non-invasive assessment of the arterial and venous circulation in the lower limb and is accepted as a valuable diagnostic technique. It is the first method of choice for arterial stenosis and occlusion, and for venous incompetence and deep venous thrombosis [2].

Magnetic resonance angiography (MRA) permits the non-invasive visualization of blood flow through the effects of moving spins on the magnetic resonance signal. MRA techniques can be divided into two main classifications depending upon the primary effect responsible for contrast in the image. Angiograms can be produced using either the time-of-flight (TOF) or phase contrast (PC) methods. Each method has particular advantages and limitations as an angiographic imaging technique and these are reflected in their respective applications [3].

Magnetic resonance angiogram (MRA) is more sensitive and specific for diagnosis and pre-interventional work-up of peripheral arterial diseases [4].

Patients and Methods

Between October 2011 and May 2012, The study included fifty patients complaining from leg ulcers, they were 36 males and 14 females with age ranging from 29-75 years and mean of 52 years. They all referred to Zagazig Radiology Department to evaluate normal and abnormal vascular supply to the leg which may lead to leg ulcers using Color Doppler Sonography (CDS) and Contrast Enhanced MRA (CE-MRA) examinations. The duration of ulcers was from two months to 48 months with mean of 25 months (Table 1). Etiology of ulcers in our study was diabetic foot ulcer (54%), varicose ulcers (24%), Non diabetic arterial ulcers (12%) then venous ulcers with DVT (10%) (Fig. 1).
Color doppler sonography

Color Doppler Sonography examinations were done using combination of real time B-mode imaging system with pulsed and continuous wave Doppler facilities and the availability of color coding of signals. The examinations were performed with SEIMENS-Sonoline Elegra computerized color flow duplex imager and by GE (logiq 5) machine. The examination started by B-mode scanning followed by color flow imaging and lastly by pulsed Doppler evaluation.

Scanning protocol for arterial system:

Beginning at the aortic bifurcation, a 3.5 MHz probe was used to examine the aorta, common iliac and external iliac arteries. A 7.5 MHz probe was used for examination of lower limb vessels. The color scale was set for about 30 cm/sec maximal mean velocity for imaging the ilio-femoral-popliteal systems. Lower scale (about 10 cm/sec) was used to scan the infra-popliteal system. The overall gain was increased until color noise appeared in the static tissues adjacent to the arterial wall then the gain was gradually decreased until tissue noise just disappeared. The Doppler angle formed by the pulsed Doppler beam and the angle cursor, was kept around 60 degrees. The angle cursor was adjusted to the follow the axis of the blood flow visualized by color Doppler flow imaging. The smallest available sample volume was placed in the midstream of the visualized flow. The peak systolic velocity (PSV) was recorded from all the examined segments and in any area of suspected stenosis, values were recorded immediately before, within and just distal to the stenosis.

Scanning protocol for venous system:

The scanner should be configured for a venous examination. The color PRF should be low, typically 1000 Hz, to detect low-velocity flow. The color wall filter should also be set at a low level, and the spectral Doppler sample volume should be increased in size to cover the vessel, so that flow is sampled across the lumen. A 10 MHz transducer, or broad-band equivalent, is normally used for scanning superficial varicose veins. However, a 5 MHz, or broad-band equivalent, flat linear array transducer should be used for examining the femoral, popliteal and calf veins. The iliac veins are examined using a 3.5 MHz curved linear array transducer. Ultrasound compression is the main method of confirming vein patency. If direct transducer pressure is applied over normal vein it will collapse, In contrast, if there is thrombus in the vein it will not collapse.

Contrast enhanced MRA with bolus chase technique:

All MRA were obtained with superconducting magnet 1.5 T MRA system (Gyroscan advanced clinical system-II; Philips, medical system, Best, the Nether lands) using a moving table technique (Mobi-Trak; Philips). The body coil was used for signal transmission and reception for all studies. Patients were placed in a supine position with their feet entering the magnet first. During infusion of the contrast agent, the subjects had to elevate their arms over their head.

First, a multistation, two-dimensional turbo-field-echo localizer sequence in three stacks, beginning with the calf, was acquired in the axial orientation. The field of view for each stack was 430mm, with an overlap of 20mm between the stacks. Thus, a maximum length of 1250mm could be imaged by moving the table between the stacks.

Scanning Parameters were TR/TE, 12/6.9; Flip angle 60, and slice thickness 3.3mm, with an interstice gap of 1 mm, Orthogonal maximum intensity projections (MIPs) for all three stacks were reconstructed automatically.

Coronal three-dimensional volumes of the MR angiographic acquisitions were positioned using the sagittal MIPs of the localizer scan. A three dimensional fast spoiled 3D gradient sequence in three stacks was acquired using the following parameters: TR/TE = 6.0/1.5, Flip angle 35, FOV = 430mm, 1.5 to 2.0mm slice thickness, 256 X 192 matrix, scan time 20 to 25 sec/station. Unenhanced mask images of the three vascular territories under consideration (aortoiliac, femoropopliteal and calf) were acquired beginning at the calf level then, infusion of 20 to 30ml of paramagnetic contrast material was begun with a flow rate of 0.5ml/sec followed by a saline flush of 20ml. After delay time (15-20 sec) post infusion, scanning of the proximal vessels territory (aortoiliac arteries) was initiated. Table movement among the stacks was performed in 3 second, and acquisition of the next stacks could be started immediately. Mask images were automatically subtracted from the contrast-enhanced images, and orthogonal MIPs of all three stacks were reconstructed immediately.

Results

Majority of patients in our study were with diabetic foot ulcer (54%) then, varicose ulcers (24%) and non diabetic arterial ulcers (12%) and lastly, venous ulcers with DVT (10%).
Duplex scanning of varicose ulcers showed tortuous varicosities and features of venous stasis and incompetent valves. The changes in peak systolic velocity (PSV) have been put forward for assessment of stenosis.

Majority of patients belong to diabetic foot ulcer hence the grade of ulcer was compared with severity of stenosis (Table 2), we applied Wagner Ulcer Classification for the grading of the ulcer [8] and Cossman et al., method [6] for severity of stenosis.

Wagner ulcer classification:
Grade I: Superficial diabetic ulcer.

Grade II: Ulcer extension:
1- Involves ligament, tendon, joint capsule or fascia
2- No abscess or osteomyelitis.

Grade III: Deep ulcer with abscess or osteomyelitis

Grade IV: Gangrene to portion of forefoot.

Grade V: Extensive gangrene of foot.

Cossman et al., method:
• Velocity shift (i.e. peak systolic velocity in the stenosis divided by peak systolic velocity proximal to stenosis).
• If ratio less than 2.0 equals lesser than 50% stenosis.
• Ratio greater than 2.0 but less than 4.0 equals 50-74% stenosis.
• Ratio greater than 4.0 equals 75-99% stenosis.

Out of 50 patients of leg ulcers, 32 cases (64%) presented with grade II ulcer, 13 cases (26%) presented with grade III and five cases (10%) with grade IV ulcer. It was also found that on comparing the ulcer grade of 27 diabetic patients with corresponding peak systolic velocity, 16 cases (32%) presented with grade II, 7 cases (14%) with grade III and four cases (8%) with grade IV.

In this study, there are 33 patients of arterial ulcers. Out of them 27 patients are diabetic, 5 cases (18.5%) had stenosis in order of (0-49%), 10 cases (37%) in range of 50-75% stenosis and 12 cases (44%) had stenosis >75%. Six cases are non diabetic, four had stenosis in range of 50%-75% and other two cases had stenosis >75%.

Cossman et al., CE-MRA observations [6] were very useful in picking up early arterial stenosis, or collaterals, as compared to Doppler. Severe stenosis and gross ischemic changes were shown by MR study. All cases showed positive findings on MRA study as occlusion or stenotic segment of the affected vessels. Hence CE-MRA study proved to be 100% sensitive MRA study proved to be 100% sensitive, 80% specificity positive predictive of 90% and negative predictive of 50% with 90% accuracy compared to Doppler which proved to be 80% sensitive with 60% specificity, positive predictive 85.7% and negative predictive 50% with accuracy 75%.

Table (1): Duration of ulcers (in months) with respect to specific etiology.

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Duration of ulcers (in months)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;6</td>
<td>6-12</td>
</tr>
<tr>
<td>Diabetic ulcers</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Non diabetic Arterial ulcers</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Varicose ulcers</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Venous ulcers with DVT</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>16%</td>
<td>28%</td>
</tr>
</tbody>
</table>

Table (2): Diabetic foot ulcer grade compared with peak systolic velocity (N=27).

<table>
<thead>
<tr>
<th>Count</th>
<th>Peak Systolic Velocity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5-2</td>
<td>2-4</td>
</tr>
<tr>
<td>Grade II</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Grade III</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Grade IV</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

Fig. (1): 3D pie graph shows percentage of leg ulcers with respect to specific etiology.
Fig. (2): A diabetic female patient 56 years old with a right leg ulcer. (a) CDS showed occluded left EIA and left CFA, (b) CDS showed damped monophasic flow pattern of the left SFA, (c) Summated MIP 3D CE-MRA image showing the arterial tree of both lower limbs, attenuated distal right popliteal artery and occluded distal part of the left popliteal artery, (d) 3D MIP CE-MRA showed occluded left EIA and left CFA and focal ostial compromise of the right femoral bifurcation.
Fig. (3): A non diabetic female patient 68 years old with ulcer on the left leg. (a) CDS showed occluded left popliteal artery, (b) CDS showed damped monophasic flow pattern of the left peroneal artery, (c) 3D MIP CE-MRA showed occluded left popliteal artery, (d) Summated MIP 3D CE-MRA image of the entire abdomino-pelvic and lower limb arterial tree.
Fig. (4): A diabetic male patient 54 years old with right Leg ulcer above medial malleolus, (a) CDS showed occluded mid segment of the right SFA, (b) CDS showed damped monophasic flow pattern of the right ATA (c) 3D MIP CE-MRA showed small focal stenotic segment (about 50% stenosis) of the proximal left CIA, (d) 3D MIP CE-MRA showed about 4 cm long occluded segment of the right SFA as well as occluded distal half of the right popliteal artery with collateral refilling of the trifurcation.

Discussion

The prevalence of leg ulceration is highly age-dependent; with leg ulcers progressively increases with advancing age [7]. In our study, the patients with leg ulcers were ranging from 29-75 aged years with mean of 52 years and the prevalence increased with advancing age.

Our study disagreed with the report of Nelzen et al. [8] that we found the patient population consists of 36 males (72%) and 14 females (28%) denoting prevalence of leg ulceration in males more than females.

Most leg ulcers are caused by venous insufficiency (approximately 45-60%), arterial insufficiency (10-20%), diabetes (15-25%) or combinations of these well known aetiological factors (10-15) [9]. Our study found that majority of patients with diabetic foot ulcer (54%) then, varicose ulcers (24%) and non diabetic arterial ulcers (12%) and lastly, venous ulcers with DVT (10%).
Duplex ultrasonography has a sensitivity of 80% and a specificity of 90% for detecting femoral and popliteal disease compared with angiography, but it is less reliable for assessing the severity of stenosis in the tibial and peroneal arteries [10]. The results of our study compared with the study of Donnelly and Hinwood [10], found that duplex ultrasonography had the same sensitivity but specificity had some difference as compared to 90% for Donnelly & Hinwood; this study reveals 60% specificity.

Classification of ulcerations can facilitate a logical approach to treatment and aid in the prediction of outcome. The most widely accepted classification system for diabetic foot ulcers and lesions is the Wagner ulcer classification system which is based on the depth of penetration, the presence of osteomyelitis or gangrene, and the extent of tissue necrosis [8]. In our study, according to the Wagner ulcer classification system, out of 50 patients of leg ulcers, 32 cases (64%) presented with grade II ulcer, 13 cases (26%) presented with grade III and five cases (10%) with grade IV ulcer. It was also found that on comparing the ulcer grade of 27 diabetic patients with corresponding peak systolic velocity, 16 cases (32%) presented with grade II, 7 cases (14%) with grade III and four cases (8%) with grade IV.

In this study, there are 33 patients of arterial ulcers. Out of them 27 patients are diabetic, 5 cases (18.5%) had stenosis in order of (0-49%), 10 cases (37%) in range of 50-75% stenosis and 12 cases (44%) had stenosis >75%. Six cases are non diabetic, four had stenosis in range of 50%-75% and other two cases had stenosis >75%. These findings closed with the study of Nandan & Chandra, 2009 [11] where they found that In 19 patients of diabetic foot ulcer, 21.05% had stenosis in order of (0-49%), 31.50% in range of 50-75% and 47.37% had stenosis >75%.

The present study agreed with the study of Joshi et al. [12] where they mentioned that Color Doppler is advantageous in hemodynamic assessment. The stenosis was confirmed by the damped flow distally and the jet flow at the stenosis site, some of the stenoses were hemodynamically significant which caused these changes and some were not significant.

MRA is an excellent noninvasive imaging method that routinely guides clinical management decisions between catheter-based and surgical lower extremity interventions. Continuing advancements include multichannel systems with whole-body multidetector arrays in combination with parallel acquisition techniques, continuous table motion, whole body MRA techniques, and high-performance gradients, new contrast agents with high relaxivity, and strategies to reduce or eliminate the dose of gadolinium contrast material in patients with impaired renal function [13].

Our patients were subjected to magnetic resonance (MR) in which patients of diabetic foot ulcer and arterial non diabetic ulcers were examined by Contrast enhanced magnetic resonance angiography (C E-MRA). Also we found that MR angiography proved to be 100% sensitive and when compared to Doppler studies which proved to be 80% sensitive with 60% specificity.

The results of our study agreed with the study of Leiner et al, 2005 [4] where the comparison between contrast-enhanced MR angiography and duplex US providing evidence that contrast-enhanced MR angiography is more sensitive and specific for diagnosis and pre interventional work-up of peripheral arterial diseases. Also, our study coincided with Collin et al, 2007 [14] that we found CE MRA has a better overall diagnostic accuracy than duplex ultrasonography.

However, in a study of Nandan & Chandra [12], for evaluation of the role of non invasive imaging modalities in leg ulcers, 30 patients were subject to color flow Doppler, only 11 patients of them were subject to MR examination, at 0.2 Tesla magnetic field without CE MRA. Duplex scanning was positive in all patients, giving vital information like degree of stenosis, abnormal waveform, luminal narrowing and plaques, collaterals, neovascularization, varicosities, and abnormal venous channels. Thus conventional B scan with Doppler (Duplex scanning) with color flow imaging was 100% sensitive in demonstrating these abnormalities. It also showed that with increasing severity of disease the frequency and number of collaterals increased. With duplex scanning it is possible to examine flow patterns in a precisely defined area within the vessel lumen. MR angiography proved to be only 60% sensitive when compared to Doppler studies.

Our study used contrast study with MRA which disagreed with the report of Nandan & Chandra, [12] in which MRA study without contrast.

**Conclusion:**

The findings of this study indicate that contrast-enhanced MR angiography is highly accurate for the detection of peripheral arterial diseases which lead to leg ulcer. Contrast-enhanced MR angiography has significantly and clinically important higher
sensitivity compared with duplex US and is slightly more effective for diagnosing disease because of its higher specificity.

References