Popliteal artery entrapment syndrome evaluation with multislice CT angiography

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Abstract  Purpose: The purpose of this study is to evaluate the use of multislice computed tomography (MCT), Doppler US, and angiography in the diagnosis of popliteal artery entrapment syndrome.

Patients and methods: In a prospective study of 26 patients referred to Doppler ultrasound examination with suspected popliteal artery entrapment syndrome, we have made Doppler study of the popliteal artery of the diseased limb using 7–10 MHz probe. Additional multislice CT angiography after bolus injection of non-ionic contrast medium (Ultravist), axial transverse sections and multiplanar reformation reconstruction images were analyzed. Conventional angiography of the diseased limb was performed with the use of pigtail catheter and injection of 60 cc Ultravist.

Results: On 22 of 26 patients, the Doppler study revealed damped flow, biphasic waves and a dramatic decrease in peak velocity. All these signs appeared in the Doppler study of popliteal artery while retaining normal flow and waves in distal tibial vessels.

When 26 patients were examined, the conventional angiography revealed sudden attenuated and decreased caliber of popliteal artery with retained average caliber of the distal run-off vessels without showing the surrounding structures.

Abbreviation: PAES, popliteal artery entrapment syndrome

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When 26 patients were examined, the CT angiography revealed decreased caliber of popliteal artery, verified the exact diameter of popliteal artery and gave an accurate idea about the wall of the vessels and the surrounding soft tissue structures. These last benefits enable us to differentiate between organic and functional causes of popliteal artery entrapment syndrome.

**Conclusion:** In conclusion, popliteal artery entrapment syndrome can be diagnosed with the use of multislice CT which is as efficient as conventional angiography. However, multislice CT provides detailed information on the wall, diameter of the artery and relation of the artery to adjacent structures by a non-invasive technique.

1. Introduction

The popliteal artery is a relatively short vascular segment, but it is affected by a unique pathological condition which is popliteal artery entrapment syndrome (1). This syndrome is a developmental abnormality that results from an abnormal relationship between the popliteal artery and the surrounding musculotendinous structures that cause repeated arterial compression with exercise (2). Here are the essential six anatomic variants of PAES (Fig. 1).

- **In type I,** the medial head of the gastrocnemius muscle is normal, and the popliteal artery is displaced around and beneath the muscle.
- **In type II,** the medial head of the gastrocnemius muscle arises from an abnormally lateral position. The popliteal artery descends normally, but it passes medial to and beneath the muscle.
- **In type III,** the popliteal artery is compressed by an abnormal slip of the gastrocnemius muscle.
- **In type IV,** the popliteal artery is entrapped by a fibrous band or by the popliteus muscle.
- **Type V** is any of the four preceding types that include the popliteal vein.
- **Type VI** compression of the popliteal artery due to normal but hypertrophied muscle is seen in young athletes PAES (normal artery) (3).

Recently, the functional popliteal artery entrapment syndrome has been described in cases of patients with normal anatomy, but compression of the popliteal artery may be due to normal but hypertrophied muscle usually seen in young sports participants or athletes who do not know cardiovascular risk factors (4). Symptoms combine transient tingling or coldness in the foot, with later intermittent claudication. If diagnosis is delayed, there may be irreversible arterial damage, which can impair viability of the affected limb. Accurate diagnosis is essential because curative treatment can be performed, even when complications have occurred (5).

2. Patients and methods

2.1. Patients

This study was conducted according to the guidelines of the ethics committee of Tanta University and was approved by our institutional review board, all patients gave us written informed consent to be imaged in our study.

In a prospective study of 26 patients; 23 men and 3 women with a mean age of 30 years were referred to other institutions due to a clinical suspicion of popliteal artery disease. The presenting symptoms were long-standing intermittent claudication, sharp pain in the calf and a fleeting episode of paleness and paresthesia while training. Multilevel disease will manifest in more severe ischemic symptoms of rest pain and tissue loss.

Table 1 shows the presenting symptoms of PAES.

Twenty patients were smokers, six had hypercholesterolemia, and six had a family history of cardiovascular disease. No patient had diabetes.

Patients were clinically complaining of suspicious symptoms of PAES, and we found them negative by imaging methods which were excluded from the study. Thus, all 26 patients of the study were clinically complaining, and the imaging methods proved the diagnosis of PAES.

<table>
<thead>
<tr>
<th>Presenting symptoms</th>
<th>No. of patients</th>
<th>% of patients</th>
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<tbody>
<tr>
<td>(1) Long-standing intermittent claudication</td>
<td>15</td>
<td>57.6</td>
</tr>
<tr>
<td>(2) Sharp pain in the calf</td>
<td>9</td>
<td>34.6</td>
</tr>
<tr>
<td>(3) Fleeting episodes of paleness</td>
<td>3</td>
<td>11.5</td>
</tr>
<tr>
<td>(4) Fleeting episodes of paresthesia</td>
<td>3</td>
<td>11.5</td>
</tr>
<tr>
<td>(5) Rest pain</td>
<td>5</td>
<td>19.2</td>
</tr>
<tr>
<td>(6) Tissue loss</td>
<td>2</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Fig. 1 Classification of PAES (quoted from Levien and Veller (3)).
At physical examination, the patient will have a decreased or absent pulse at or below levels of significant disease. Bruits may be auscultated at levels of significant stenoses.

All 26 patients are prospectively studied by the following examination methods.

All patients had undergone duplex and color Doppler US, conventional angiography and multislice CT angiography. All these studies were done in neutral position.

3. Doppler US

All patients underwent Doppler US examination of the complaining lower limb using PHILIPS HD11 instrument with 7–10 MHz probe; the arterial flow, wave pattern and the peak velocity in each vessel were evaluated.

4. Multislice CT angiography

Multislice CT angiography was performed by a TOSHIBA MULTISLICE 16 Activion CT. After a popliteal scout projection was obtained, unenhanced sequential scanning (160 mA, 120 kV) with continuous 5-mm-thick transverse axial sections was performed. From 8 cm above to 7 cm below, the femoro-popliteal junction was routinely performed.

Bolus injection of 110 ml of ultrafast was injected into the antecubital fossa vein at a rate of 20 ml/s in a duration of 5.5 s. While the patient foot is in the neutral position, a short dynamic sequence of scans (12-s scanning delay, 4-s interscan delay, no table incrimination) was obtained at the level of the popliteal artery. An additional 5 s, added to the observed transient time as maximum contrast enhancement, is achieved later with the larger volume of contrast material used during spiral CT angiography. Scanning delay ranges from 29 to 45 s, and the mean scanning delay is 35 s. Total scanning time is 32 s. Multiplane reformations were routinely performed to analyze the popliteal arteries in more detail by the reformation of a three-dimensional model in Voxel-Q. Using the algorithms Shaded Surface Display (SSD), Volume Rendering (VR) and multiplanar reformations (MPRs) were routinely performed to analyze the popliteal arteries in more detail. The average time to perform the three-dimensional reconstructions is 15 min.

5. Conventional angiography

All 26 patients who underwent this study helped accurately determine the sensitivity of conventional angiography in the diagnosis of this vascular lesion.

All 26 patients were submitted to the conventional angiography of the diseased limb using PHILIPS. We punctured the femoral artery of the healthy side using a pigtail flush catheter length of 120 cm and 5 F in diameter. We enter selectively to the diseased limb. The maximum distance was the catheter advanced which is the lower third of superficial femoral artery at the diseased limb (NB: this study was carried out in the neutral position). Then the contrast material (Ultravist) of a total dose of 60 cc. was injected for a latent period of 2–3 s at a rate of injection of 15–20 ml/s of 3–4 s of the total duration and the pump injector pressure 100–120 Hg by automatic pump injector, antero-posterior images of the lower limb circulation were obtained with a field of view 38 cm. If visualization was not considered adequate, right or left anterior oblique views were also obtained. All examinations were obtained from computer assisted digital subtraction techniques. The arteriogram was examined to determine the presence or absence of popliteal artery stenosis (> 50% diameter reduction), to determine if there were signs of extrinsic compression of the popliteal artery by adjacent structures, and to determine if the course of the artery was abnormal.

We do all three types of investigations to evaluate the potential role of different items in the diagnosis of PAES.

Authors interpreted these studies blinded to the findings of other studies.

Fig. 2 Duplex color Doppler sonography of the right popliteal artery showed damped flow and biphasic wave.
6. Results

In all 26 patients, popliteal arteries were adequately visualized. In these 26 arteries, arteriography showed 22 hemodynamically significant (>50% diameter reduction) stenoses, 4 arteries showed <50% reduction in diameter, and in 2 of 26 cases are associated with popliteal artery aneurysms. Arteriography did not suggest a non-atheromatous cause in any of the other cases of stenoses or occlusion. Table 2 shows signs of PAES in conventional angiography.

PAES was demonstrated by Doppler examination in 22 of 26 patients studied (as shown in Fig. 2). Occlusion of the popliteal artery was seen in B-scan examination, duplex US demonstrated stenosis at color imaging and increased velocities proximal to the lesions, and damped biphasic waves at the site of entrapment. On four patients, the reduction in the diameter was < 50%, so we could not diagnose using Doppler study.

Multislice CT was performed on 26 patients and correctly demonstrated stenosis on 26 patients that vascular enhancement was excellent (>160 HU) as shown in Fig. 3 – Fig. 7. CT angiography correctly demonstrated the 26 cases of stenosis detected with arteriography whereas CT angiography and conventional arteriography both enabled the detection of disease on four out of 26 arteries which cannot be detected by Doppler. On the patients whom abnormality was detected, subsequent confirmation of the diagnosis was obtained during an interventional procedure.

Multislice CT provided supplementary additional soft tissue information, so it could help to verify different types of

<table>
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<th>Table 2</th>
<th>Signs of PARS in conventional angiography.</th>
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<tr>
<td>Signs</td>
<td>Number of patients</td>
</tr>
<tr>
<td>&gt;50% Diameter reduction</td>
<td>22</td>
</tr>
<tr>
<td>&lt;50% Diameter reduction</td>
<td>4</td>
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<tr>
<th>Table 3</th>
<th>Types of PAES as detected by multislice CT angiography.</th>
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<tbody>
<tr>
<td>Types of PAES</td>
<td>Number of patients</td>
</tr>
<tr>
<td>Type I</td>
<td>6</td>
</tr>
<tr>
<td>Type II</td>
<td>2</td>
</tr>
<tr>
<td>Type III</td>
<td>4</td>
</tr>
<tr>
<td>Type IV</td>
<td>7</td>
</tr>
<tr>
<td>Type V</td>
<td>2</td>
</tr>
<tr>
<td>Type VI</td>
<td>5</td>
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<th>Table 4</th>
<th>Accuracy of Doppler, conventional angiography and CT angiography in diagnosis of PAES.</th>
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<tbody>
<tr>
<td>Number of patients</td>
<td>Doppler</td>
</tr>
<tr>
<td>26</td>
<td>22</td>
</tr>
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</table>

PAES. Table 3 shows the types of PAES as detected by multislice CT angiography.

Table 4 shows the accuracy of Doppler, conventional angiography and CT angiography in the diagnosis of PAES.

Case 1: Male patient, 35-years-old complaining of pain in the right calf while walking Fig. 2.

Case 2: Male patient, 28-years-old, noticed a sharp pain in the left calf while walking Fig. 3.
Case 3: Male patient, 25-years-old, complaining of intermittent claudication Fig. 4.
Case 4: Male patient, 30-years-old, noticed a sharp pain in the left calf while walking Fig. 5.
Case 5: Male patient, 24-years-old, smoker, complained of paleness and paresthesia while walking Fig. 6.
Case 6: Male patient, 32-years-old, complaining of intermittent claudication of both lower limbs Fig. 7.

7. Discussion

Popliteal artery entrapment refers to the compression of the popliteal artery due to abnormal anatomic relationship between the vessel and the neighboring musculotendinous structures or due to muscle hypertrophy of the popliteal region especially the gastrocnemius muscle (6). Our study demonstrates the value of multislice CT angiography when evaluating popliteal artery entrapment syndrome. Multislice CT angiography provided the same information as arteriography regarding the lumen of the popliteal artery, and it also provided clinically relevant additional information notably regarding the vessel wall, e.g. presence or absence of classification, and on the involvement of adjacent structures such as bones and muscles. Doppler US examination is the initial imaging technique performed on most patients with suspected popliteal abnormality. The popliteal fossa is ideally suitable for US, which, in conjunction with Doppler interrogation, can demonstrate popliteal artery stenoses and popliteal aneurysms. However, Rubin et al. (7) and Rey et al. (8) demonstrated that if the artery is occluded, assessment of the distal circulation is rarely possible. Doppler US provides indirect evidence of popliteal artery entrapment syndrome but cannot directly demonstrate the cause of the obstruction to flow. These limitations account, in Chew and Bui-Mansfield (9) and Beregi et al. (10) for studies on the false negative results that are sometimes observed; furthermore, operator experience plays an important role because
correct positioning of the Doppler sample volume is critical. We diagnosed popliteal artery stenosis by Doppler US on 22 patients, but on four patients no stenosis could be diagnosed because the reduction in the diameter of the popliteal artery was < 50%. Arteriography was the traditional golden standard exploration of the diagnosis of popliteal entrapment as proved by Met et al. (11) in his study. This study could accurately identify the site of arterial stenosis, and if there is associated pathology, it is an invasive method. Furthermore, this study fails to provide information about musculo-tendineous structures. In our study, diagnosis of popliteal artery stenosis was made on 26 patients, but the cause of stenosis could not be accurately diagnosed. However, two associated popliteal aneurysms could be diagnosed on two patients. Multislice CT with or without 3D reconstruction provides excellent images not only of the lumen and the wall of the popliteal artery but also of the adjacent structures, e.g. muscles, bones, and tendons (12). CTA was done to 26 patients and it was adventitious in the detection of the relation of soft tissue structure in popliteal fossa in relation to the popliteal artery, thus enabling us to verify different subtypes of PAES from type I to type VI, by means of CTA. Six patients showed type I PAES in which the popliteal artery was only displaced around and beneath the muscle, type II in 2 patients where the medial head of gastrocenemius arises from abnormal lateral position, type III in 4 patients where the popliteal artery is compressed by an abnormal slip of the muscle, type IV in 7 patients where the popliteal artery is entrapped by a fibrous band, type V in 2 patients and type VI in 5 patients. The examination is less invasive, does not require hospitalization, and potentially provides more detailed information. However, the amount of contrast material required, e.g. 90 ml for the CT angiography study and 20 ml for the test bolus, is more than the material used for arteriography of the popliteal vessels (4). Kei et al. (13) studied the relation between the popliteal artery and the gastrocenemius muscle as a cause of popliteal artery entrapment syndrome using 3D reconstruction that has the ability to demonstrate the relation between the pathologic condition and adjacent structures. That approach coincides with our series when six patients have done 3D reconstruction.

In addition, recent progress in both image processing software and console design currently allowed reconstructions to be performed almost instantaneously. According to radiology, all the necessary diagnostic information was obtained through the axial transverse views. However, the additional recent processed views were considered useful by the surgeons and clinicians to understand anatomy. In our study, the severity of stenosis, assessed by multislice CT angiography in all cases, was identical to that documented with arteriography. Popliteal aneurysms were visualized in two cases in multislice CT angiograms, and conventional arteriography (7).

Reconstruction images were used to directly demonstrate the trajectory of the artery, thus proving or excluding the presence of external compression, and showing the presence or absence of thrombosis and its extent. In popliteal artery entrapment syndrome, multislice CT angiography can help confirm the diagnosis and can also demonstrate the anatomic relation between the artery, even in the presence of occlusion, and the adjacent muscles and bones.

8. Conclusion

Popliteal artery entrapment syndrome is ideally diagnosed by multislice CT angiography which provides detailed information on the wall and diameter of the artery and relation between the artery and the adjacent structures.

References