ORIGINAL ARTICLE

Evaluation of popliteal arteries with CT angiography in popliteal artery entrapment syndrome

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Abstract

Background: Popliteal artery entrapment is an uncommon clinical entity that occurs due to compression of the popliteal artery by adjacent muscle and tendinous structures. Early diagnosis should be established through a combined approach of careful physical examination and history-taking, duplex ultrasonography, and CT angiography.

Patients and methods: We have studied retrospectively 16 patients of popliteal artery entrapment syndrome, 9 men and 7 women. All patients were scanned with a scanner Picker PQ 5000 after bolus injection of nonionic contrast medium and they all underwent a two-part examination first, with the knee in a neutral position, and, second, with the knee hyperextended.

Results: At the second phase of the examination 3 patients showed normal findings, 10 patients have shown mild stenosis of the popliteal artery or more severe stenosis due to compression, 2 patients have exhibited bilateral stenosis and 1 patient has also showed popliteal venous compression

Conclusion: CT angiography images and three-dimensional images are useful not only for depiction of the arterial changes but also identification of the abnormal anatomic structures responsible for the entrapment. Hippokratia 2009; 13 (1): 32-37

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Keywords: computed tomography; three-dimensional imaging; popliteal artery; popliteal artery entrapment syndrome

Popliteal artery entrapment syndrome (PAES) is an uncommon clinical entity that occurs because of compression of popliteal artery by adjacent muscle and tendinous structures. Extrinsic arterial compression causes chronic vascular microtrauma, early arteriosclerosis and thrombus formation that cause distal ischemia.

The sudden onset of severe disabling claudication in a young adult without atherosclerotic risk factors is highly suggestive of popliteal artery occlusion due to entrapment. Since PAES is a progressive disease that can create serious vascular obstructive disease, the detection and treatment of PAES at an early stage is essential. However, diagnostic delay is common because this problem usually occurs in young, athletic patients, who lack vascular conditions that would predispose them to atherosclerosis.

Early diagnosis should be established through a combined approach of careful physical examination, history-taking, ultrasonography and CT angiography. CT angiography images and three-dimensional images are useful not only for depiction of the arterial changes but also identification of the abnormal anatomic structures responsible for the entrapment.

In this report, we present clinical and radiological findings of patients with popliteal artery entrapment syndrome.

Material and Methods

The period 2002-2007, nine men and seven women with age range 18 to 72 years (mean age 26 years) with popliteal artery and entrapment syndrome were studied retrospectively in the Radiology Department of Papageorgiou General Hospital. The above patients showed different degrees of intermittent claudication and cramping of the calf during intense physical exercise and for this reason underwent Computed Tomography Angiography.

A scanner Picker PQ 5000 was used and a bolus i.v. injection of 150 ml nonionic contrast medium at a rate of 4 ml/sec was given.

They all underwent a two-part examination, first, with the knee in a neutral position, and, second, with the knee hyperextended. In order to achieve extension of the muscles, a weight was put on patient's legs and was counterbalanced by the patient.

Helical parameters included 1-3 mm-thick image and 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) and Volume Rending (VR).

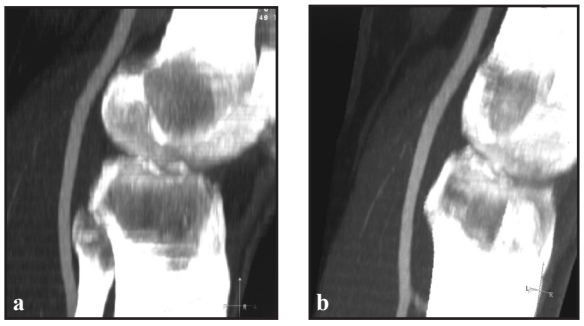


Figure 1 a, b: Three dimensional CTA. Normal width of popliteal artery and normal anatomic realationships.

Results

In all cases, the degree of opacification of popliteal artery was identical. The results of CTA in neutral position were normal in all the patients (Figures 1a-b), with the exception of one patient in whom CTA demonstrated obstruction of the popliteal artery (Figures 2a-d). At the second phase of the examination during active plantar extension of the foot 3 patients showed normal findings (Figures 3a-b). At this phase 10 patients have shown mild stenosis of the popliteal artery due to compression from the medial head of the gastrocnemius muscle (Figure 4) or more severe stenosis where the popliteal artery has not dipected in the popliteal fossa. Two patients exhibited bilateral stenosis of the popliteal arteries. One patient had also showed popliteal venous compression (Figure 5a-d)

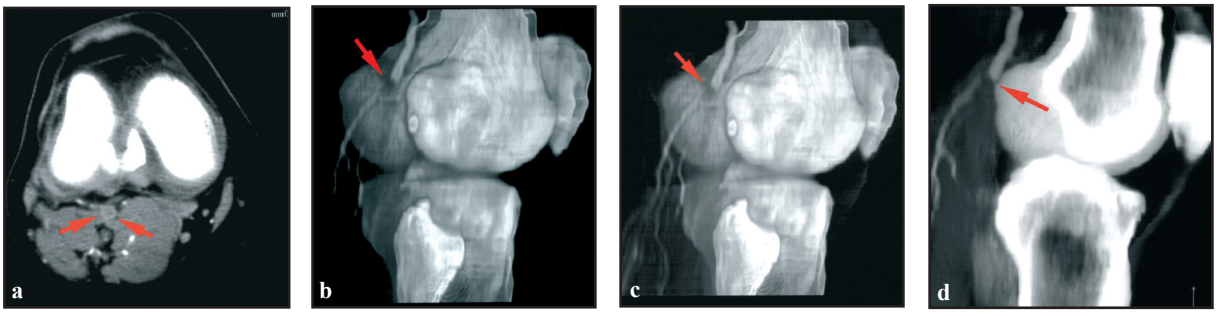


Figure 2 a-d: Axial CT scans at the level of popliteal fossa and 3D reconstructions of popliteal artery. Occlusion of distal popliteal artery.

Discussion

The popliteal artery is the continuation of the superficial femoral artery and courses through the popliteal fossa. It extends from the opening in the adductor magnus, at the junction of the middle and lower thirds of the thigh, downwards and laterally toward the intercondyloid fossa of the femur, and then vertically downward to the lower border of the popliteus, where it divides into the anterior tibial aretery and tibioperoneal trunk**.**

The first case of popliteal artery entrapment was reported in 1879 by Anderson Stuart[1], a medical student in Medical School of Edinburgh, although it was not until 1959 that Hamming performed the first popliteal artery surgical decompression in Holland[2]. Love and Whelan coined the term popliteal artery entrapment syndrome in 1965[3].

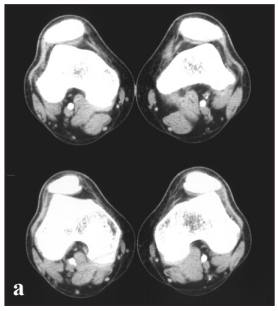
The normal popliteal artery in adults is the product of the fusion of multiple embryonic elements: the ramus communicans superius, arteria ischiadica, arteria poplitea superficialis and the arteria interossea. The deep popliteal artery, which is located medial and deep to the popliteal muscle, is obliterated and disappears during embryonic development[4].

Embryologically, PAES could be the result of anomalous development of the popliteal artery caused by perpetuation of the deep popliteal artery or due to excessive cranial migration of the medial head of the gastrocnemius muscle at its femoral insertion. Popliteal artery might be entrapped by neighboring muscles and tendons due to variations that occur during embryologic development of the muscles and arteries. Due to the complexity of embryologic development, anatomical abnormalities that cause PAES are classified into various types.

The common anatomical abnormalities related to the medial head of gastrocnemius are classified into five types[5] (Table 1).

Table 1: Types of common anatomical abnormalities of gastrocnemius.

Type 1*:* The medial head of gastrocnemius muscle is normal and the popliteal artery is deviated medially and has an aberrant course
Type 2*:* The medial head of gastrocnemius muscle is located laterally, no deviation of the popliteal artery
Type 3*:* Abnormal muscle bundle from the medial head of gastrocnemius muscle surrounding the popliteal artery
Type 4*:* The popliteal artery is located deeply and entrapped by the popliteus muscle or a fibrous band
Type 5*:* Popliteal vein is also entrapped with any type of the popliteal artery



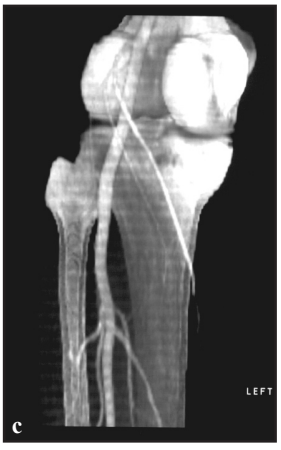


Figure 3 a-c: Axial CTA scans at the level of popliteal fossa and 3D reconstructions of popliteal artery after contraction of gastrocnemius muscle. Normal demonstration of popliteal artery.

A sixth type of entrapment has been described as a "functional" entrapment. In this type nerve and vascular popliteal entrapment exists, in absence of any kind of anatomical abnormality and has been described among athletes with largely developed muscles. It is believed that the popliteal nerve, vein and arteries could be compressed either by the hypertrophic soleus muscle against the tibial condyle or by excessive development of the plantaris muscle.

There is also a more simple classification system made by Heidelberg[6]:

Type 1*:* the popliteal artery has an atypical course

Type 2: the muscular insertion is atypical

Type 3: both conditions are present

Popliteal artery entrapment syndrome (PAES) is an uncommon clinical entity. The syndrome was previously thought to be more common in males, possibly related to the military nature of the populations studied. More recent publications suggest a male: female ratio of 2:1. This anomaly usually affects young men (aged 20 to 40 years). Bilaterality is common.

The clinical diagnosis of popliteal artery entrapment relies upon recognition of a history of calf claudication in the young and often athletic individual, which is sometimes accompanied by paresthesias of the foot. Ankle pulses are normal at rest if occlusion has not occurred. Often the symptoms are of sudden onset and precipitated by an episode of intense physical activity of the lower limbs (e.g., running a marathon)

Additional reported symptoms include cramping in the calf and foot, coldness, blanching, and numbness. Untreated, the compression mechanism frequently results in deterioration of the popliteal artery that may progress to eventual occlusion.

The sudden onset of severe disabling claudication in a young adult without atherosclerotic risk factors is highly suggestive of popliteal artery occlusion due to entrapment. The development of critical ischemia with occlusion of the popliteal artery is rare.

Distal emboli may result as a consequence of focal thrombus formation at the site of entrapment or from popliteal aneurysm formation. Any popliteal artery aneurysm in a young patient without a history of risk factors should suggest the presence of popliteal arterial entrapment syndrome.

PAES is an uncommon cause of lower extremity claudication, which usually occurs in younger patients who lack the risk factors for atherosclerosis and who are healthier and more active than average for their age group. Most of them are sportsmen, and some play professionally and have well-developed muscles. The exercise and enlargement of muscles adjacent to the popliteal artery exacerbates the consequences of the anomalous relationship between muscle and artery. The most frequently involved activities are team sports, such as soccer, rugby and basketball and martial arts, as all these activities require repeated sudden and forceful contraction of the calf, which results in hypertrophy of the calf muscles.

Similar contraction can cause PAES in heavy-vehicle drivers, such as military personnel who drive armored vehicles[6] as calf-muscle hypertrophy can be the result of an acutely flexed knee and of their repeatedly alternating forced plantar extension with forced plantar flexion.

PAES occurs due to abnormal anatomical relationship between the popliteal artery and the surrounding musculotendinous structures which are hypertrophied and repeated arterial compression upon exercise.

Most patients are diagnosed years after the initiation of symptoms and complications, post-stenotic aneurysm or distal embolization, have usually already developed at the time of diagnosis. The main reason of the delay in diagnosis is the lack of consideration of any vascular etiology in patients without cardiovascular risk factors. Other causes of acute vascular insufficiency of the limb in young persons are premature accelerated atherosclerosis, thromboangiitis obliterans, adventitial cystic disease, adductor canal outlet syndrome, microemboli, collagen vascular disease, Takayasu's arteritis, and coagulopathy[7].

The characteristic signs and symptoms are a history of leg swelling, aching pain, pain at rest, and tiredness or cramping of the calf; but symptoms can vary and, until complications develop, physical signs are absent at rest[8]. In the early stages, when the artery is patent except during calf-muscle contraction, symptoms in young persons are usually limited to transitory cramps or a feeling of coldness. Patients may report numbness, blanching, coldness, or cramps of the limb in a variety of postures, which usually resolve with a change of position. The onset of the symptoms is often sudden, during intense physical exercise[9].

Figure 4: Three dimensional CTA of both popliteal arteries (a) Normal demonstration of the left popliteal artery in neutral position (b-d). Stenosis of the left popliteal artery after contraction of gastrocnemius muscle (e-g). Normal demonstration of the right popliteal artery.

Early in the course of entrapment syndrome, a provocative test is needed for diagnosis: the patient is asked to hyperextend his leg and to contract the gastrocnemius muscle by means of active plantar extension or maximal passive dorsal flexion, which should lead to a decrease or disappearance of pulses of the foot[10].

In the later stages of undiagnosed PAES, when the artery is affected by stable lesions (local stenosis or occlusion, local thrombotic interruption or poststenotic aneurysm) typical symptoms are severe acute ischemia and intermittent calf claudication, usually unilateral. Such symptoms are surprising when they occur in healthy-looking young subjects who lack atherogenic risk factors[11].

Acute ischemia occurs as a result of thrombosis in situ and is common in young patients who have not developed sufficient collateral circulation.

Duplex ultrasonography with provocation maneuvers is a screening technique for PAES. The popliteal artery is ideally situated for ultrasonographic examination and the effect of dynamic maneuvers can be assessed with Doppler examination. The superficial location of the popliteal artery renders it easily accessible for ultrasound examination. The Doppler examination is performed with the patient in a prone position while the knee is fully extended, and in neutral position. Diagnostic maneuvers consisted of actions causing gastrocnemius muscle contraction and such maneuvers include active ankle extension and passive dorsiflexion of the foot, and knee hyperextension. A decrease in peak systolic flow of the popliteal artery could be indicative of PAES. However, false positive results are also possible with this test, mainly among athletes, as it does not discriminate between anatomical entrapment or functional flow impairment[12].

Arteriography was the traditional gold standard exploration for the diagnosis of popliteal entrapment as it could identify the site of arterial injury, wheth-

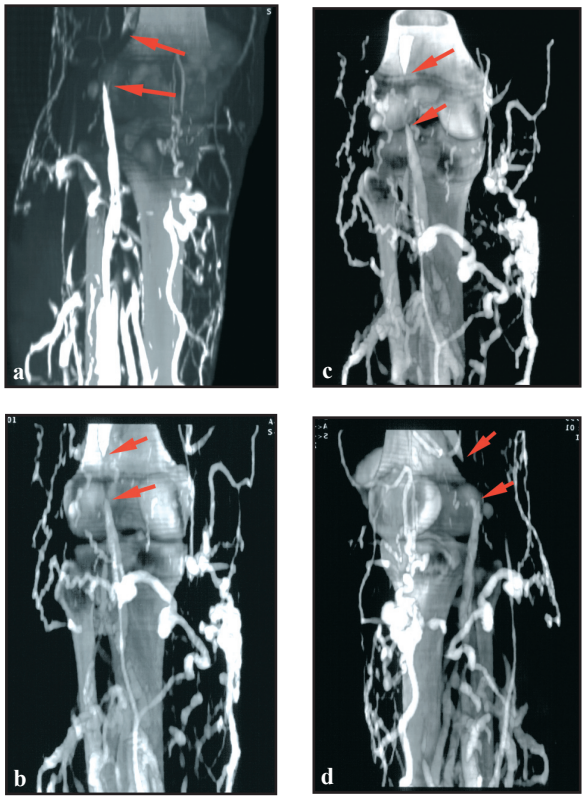


Figure 5 a-d: Three dimensional CTA of popliteal artery. Popliteal artery entrapment syndrome and stenosis of popliteal vein.

er it was occlusive or aneurysmatic. Diagnostic arteriography was performed by the Seldinger technique, via the transfemoral approach. Arteriography with the foot in a neutral position was compared with arteriography during active plantar extension of the foot for assessment of compression of the artery in the popliteal fossa. Typical angiographic findings are medial deviation and well-defined focal narrowing of the popliteal artery. Occlusion in the mid portion of the artery and post-stenotic dilatation in the distal portion may be seen. However, it does not always demonstrate the characteristic findings of medial deviation and post-stenotic dilatation of the popliteal artery. Also in some cases it is quite difficult to recognize whether the occlusion or dilatation is due to PAES or to arteriosclerosis.

Spiral CT angiography provides excellent images not only of the lumen and the wall of the popliteal artery, but also of the adjacent structures, muscles, bones, and tendons. CT angiography may be the procedure of choice in young adults with intermittent claudication and is demonstrated to be a very sensitive diagnostic modality for PAES. A spiral dynamic CT scan with intravenous bolus contrast enhancement at the level of the popliteal fossa is performed. A bolus injection of 100-200 ml nonionic contrast medium at a rate of 4 ml/sec is demanded. The first phase of the examination is performed in neutral position, without muscle contraction. In order to be achieved contraction of the regional muscles, a weight is positioned at the legs of the patient who is trying to control it and the same CT scans are obtained[13]. The main advantage of the CT scan arises from its capacity to view the three dimensional model from any angle after data acquisition in order to best visualize soft-tissue anatomy, the position of the artery in relation to that of the surrounding muscles. The inherent high contrast available with CT, along with its ability to reconstruct scans the superimposition of overlying structures, excellent visualization of normal, stenosed and thrombosed vascular lumen.

Careful analysis of axial scans on the monitor enables accurate grading of popliteal arterial stenoses and evaluation of surrounding muscular anomalies. Once images are loaded at the workstation, axial scans can be viewed rapidly by scrolling up and down the vascular tree. Interpretation of axial scans on the monitor also enables electronic enlargement of each affected leg segment and rapid changing of window parameters[14]. Lateral and oblique views of CT images are useful for detection of arterial deviation and aberrant muscle[15].

CT may provide important information such as the presence of aberrant muscle, the relationship between the popliteal artery and surrounding structures and information about other conditions affecting the popliteal artery, such as cystic adventitial disease and thrombosed popliteal artery aneurysm. Computed tomography can detect occlusion, deviation and stenosis of the popliteal arteries[16].

Thus, in popliteal artery entrapment syndrome, spiral CT angiography can help confirming the diagnosis and can also demonstrate the anatomic relationship of the artery, even in the presence of occlusion, to the adjacent muscles and bones.

PAES should be treated by surgery regardless of the degree of symptoms. Surgical treatment technique is releasing of the vessel by extracting the muscle that causes entrapment, and reconstructing the narrowed lumen by endarterectomy or by-pass grafting. Treatment of the occlusion by angioplasty may be a proper approach after removal of the factor that causes entrapment[17]. Endovascular treatment is not effective without removing the underlying reason of vessel entrapment, in which case the risk of reocclusion is high[18]. The choice of surgical procedures was dependent on the condition of the popliteal artery. If transection of the anomalous muscle is not performed together with the arterial reconstruction, symptoms can recur because of persistent extrinsic compression on the graft[19].

Since PAES is a progressive disease that can create serious vascular obstructive disease, the detection and treatment of PAES at an early stage is essential. However, diagnostic delay is common because this problem usually occurs in young, athletic patients, who lack the vascular conditions that would predispose them to atherosclerosis and limit their normal social and professional activities in the presence of even mild symptoms.

CT scanning was demonstrated to be the most sensitive diagnostic modality for PAES and should be performed for younger male patients presenting with intermittent claudication.

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