3D DCE-MRA of pedal arteries in patients with diabetes mellitus

M Zamyshevskaya¹, V Zavadovskaya¹, M Zorkaltsev¹, V Udodov¹, E Grigorev¹

¹ Department of Radiology and Radiotherapy, Siberian State Medical University, Tomsk, Russian Federation

E-mail: zamyshevskayamari@mail.ru

Abstract. Purpose was identification and evaluation of pedal vascularization in diabetic patients of using contrast MR-angiography (3D DCE-MRA). 23 diabetic feet of 23 patients (15 male, 8 female; mean age 56±14.6) underwent 3D DCE-MRA (Gadobutrol 15ml) at 1.5 T. Imaging analysis included blood-flow’s speed, vascular architectonic’s condition and character of contrast’s accumulation. Osteomyelitis was verified by surgery in 15 cases. All patients were divided in 3 groups: neuropathic, neuroischemic, ischemic forms of diabetic foot. First-pass MRA detected significant delay of contrast’s arrival in ischemic group. There were no significant differences between the values of neuropathic and neuroischemic forms of diabetic foot. Pedal vessels in patients were absent. Contrast MRA revealed three types of contrast distribution in soft tissues: uniform, local increase and local absence. Osteomyelitis was associated with diffuse enhanced contrast accumulation in all cases. In summary, MRI blood vessel imaging is a promising and valuable method for examining peripheral arterial changes in diabetic foot and might be useful for treatment planning in different forms of diabetic foot.

1. Introduction

Diabetic foot syndrome (DFS) is one of the most common and serious complications of diabetes mellitus [1]. This syndrome includes arterial and microvasculature involvement, neurotrophic disorders and is accompanied by bone and soft tissue structural changes. Infection and the subsequent development of osteomyelitis are often associated with high risk of amputation. High mortality in patients with DFS after amputation is well known [2].

The main conditions for reducing the amputations and mortality are early detection and subsequent treatment of osteomyelitis, which is impossible without blood-flow correction [3]. Radiological methods, including selective digital subtraction angiography (DSA) as the "gold standard", widely used in evaluation of the main and peripheral pedal blood vessels [4]. However, despite the fact that DSA is a standardized method, it has some limitations, such as invasiveness, relatively high radiation dose, and the possibility of contrast-induced nephropathy in such patients.

Magnetic resonance angiography (MRA) is an alternate method, characterized by high spatial resolution and absence of nephrotoxic effects of the contrast media. Many publications show the advantages of using MRA for DSA patients [5]. However, majority of publications focuses on vascular permeability; MRA data on DFS patients with complicated purulent necrotic process are limited.
The purpose of the study was to characterize pedal arteries (vascular architectonics, contrast arrival time and character of contrast accumulation) in patients with complicated diabetic foot using contrast-enhanced MRA.

2. Materials and methods

Our study was full-design. 23 patients (15 men, 8 women, mean age 56 ± 14.6 years) with neuropathic (n = 9; 39.0%), mixed (n = 10; 43.5%), ischemic (n = 4; 17.5%) DFS forms with suspected osteomyelitis (OM) underwent 3D DCE-MRA (Gadobutrol 15ml) at 1.5 T MR imaging unit (Siemens MAGNETOM Essenza, Germany). The diagnosis of diabetes mellitus was established according to WHO criteria, 1999. All patients complained of pain in the affected foot. An objective study identified the following symptoms: swelling of the soft tissues (100%), hyperaemia (82.6%), ulcer (43.5%) or fistula (26.1%), local temperature increase (69.6%), the weakening of pedal vessels pulsation (34.8%). All patients had either normal or only slightly reduced renal function with estimated glomerular filtration rates (GFR)>30 ml/kg body weight. Osteomyelitis was verified according to operations in 15 cases.

Magnetic resonance imaging of ankle and foot was carried out using MR-tomography 1.5 T clinical scanner in three standard planes - sagittal, coronal and transversal, slice thickness of 3-5 mm, by using T1-WI and T2-WI, FSat sequences. After receiving the native image MRA with contrast agent bolus Gadovist (Bayer HealthCare Pharmaceuticals) in 15 ml was performed. Angiographic images were recorded within 180-300 seconds since the contrast administration by taking cyclically repeating series of 17-second scans, which were subsequently processed using subtraction and building MIP-reconstructions. It was performed delayed postcontrast MR - study of feet using sequences T1-WI for comparison angiography and perfusion.

3. Results

The study included three stages. In the first stage the contrast arrival time in pedal vessels was assessed, which was averaged 21 ± 11.4 sec according to a study in the total group. At the same time, was revealed significant difference of contrast arrival time in DFS ischemic form, which was 53 ± 33.15 seconds. Approximately the same values were obtained for neuropathic form - 20 ± 12.5 sec and mixed form - 19 ± 9.3 sec.

Next, using as reference data Martin R. Prince (2001) [6], all patients were divided into 3 groups: with timely (n = 11, 48%), accelerated (n = 8, 35%) and delayed (n = 4, 17%) contrast arrival in pedal vessels. Accelerated contrast arrival observed equally in neuropathic (n = 4, 50%) and mixed (n = 4, 50%) forms DFS [Fig. 1a,b].

Delayed contrast arrival was determined mainly in ischemic form of DFS (n=3, 75%) and only in 1 case (25%) it was identified in the neuropathic form of DFS.

In the second stage of the study was evaluated pedal vascular architectonics’s condition. In this study the normal vascular pedal vascular architectonics was established in 12 (52.2%) cases. It was revealed visualization absence of aa. digitales dorsales in 12 (52.1%) cases, mainly in patients with ischemic (100%) and mixed (40.0%) DFS forms [Fig. 2].

In rare cases, there was no visualization of arcus plantaris (n = 1, 4.3% mixed form), a. arcuata (n = 1, 4.3%; ischemic form), a. metatarsae dorsales of 2nd and 3rd fingers (n = 1, 4.3% mixed form).

Another feature of the circulation in the studied group of patients was an early visualization of veins [Fig. 1b]. This picture has been diagnosed in 8 patients (34.8%) with neuropathic (n=6, 66.7%) and mixed forms of DFS (n=2, 20.0%).

In the third stage was studied character of pedal soft tissue contrast accumulation reflecting the state of the microcirculation. All patients were divided into 3 groups: with uniform (n = 2, 8.7%), local increase (n = 20, 87.0%), local absence (n = 1, 4.3%) of contrast accumulation. Local increase of contrast accumulation visualized in two variants: until distinct pedal vascular imaging (n = 3, 15.0%) and simultaneously with the appearance of pedal vascular architectonic (n = 17, 85.0%).
Figure 1. Patient K., 54 years old, diabetes type 2, mixed form of DFS. Objective: foot swelling, hyperemic, with ulcers on the medial surface of the 1st finger of the right foot. MRA: A. Early opacification diffuse soft tissue to distinct visualization of the main arteries of the foot (0-17 sec). B. Early visualization of the venous outflow - an accelerated arteriovenous transport (18-34 sec).

Figure 2. Patient K. 29 years, type 1 diabetes, a mixed form of VTS, suspected osteomyelitis. MRA: absence of aa. digitales visualization.

Uniform soft tissue contrast accumulation was observed equally in ischemic and neuropathic forms of DFS (n = 1, 4.3% respectively). Local increased accumulation was detected only in patients with neuropathic (n = 2, 8.6%) and mixed (n = 1, 4.3%) forms. Increased contrast local accumulation simultaneous with the vessels visualization principally was detected in the mixed (n = 8, 34.8%) and neuropathic (n = 6, 26.1%) DFS forms, ischemic form was characterized by a smaller number of cases (n = 3, 13.0%) [Fig. 3].

Figure 3. Patient L., 27 years old, diabetes type 1, neuropathic form of DFS. Objective: hyperemia, swelling, ulcer with purulent contents of the medial surface of the 1st left toe. MRA: Local long-term increased contrast accumulation in the soft tissues of the 1st left toe without clear visualization of vascular architectonics.
Absence of contrast accumulation was detected in the case of mixed form (n=1, 4.3%) in a patient with gangrene of the 1st finger of the left foot [Fig. 4a].

4. Discussion

Complications of diabetic foot, neuropathy caused by ischemia and joining infections are a common cause of amputations of the lower limbs, which leads to severe disability and makes a significant contribution to mortality. Early diagnosis enables timely surgical or radiological intervention and revascularization in 80% of cases [7]. 3D contrast-enhanced MR-angiography is rapidly gaining acceptance as a versatile noninvasive alternative to conventional angiography and has been reported as an accurate technique for analyzing the foot arteries in patients with diabetes [8].

At the first stage of study delayed contrast arrival time was revealed principally in ischemic form of DFS and conversely, accelerated blood-flow - in mixed and neuropathic forms of DFS, which corresponds to the pathogenesis.

When comparing the average contrast arrival time depending on the form of DFS statistically significant difference between the rates for ischemic and neuropathic (p <0.005) and between the ischemic and mixed (p <0.031) DFS forms were identified. At the same time there no statistically significant differences between the values of the average contrast arrival time in neuropathic and mixed forms of DFS were found.

In the second phase in the assessment of vascular architectonics condition it was revealed the absence of several pedal vessels branches in ischemic and mixed forms of DFS, which corresponds to the literature data. In addition, mostly for neuropathic and, to a lesser extent, in mixed forms was determined early visualization of the pedal veins due to arteriovenous shunting. Thus in 5 (62.5%) of 8 cases arteriovenous shunt, this picture has been associated with purulent inflammation.

In the third stage - evaluation the character of pedal soft tissue contrast accumulation - particular attention was paid for long-term diffuse enhanced contrast accumulation in neuropathic and mixed forms of DFS, preferably (n = 16, 80.0%) was accompanied by a purulent inflammation. However, a local increase of contrast accumulation is not specific feature for the presence of purulent inflammatory process and occurs in other clinical situations, including the Charcot foot (n = 4, 20%). Particularly interesting are the cases of extravasates before visualization of pedal vascular architectonics (n = 3, 15%), due to, in our opinion, significantly increased vascular permeability [Fig. 5a, b].

5. Conclusions

In assessing the 3D DCE-MRA patterns in patients with diabetic foot syndrome the following changes in pedal vascularization were found: absence of several pedal vessels visualization in patients with ischemic and mixed forms of diabetic foot syndrome; early visualization of the veins due to arteriovenous shunting; the combination of delayed arrival time of contrast agent with the presence of purulent inflammation in diabetic foot syndrome in some cases; the presence of long-term diffuse enhanced contrast accumulation in soft tissues associated with osteomyelitis.
Figure 5. Patient P., 53 years old, diabetes type 2, ischemic form of DFS. Objective: hyperemia, swelling, ulcer with purulent contents of the medial surface of the 4th left finger. MRA: A. Local increase contrast accumulation of in the 4 left toe before visualization of main pedal vessels (18-34 seconds). B. Local increase contrast accumulation of in the 4 left toe stored for a long time (1.28-1.44 sec).

In summary, MRI blood vessel imaging is a promising and valuable method for examining peripheral arterial changes in diabetic foot; it might be useful for treatment planning in different forms of diabetic foot.

References
[1] Ametov AS  Diabetes mellitus type 2 2014 Problems and Solution Moscow: GEOTAR-Media 1032 (in Russian)
[2] Malhotra R, Chan CS, Nather A 2014 Osteomyelitis in the diabetic foot Diabet Foot Ankle 30 5
[3] Bargellini I, Piaggesi A, Cicorelli A, et al 2013 Predictive value of angiographic scores for the integrated management of the ischemic diabetic foot J Vasc Surg 57(5) 1204-12
[4] Manzi M, Cester G, Palena LM, et al 2011 Vascular imaging of the foot: the first step toward endovascular recanalization Radiographics 31(6) 1623-36
[5] Röhrl B, Kunz RP, Oberholzer K, et al 2009 Gadofosveset - enhanced MR angiography of the pedal arteries in patients with diabetes mellitus and comparison with selective intraarterial DSA Eur Radiol 19(12) 2993-3001
[6] Prince MR, Wang Y, Watts R, et al 2001 Contrast travel times measured on 2D Projection MRA in patients with Peripheral Vascular Disease Proc. Int Soc Mag Reson Med 9 47
[7] Ranachowska C, Lass P, Korzon-Burakowska A, Dobosz M 2010 Diagnostic imaging of the diabetic foot. Nucl Med Rev Cent East Eur 13(1) 18-22
[8] Li J, Zhao JG, Li MH 2011 Lower limb vascular disease in diabetic patients: a study with calf compression contrast-enhanced magnetic resonance angiography at 3.0 Tesla Acad Radiol 18(6) 755-63