ORIGINAL ARTICLE

MRI and DSA findings in popliteal artery entrapment syndrome

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PURPOSE
To evaluate magnetic resonance imaging (MRI) and digital subtraction angiography (DSA) findings in popliteal artery entrapment syndrome.

MATERIALS AND METHODS
Seven limbs of 6 patients (5 men and 1 woman; mean age, 36 ± 12 years) with popliteal artery entrapment syndrome were evaluated retrospectively. Both MRI and DSA were performed on each affected limb.

RESULTS
MRI findings established the diagnosis of type-3 popliteal artery entrapment syndrome in 4 limbs, and type-2 in 3 limbs. Abnormal MRI findings included popliteal artery thrombosis with aneurysm in 2 limbs (29%), popliteal artery thrombosis without aneurysm in 1 limb (14%), aberrant fibrous band in 3 limbs (43%), aberrant thick muscle bundle in 1 limb (14%), insertion anomaly of medial head of the gastrocnemius muscle (MHG) in 3 limbs (43%), lateral deviation of the MHG in 4 limbs (57%), hypertrophy of the MHG in 1 limb (14%), and atrophy of the MHG in 2 limbs (29%). Deviation of the popliteal artery in 4 limbs (57%) and distal crural embolic occlusions in 2 limbs (29%) were detected with both angiography and MRI imaging. DSA was diagnostic in 2 limbs of 1 patient, and MRI was diagnostic in all limbs examined.

CONCLUSION
Popliteal artery entrapment syndrome should be considered in patients younger than 50 years of age with isolated popliteal artery stenosis or occlusion. MRI is the preferred imaging modality for diagnosis of entrapment syndrome, and may obviate the use of DSA.

Key words: • popliteal artery • peripheral arterial disease • magnetic resonance imaging • digital substraction angiography

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The popliteal artery is a short vascular segment affected by many pathologic conditions including atherosclerosis, aneurysm, trauma, arterial embolus, Buerger's disease, cystic adventitial disease, and popliteal artery entrapment syndrome (PAES) (1). PAES occurs when the popliteal artery is compressed secondary to an abnormal relationship of the popliteal artery to the adjacent muscle and tendons. Deviation and compression of the popliteal artery due to the abnormal position of the adjacent structures may result in repetitive microtrauma and early atherosclerosis, leading to popliteal artery stenosis or occlusion. Abnormal development of the muscular and arterial structures in the popliteal fossa may lead to various forms of PAES (2, 3).

Digital subtraction angiography (DSA) and magnetic resonance imaging (MRI) have been used to diagnose PAES. Occlusion, deviation, aneurysm, ectasia, and dynamic stenosis can be demonstrated by conventional and stress angiography (4, 5), but these modalities may not identify an underlying anatomic abnormality. MRI recently has become the preferred noninvasive diagnostic test because it provides better resolution of the vessels as well as the surrounding muscular and tendinous structures. There are many published clinical and radiologic reports on PAES focusing primarily on DSA and MRI; however, few of these reports provide detailed data of MRI findings on PAES (6–8). The aim of this study was to describe specific MRI and DSA findings of anatomic PAES.

Materials and methods

Seven lower limbs of 6 patients with popliteal artery disease secondary to PAES, were reviewed retrospectively. Five males and one female, ranging in age from 17 to 50 years (mean, 36 ± 12 years), were evaluated. Five patients had intermittent claudication, and 1 had acute leg ischemia; all were symptomatic. The diagnosis of PAES was established with MRI and DSA in all patients. One patient had popliteal artery occlusion 18 year prior to her admission, and had undergone bypass surgery twice. On admission, her bypass graft was occluded.

MR images were obtained with one of two 1.5-T scanner units (Vision Plus or Avanto; Siemens, Erlangen, Germany) using a standard knee coil. The MRI sequences included spin echo T1-weighted axial and coronal (TR/TE 500–700 ms/11–14 ms, 2 NEX), turbo spin echo (TSE) T2-weighted axial and sagittal (TR/TE 4000–4500 ms/80–100 ms, 2 NEX) images.

MR images were examined for atrophy or hypertrophy of the medial head of the gastrocnemius muscle (MHG), abnormal deviation of the MHG, insertion of the MHG, presence of aberrant fibrous bands, aneurysm and/or thrombosis of the popliteal artery in each patient. Subtypes of PAES were determined with MRI according to Whelan and Rich classification (Table 1) (2, 3).
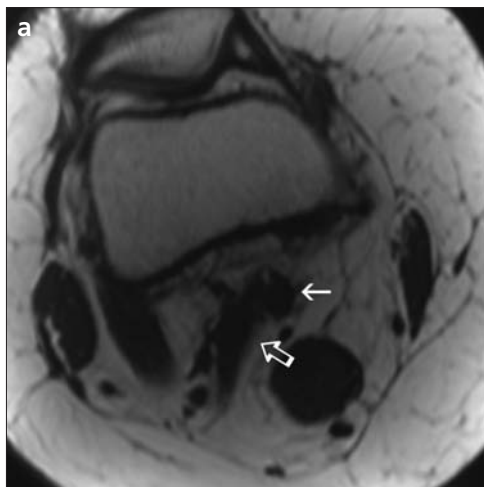
Figure 1. a, b. A 39-year-old woman with popliteal artery occlusion (PAES type 2). Axial T1-weighted MR image **(a)** shows lateral location of the medial head of the gastrocnemius muscle *(open arrow)* crossing the popliteal artery *(arrow)*. Selective right lower-limb DSA **(b)** reveals popliteal and crural artery occlusion (posterior and anterior tibial arteries) possibly due to distal embolization.
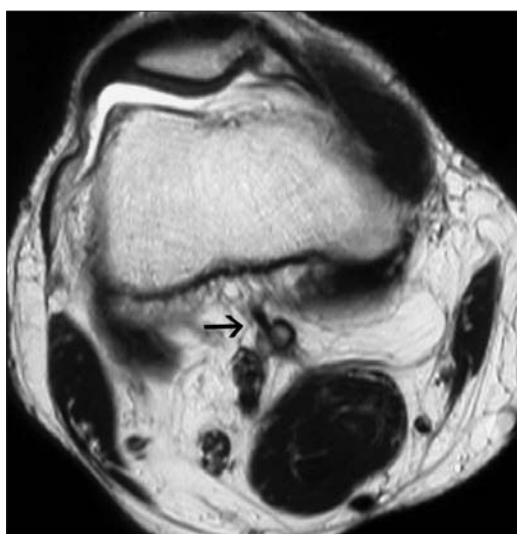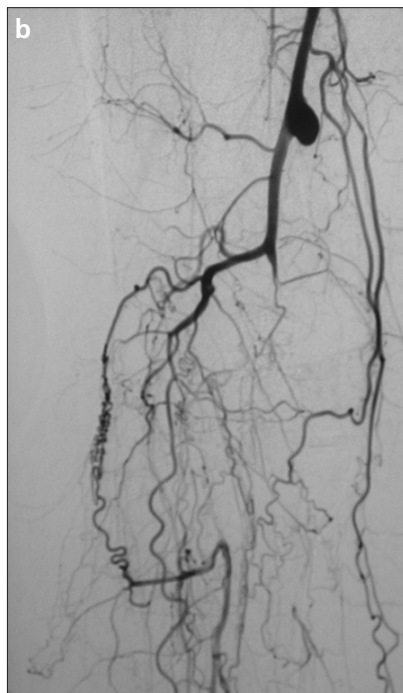
Figure 2. A 50-year-old man with popliteal artery occlusion (PAES type 3). Axial T2-weighted MR image reveals a fibrous band *(arrow)* originating from the medial head of the gastrocnemius muscle crossing the occluded popliteal artery and inserting into the intercondylar notch.

DSA was performed via retrograde contralateral common femoral artery puncture in 4 patients; 2 patients underwent antegrade ipsilateral common femoral artery puncture. DSA images were examined to determine the presence or absence of stenosis, thrombosis, aneurysm, abnormal course of the popliteal artery, and presence of distal crural embolic occlusions.

The first 4 patients had surgical bypass of the occluded popliteal artery; the last 2 patients had endovascular recanalization of the occluded popliteal artery with catheter-directed thrombolysis and percutaneous transluminal angioplasty. One of the two patients refused decompressive surgery; the other had surgical decompression of the popliteal artery.

Results

Popliteal artery entrapment was bilateral in 1 patient (17%), and unilateral in 5 patients (83%). Type-3 PAES was diagnosed in 4 limbs, and type-2 in 3 limbs on MRI, according to Whelan and Rich classification (Figs. 1, 2) (2, 3). Patient demographics and MRI findings are shown in Table 2. The MHG thickness was normal in 4 limbs. The medial head of the MHG was prominent in 1 limb, and was atrophic in both limbs of another patient with bilateral involvement (Fig. 3). The MHG medial head was attached at its normal site in 4 limbs (57%) and was attached to the intercondylar notch in the other 3 limbs (43%). The MHG was deviated laterally in 4 limbs (57%), and the direction of the muscle was normal in 3 limbs (43%). Hypertrophy of the MHG in 1 limb (14%) and atrophy of the MHG in 2 limbs (29%) were present in a patient with bilateral involvement. In 3 of 4 limbs in patients with type-3 PAES, the compressing part of the MHG was not a muscular bundle, but a fibrous band that attached to the intercondylar notch after crossing the popliteal artery. Compression was the result of an aberrant thick muscle bundle surrounding the popliteal artery in 1 limb with type-3 PAES. The compression of the popliteal artery between the medial femoral condyle and a fibrous band or MHG was evident on MRI in 5 limbs (71%). In all 5 limbs, the popliteal artery was devoid

Table 1. Classification of the popliteal artery entrapment syndrome according to Whelan and Rich classification (2, 3)

Type 1	Aberrant course of the popliteal artery medial to a normal MHG
Type 2	Abnormal lateral insertion of the MHG and medial deviation of the popliteal artery
Type 3	Compression of a normally positioned popliteal artery by an accessory slip of the MHG
Type 4	Abnormal location of the popliteal artery, deep in the popliteus muscle or beneath fibrous bands in the popliteal fossa
Type 5	Any form of the entrapment that involves both the popliteal artery and vein

MHG, medial head of gastrocnemius muscle.
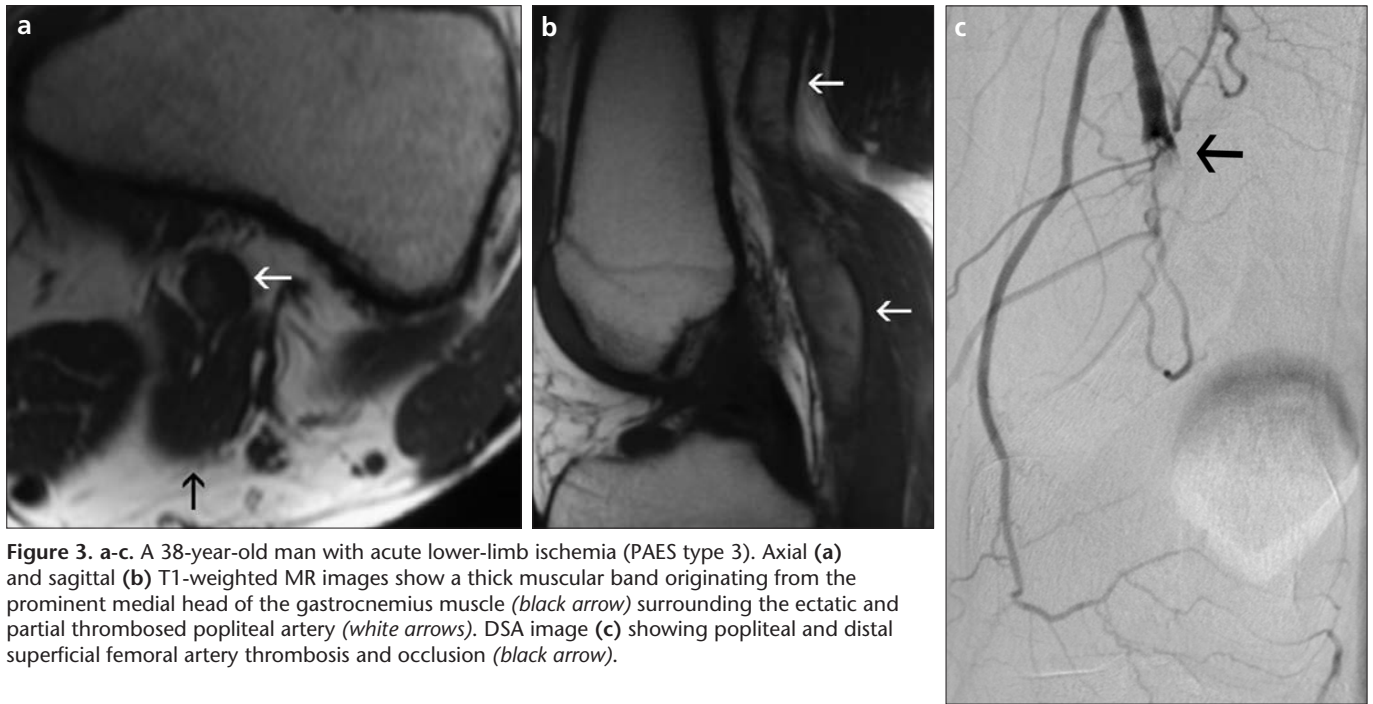
Figure 3. a-c. A 38-year-old man with acute lower-limb ischemia (PAES type 3). Axial **(a)** and sagittal **(b)** T1-weighted MR images show a thick muscular band originating from the prominent medial head of the gastrocnemius muscle *(black arrow)* surrounding the ectatic and partial thrombosed popliteal artery *(white arrows)*. DSA image **(c)** showing popliteal and distal superficial femoral artery thrombosis and occlusion *(black arrow)*.

of a surrounding fat plane. Additional abnormalities of the popliteal artery included thrombosis with aneurysm in 2 limbs (29%), thrombosis without aneurysm in 1 limb (14%), and anatomic deviation in 4 limbs (57%).

Twenty-four abnormal MRI findings (range, 2–5; median, 4) were encountered in the popliteal artery as well as in structures surrounding it. Most patients had more than one abnormal finding related to the MHG (size, shape, direction, and attachment points of the muscles or fibrous bands), or to the popliteal artery.

DSA images revealed stenosis of the popliteal artery in 3 limbs (43%) and

occlusion in 4 limbs (57%). Occlusion of the artery extended up to the distal femoral artery in 2 limbs, most likely secondary to propagation of the thrombus. Long-segment occlusion in these 2 limbs made angiographic diagnosis of PAES virtually impossible. The two youngest patients (aged 17 and 24 years) had stenosis, and 4 older patients (aged 38–50 years) had occlusion of the popliteal artery (Table 3). Angiography further revealed a thrombosed aneurysm of the popliteal artery in 2 limbs (29%), thrombosis without aneurysm in 1 limb (14%) and distal crural embolic occlusions in 2 limbs (29%). No additional arterial pathology of the

aorta, the iliac arteries, or the proximal part of the femoral arteries was noted in any of the patients.

On DSA images, stenosis of the artery was diagnosed in both limbs of 1 patient (Fig. 4). In the other patients, angiography was only suggestive of the diagnosis; the diagnosis was established in consideration of the patient's age, absence of atherosclerosis in other artery segments, and isolated involvement of the popliteal artery. MRI established the diagnosis in all cases.

One patient who had endovascular recanalization and decompressive surgery had a patent popliteal artery at 6-month follow-up. The other patient,

Table 2. Patient demographics and MRI findings in popliteal artery entrapment syndrome

Patient No.	Age/Sex	PAES type	Insertion of MHG	Shape of MHG	Free fat around PA	Deviation of MHG	Aberrant fibrous band	PAA	PAT
1	24/M	III	N	N	(–)	(+)	(+)	(–)	(–)
2	48/M	II	ICN	N	(–)	(+)	(–)	(+)	(+)
3	39/F	II	ICN	N	(–)	(+)	(–)	(–)	(+)
4	50/M	III	N	N	(–)	(–)	(+)	(–)	(–)
5	38/M	III	N	Hyt	(+)	(–)	(+)	(+)	(+)
6R	17/M	III	N	Atr	(+)	(–)	(+)	(–)	(–)
6L		II	ICN	Atr	(–)	(+)	(–)	(–)	(–)

R, right; L, left; M, male; F, female; PAES, popliteal artery entrapment syndrome; MHG, medial head of the gastrocnemius muscle; N, normal; ICN, intercondylar notch; Hyt, hypertrophic; Atr, atrophic; PA, popliteal artery; PAA, popliteal artery aneurysm; PAT, popliteal artery thrombosis.

Figure 4. Digital subtraction angiography image shows focal, well-defined, severe stenosis and lateral deviation of popliteal artery bilaterally *(arrows)*.

who refused decompressive surgery after endovascular recanalization, had recurrent thrombosis of the artery 2 months after the treatment. She underwent bypass surgery.

Discussion

PAES is an uncommon clinical entity resulting from compression of the popliteal artery by adjacent muscle and/or tendinous structures in the popliteal fossa. True prevalence of PAES is unknown, but it may be more common than previously reported because vascular studies may not be performed in patients with claudication in the absence of cardiovascular risk factors (6). PAES prevalence was 3.5% in a postmortem study and 0.16% among young males recruited to military service (9, 10). Most authors report that PAES is bilateral in 25% of cases, but bilateral involvement in two studies was reported to be 67% and 81% (4, 8, 11). Bilateral symptoms were present in 25% and 58% of the patients in those two studies. A milder or asymptomatic form of the syndrome possibly could be present in the contralateral limb and thus, the prevalence of bilateral involvement could be higher than previously appreciated.

Popliteal artery entrapment resulting from abnormal development of the muscular and vascular structures in the popliteal fossa has been described as anatomic PAES. There are five anatomic subtypes of PAES, based on the anomalies of the MHG. Recent MRI studies have reported involvement of the lateral head of the gastrocnemius muscle in a subset of patients (8). In patients with normal anatomy, PAES syndrome is described as type-6, or functional PAES. In such patients, compression of the popliteal artery is due to anatomically normal but hypertrophic calf muscles. Demographics of patients with anatomic entrapment is usually different from that of functional entrapment. Patients with anatomic PAES are older than those with functional PAES (mean age, 43 vs. 24 years), and are more commonly male (72% vs. 40%) (12). Evidence in the present study of patients with anatomic PAES was consistent with these two findings; 5/6 were male (83%) and the mean age (36 years) was older than that of functional PAES. Review of the surgical findings of PAES revealed 19 different findings in 15 limbs of 11 patients (4). These were fibrous bands linking the MHG to the lateral condyle in 5 limbs (33%), and a band crossing behind the popliteal artery in 5 other limbs. This anomaly also was found in association with an abnormally high or internal insertion of the MHG muscle. A muscular insertion anomaly was associated with muscular hypertrophy, which caused arterial compression in 4 limbs.

MRI is a valuable noninvasive modality that allows optimal visualization of the popliteal artery as well as the surrounding structures. Intrinsic vascular disease also can be distinguished from extrinsic compression by MRI (6, 8, 13). MRI can demonstrate a variety of findings including abnormal intercondylar insertion of the MHG, medial displacement and occlusion of the popliteal artery in the popliteal fossa, and fat tissue filling the normal location of the MHG (5–8). Kim et al. retrospectively reviewed

Table 3. Angiographic findings of the patients with popliteal artery entrapment syndrome

Patient No.	Lesion type	Unilateral/Bilateral	Deviation of PA	Crural embolus	Aneurysm of PA	Thrombosis of PA
1	Stenosis	Unilateral	(–)	(–)	(–)	(–)
2	Occlusion	Unilateral	(+)	(–)	(+)	(+)
3	Occlusion	Unilateral	(–)	(+)	(–)	(+)
4	Occlusion	Unilateral	(+)	(–)	(–)	(–)
5	Occlusion	Unilateral	(–)	(+)	(+)	(+)
6R	Stenosis	Bilateral	(+)	(+)	(–)	(–)
6L	Stenosis		(+)	(–)	(–)	(–)

R, right; L, left; PA, popliteal artery.

studies of 23 limbs in 12 patients with PAES that had been diagnosed by MRI, computed tomography, DSA, or a combination of these modalities (8). In their study, popliteal entrapment was bilateral in most patients (81%) with bilateral symptoms in 58%. Patients with prominent unilateral symptoms showed a variety of associated anomalies in the same limb. These anomalies included ganglion cyst, bony tubercle, and accessory slip of the MHG with a more prominent muscle belly (8). In our study, on MRI we found 24 different abnormalities (atrophy or hypertrophy of the MHG, lateral deviation and/or insertion abnormality of the MHG, aberrant fibrous band, and aneurysm and/or thrombosis of popliteal artery) in seven limbs of six patients (Table 2). Every patient had more than one abnormal MRI finding (range, 2–5; median, 4), most of which involved structures surrounding the artery rather than the artery itself. Existence of more than one anomaly in every patient in our study group and in patients described in previous studies suggests that a variety of anomalies, not just one, may play a role in the development of PAES.

DSA findings of PAES are nonspecific in most cases, and may not elucidate the underlying cause of the occlusion and thrombosis. Typical angiographic findings in our study were seen in only 1 patient. These included medial deviation and focal, well-defined narrowing of the popliteal artery in both limbs. The diagnosis was suspected with clinical findings and angiography, but it was established with MRI in the other 5 patients. In a review of the literature, Rosset et al. reported occlusion of the popliteal artery in 36%, deviation in 24%, aneurysm or ectasia in 9%, and dynamic stenosis in 32% of patients with PAES (4). In that study, MRI and DSA showed occlusion of the popliteal artery in 57%, deviation in 57%, aneurysm formation in 29%, and thrombosis in 43% of seven limbs. In addition, 43% of patients had distal crural embolism. Some of the patients in our study were diagnosed months after the onset of symptoms; ectasia, distal embolization, occlusion, and thrombosis already had been established by the time of diagnosis. The definitive diagnosis was delayed because in young patients in whom cardiovascular risk factors are not evident, vascular disease typically is not considered. Delayed diagnosis for such a reason has been discussed previously (6).

Symptomatic PAES must be treated because the disease always progresses to permanent narrowing of the popliteal artery. Progression results from repetitive microtrauma to the intima of the vessel; subsequent fibrosis renders the vessel susceptible to thrombosis (14). If the diagnosis and treatment are established early in the course of the disease, symptoms related to PAES resolve. Surgical treatment consisting of resection of the muscle or tendon compressing the popliteal artery and bypass grafting (if necessary) is the standard treatment modality. As reported in the literature, either catheter-directed thrombolysis, or percutaneous transluminal angioplasty combined with surgical decompression without bypass surgery may be a reasonable, less-invasive approach to these lesions (15).

PAES is a rare disease that should be considered in patients aged younger than 50 years of age who present with symptoms related to isolated popliteal artery stenosis or occlusion, or who have radiographic evidence of popliteal artery pathology. MRI allows visualization of an abnormal relationship of the popliteal artery to adjacent musculotendinous structures, and usually demonstrates more than one abnormality. MRI is a diagnostic tool superior to angiography, and thus, may obviate the need for angiogaphy in the dianosis of PAES.

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