ORIGINAL ARTICLE

Three-Dimensional Dynamic Subtraction Contrast Enhanced Magnetic Resonance Angiography of the Peripheral Arteries - An Initial Experience

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Summary

This is a prospective study with the objective of comparing Three Dimensional (3D) Dynamic Subtraction Contrast Enhanced Magnetic Resonance Angiogrphy (3DDSCEMRA) with Conventional Catheter Arteriography (CCA) as the gold standard, in the diagnosis of peripheral occlusive disease. Three patients scheduled for CCA in this hospital in between September and October 2000 were included in this study. Patients underwent 3DDSCEMRA before proceeding to CCA on the same day. The 3DDSCEMRA reader was blinded to the CCA results. The results showed good correlation in ilio-femoral segment and poor correlation in the infrapopliteal segment due to artifacts in 3DDSCEMRA images. 3DDSCEMRA is a new, non-invasive and promising technique in the diagnosis of peripheral occlusive disease.

Key Words: Contrast enhanced, Magnetic Resonance Angiography (MRA), Peripheral occlusive disease

Introduction

Conventional catheter arteriography (CCA) of the femoral and lower limb arteries has been the gold standard in the diagnosis of various occlusive diseases involving the peripheral arteries. However due to its invasive nature and the small but significant complication rate, various non-invasive imaging methods have emerged to provide an alternative in imaging the peripheral arteries. Three dimensional dynamic subtraction contrast enhanced magnetic resonance angiography (3DDSCEMRA) has been the most recent addition.

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There has been rapid development and advances ever since MR angiography was introduced into clinical practice for vascular imaging 10 years ago. Both time-of-flight (TOF) and phase contrast (PC) MRA had been utilized for imaging the peripheral arteries. These flow-dependent MRA techniques suffered from various drawbacks such as lengthy examination time, in-plane saturation artifacts, motion artifacts and signal loss due to retrograde flow[1,2]. These problems have largely been addressed with the advent of contrast enhanced MRA. Contrast enhanced MRA makes use of T1 relaxation time shortening of blood after the administration of paramagnetic contrast medium, gadopentetate dimeglumine to produce high quality angiograms[1].

Materials and Methods

From September to October 2000, three consecutive patients aged between 30 and 52 with mean age of 43.7 years scheduled for CCA of the femoral and peripheral arteries were selected for 3DDSCEMRA. There were one male and two females. The clinical problems were: painful non healing ulcer in the toes of both feet in 1 patient, gangrene right foot in 1 patient and swelling of right big toe in the last patient. All three patients underwent CCA of the femoral and peripheral arteries on the same day after 3DDSCEMRA.

We performed 3DDSCEMRA on a 1.5 Teslar MR scanner (Magnetom Symphony, Siemens Medical System, Germany) with high performance gradient (maximum amplitude 20mT/m) and slew rate of 50 mT/m/msec. We used the moving table, multistations, bolus chase technique[1,2,3] to image the peripheral arteries.

Results

The correlation between 3DDSCEMRA and CCA at the iliofemoral segment was good, however there was poor correlation for the popliteal and infrapopliteal segment due to artifacts on 3DDSCEMRA images.

The 3DDSCEMRA and CCA findings, 3DDSCEMRA pitfalls and treatment of all 3 patients are summarized in Table I.

Table I
Summary of 3DDSCEMRA Findings, CCA Findings, 3DDSCEMRA Pitfalls and Treatment of all 3 Patients

Patient	3DDSCEMRA Findings	CCA Findings	3DDSCEMRA Pitfalls	Treatment
1	Normal distal aorta, iliac & femorals. Irregular narrowing distal right popliteal. Left popliteal and its trifurcation were normal. Tibial and peroneal arteries were not visualized due to venous contamination. No diagnosis was made	Normal distal aorta, iliac & femorals. Irregular narrowing distal right popliteal and collateral vessels right calf. Left popliteal and its trifurcation were normal. Irregularities of calf arteries noted in left calf. Diagnosis: Buerger's disease.	Venous contamination rendering visualization of calf arteries impossible. Poor signal to noise ratio in thigh and calf.	Conservative.
2	Normal distal aorta & iliac. Extensive arteriosclerosis of femoral & popliteals. Occlusion of mid right popliteal with reconstitution of posterior tibial.	Normal distal aorta & iliac. Extensive arteriosclerosis of femoral & popliteal. Occlusion of mid right popliteal with reconstitution of posterior tibial.	Poor signal to noise ratio in thigh and calf.	Right below knee amputation
3	Normal distal aorta, iliac, femorals, popliteals & their trifurcation. Mild arteriosclerosis of calf arteries.	Normal distal aorta, iliac, femorals, popliteals & their trifurcation. Mild arteriosclerosis of calf arteries.	Poor signal to noise ratio in thigh and calf. Pseudo-occlusion of femoral arteries due to inappropriate image coverage	Conservative.

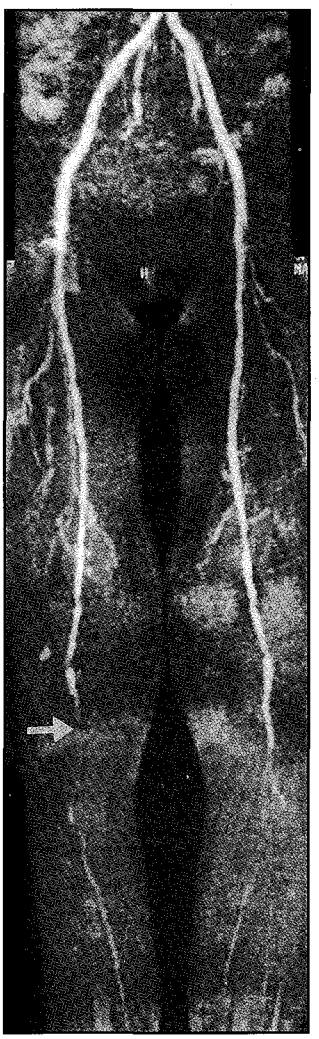

Fig. 1: **Composite contrast enhanced MRA image after MIP reconstruction showing:**
(i). extensive atherosclerotic disease of the superficial femorals and popliteals,
(ii). occlusion of mid right popliteal (arrow) with reconstitution at origin of right posterior tibial.
(iii). occlusion of left tibio-peroneal trunk and left anterior tibial with reconstitution of posterior tibial and peroneal at mid calf.

Fig. 2: Composite conventional film-screen arteriogram of same patient as in Figure 1, showing:
(i). extensive atherosclerotic disease of the superficial femorals and popliteals,
(ii).occlusion of mid right popliteal (arrow) with reconstitution at origin of right posterior tibial and,
(iii).occlusion of left tibio-peroneal trunk and left anterior tibial with reconstitution of posterior tibial and peroneal at mid calf.

Discussion

For many years, conventional catheter arteriography (CCA), be it conventional film-screen arteriography or digital subtraction arteriography, has been the investigation of choice in patients with suspected peripheral occlusive disease. It provides a road map for the interventional radiologist and vascular surgeon to plan their approach and intervention.

Conventional catheter arteriography (CCA) is a relatively safe and established technique with a low complication rate of approximately 1.8%[3]. It has benefited from the long history of x-ray vascular imaging. On the other hand, 3DDSCEMRA represents the latest advances in MR angiography, which was introduced into clinical practice only in the last few years[4].

In order to provide a road map for intervention in patients with peripheral occlusive disease, a good MR arteriogram should be able to detect and display the proximal as well as distal stenotic lesion, the severity of the lesion (ability to distinguish between high grade stenosis of >50% and low grade stenosis of 50% or less), the length of the lesion and the condition of the inflow and outflow arteries of the lesion. Several studies[2,3,5,6,7] had shown that contrast enhanced MRA is able to or potentially able to provide these information.

Currently there are several techniques available in performing 3DDSCEMRA of the peripheral arteries. These include the moving table, multistation, bolus chase technique[1,2,3] time-resolved multistation and multiple injection technique[1,5,6] and multistation with single continuous infusion technique[1]. We used the first technique for the simple reason that it is easy, fast, convenient and focuses primarily on the arterial system.

Our initial data indicates that 3DDSCEMRA of the femoral and peripheral arteries correlates fairly well with CCA in the ilio-femoral segment and poor correlation in the infrapopliteal segment of the peripheral arterial system. The main disadvantage of 3DDSCEMRA is the relatively poor spatial and contrast resolution in displaying the smaller and more peripherally located arteries like small collateral arteries around the knee and distal calf arteries[1,2,4]. This information is important for the vascular surgeon to quantify severity of the disease and make revascularization decisions. To improve the image quality of calf and small arteries, use of surface coil and subtraction technique may be the answer[4,5,6].

One problem related to 3DDSCEMRA is accurate timing of the arrival of contrast bolus in the appropriate vasculature. Delay in starting data acquisition relative to contrast infusion would result in enhancement of venous structures. This happened in patient No.1.

There are authors who advocate performing 2D Time-Of-Flight (TOF) MRA of the calf arteries before proceeding to 3DDSCEMRA[2]. This method serves to eliminate venous enhancement, as it is a flow sensitive sequence. However the setback of this additional sequence is lengthy examination time and its associated flow related artifacts[2,5,6].

Another method of circumventing this problem is to perform 3DDSCEMRA using the time resolved dynamic subtraction method, whereby three escalating doses of gadopentetate dimeglumine are administered at three different times at three separate stations (pelvis, thigh and calf) with three to five sets of data acquired rapidly at each station[1,5,6]. The operator can choose from these data sets for subsequent digital subtraction and MIP reconstruction. This method practically eliminates venous contamination and test bolus may not be necessary. The setback of this method again is prolonged table time. It takes approximately 30 minutes to perform this examination as compared with 15 minutes for the moving table, bolus chase technique in specialized centers[8].

Pseudo-occlusion artifact of the arteries as seen in patient No.3 is due to inappropriate image coverage[5]. By meticulous review of the

scout images and careful placement of the 3D volume box, one can avoid this problem. Other problems related to 3DDSCEMRA but were not seen in this limited series include: subtraction misregistration, pseudodissection and phase artifacts[5].

The advantages of 3DDSCEMRA as compared with CCA are many. These include: 1) It is non invasive. 2) It can be performed on an outpatient basis. 3) It is less costly in terms of consumables if compared with CCA. 4) No ionizing radiation involved. 5) Contrast agent used (gadopentetate dimeglumine) has an excellent safety profile. Contrast media reactions are extremely rare[1,2]. 6) Contrast agent (gadopentetate dimeglumine) has no clinically detectable nephrotoxicity. It can be used safely in patients with renal impairment[1,2,5]. 7) MIP images allow unlimited viewing projections without additional contrast medium or extra scan time. 8) Besides post processing with MIP algorithm, multiplanar reconstruction (MPR) of the 3D data set provides another way of scrutinizing the blood vessels in detail with added accuracy.

With the advent of MR angiography in the past decade and 3DDSCEMRA in the past few years, the diagnostic algorithm of patients with suspected peripheral occlusive disease is changing. Due to its non-invasive nature, 3DDSCEMRA is poised as a screening tool for patients with suspected peripheral occlusive disease[2,4]. With further improvement in MR hard ware and soft ware in the future, one can envisage that vascular imaging in the next decade is going to be exciting and challenging.

In conclusion, 3DDSCEMRA has emerged as a non-invasive imaging technique of the peripheral arteries. It is not a replacement of the time-honored conventional arteriography, however it certainly provides a compelling alternative in a few subsets of patients i.e. patients with renal impairment and those with allergy to iodinated contrast medium.

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