Functional popliteal artery entrapment syndrome: A poorly understood and often missed diagnosis that is frequently mistreated

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Objectives: Functional popliteal artery entrapment syndrome (FPAES) is an uncommon overuse injury in young physically active adults manifest by neuromuscular symptoms (gastroc/soleus cramping, plantar paresthesias). It is commonly confused with chronic recurrent exertional compartment syndrome (CRECS). This study evaluated the diagnostic testing, mechanism of injury, and treatment differences between FPAES and CRECS.

Methods: Between 1987 and 2007, 854 patients (557 women, 297 men; mean age, 28.5 years) were surgically treated for the diagnosis of CRECS or FPAES, or both. Compartment pressures were measured in all patients who had anterior lateral or posterior superficial calf symptoms (normal pressure <15 mm Hg). Noninvasive stress positional plethysmography was routine. Stress positional magnetic resonance imaging (MRI) or angiography (MRA) was performed on patients with positive plethysmography result and symptoms consistent with FPAES.

Results: Of the 854 patients, 757 (95%) had elevated compartment pressures (>25 mm Hg), and fasciectomy was performed for CRECS under local anesthesia (anterior lateral, 508; posterior superficial, 191; distal deep posterior, 101). The result of stress plethysmography was positive in 139 (18%), but they were asymptomatic. Forty-three patients (27 women, 16 men; mean age, 26.6 years) had positive stress plethysmography, appropriate FPAES symptoms, and normal compartment pressures. MRA/MRI in all 43 demonstrated normal musculotendinous anatomy and lateral neurovascular compression with plantar flexion. Under general anesthesia, all had excision of the soleal band, with relief from symptoms. In 19 of the 43 FPAES patients (44%), CRECS releases were done before or after FPAES surgery. Follow-up ranged from 12 to 240 months.

Conclusion: FPAES and CRECS occur in the same population with similar symptoms but require different treatment. (J Vasc Surg 2009;49:1189-95.)

Overuse injury is more commonly recognized as a cause for claudication in young, physically active adolescents and adults. Atypical symptoms frequently occur in the absence of obvious musculoskeletal injury or arterial venous disease and affect isolated muscle groups of the infrageniculate lower extremity. Chronic recurrent exertional compartment syndrome (CRECS) and functional popliteal entrapment syndromes (FPAES) are two of the more common causes for atypical claudication and are frequently confused with one another because the complaints are similar in quality and in anatomic location and often overlap; yet, they require different surgical treatments for successful outcomes. This study evaluates the diagnostic testing, mechanisms of injury, and treatment differences between CRECS and FPAES.

METHODS

In the 20-year period between 1987 and 2007, 854 patients (557 women, 297 men) were evaluated and surgically treated for atypical claudication associated with a diagnosis of CRECS or FPAES. These patients were referred to our clinic from local and regional sports medicine facilities, coaches, trainers, and previously treated patients. Most were healthy, physically fit adolescents and young adults with long-standing symptoms aggravated by vigorous athletic activity. Symptoms were clinically manifest by cramping and swelling of isolated muscle groups and occasional paresthesia on the plantar or dorsal surface of the foot.

All patients provided a detailed history and underwent a physical examination. Almost all patients referred from orthopedic or sports medicine consultants had undergone musculoskeletal testing in the form of radiographs, computed tomography scans, and magnetic resonance imaging (MRI) that had excluded structural orthopedic injury. In our clinic, all patients had screening ankle-brachial indices (ABI) and stress positional plethysmography using the Flo-Lab pulse volume recorder (Parks Medical Electronics Inc, Aloha, Ore) to screen for arterial occlusive disorders and for anatomic popliteal entrapment. Arterial occlusive disorders are very uncommon in atypical claudication patients, but popliteal artery impingement can be documented in up to 30%.

Stress positional testing was performed using a 10-cm cuff inflated to 60 mm Hg with patients supine, the knees extended, and the foot in neutral, forced plantar and dorsiflexion positions. Abnormal stress positional tests consisted of an ABI drop >30% or flattening of the plethysmographic waveforms in plantar or dorsiflexion, or both. Clinical relevance of a positive entrapment test was based on patient symptoms.
Compartment pressures were routinely measured using the Stryker computer system (Stryker Surgical, Kalamazoo, Mich) when claudication symptoms were referable to the anterior, lateral, or posterior superficial muscle groups. Resting pressures were measured bilaterally even if complaints were unilateral. Pressures after exercise were only measured if patients had been inactive for >1 month before examination, because prolonged periods of inactivity result in loss of muscle tone and compartment pressures that do not accurately reflect the active physiologic status of the conditioned athlete.

When exercise testing was required, the patient ran outside the clinic until symptoms developed to more accurately reduplicate stress conditions. Pressures normally return to baseline levels ≤ 3 minutes after exercise. With this in mind, compartment pressures were measured at least 10 minutes after exercise.

In our early practice, postoperative pressure measurements were taken once the rehabilitation period had ended and patients returned to normal activity. However, our experience strongly suggested that in the absence of recurrent symptoms, confirmatory compartment pressures were unnecessary. Current practice is to perform postoperative compartment pressure measurements only in patients who develop recurrent symptoms in the release area. Normal resting pressures in our clinic range from 15 to 17 mm Hg. Pressures > 25 mm Hg were considered to be abnormal.

Arterial venous duplex ultrasound testing was not routine unless global limb edema, saphenous varices, positional swelling, or a popliteal fossa mass was identified by history or physical exam. Pulse volume recordings (PVRs) were only measured in individuals with absent or diminished axial pulses on physical examination or in those with an abnormal result on screening ABI.

Our preferred arterial imaging study for symptomatic patients with abnormal results on PVRs or stress positional plethysmography was magnetic resonance angiography (MRA) or stress positional MRI/MRA in patients with symptoms suggestive of popliteal entrapment. Arterial imaging with MRA techniques in young adults is excellent, avoids catheter and dye risks, and allows a detailed evaluation of musculotendinous as well as arteriovenous anatomy in the popliteal fossa.

The surgical treatment for CRECS was fasciectomy performed using local anesthesia with sedation. The most commonly released compartments in order of current prevalence were the anterior lateral in 47%, posterior superficial in 44%, and the distal deep posterior in 9%. The anterior lateral and distal deep posterior compartment release procedures were done with the patient supine. The posterior superficial compartment releases were usually done with the patient prone.

Unlike in the other compartment release procedures, drains were routinely used when a posterior superficial release was done because of the tendency for seromas to form postoperatively. The techniques for the posterior superficial CRECS and FPAES procedures are described to emphasize the significant differences in treatment for these two conditions that are commonly confused with one another.

Posterior superficial compartment release technique. After prone positioning and sedation, incisions are marked in the upper third of the calf. Incision marks are 2 to 3 cm long and are placed half way between the posterior midline of the calf and the medial border of the tibia or lateral border of the fibula, or both, depending on whether the medial or the lateral component, or both, of the posterior superficial compartment is to be released.

Local anesthesia is injected along the marks, and the incisions are carried down to the fascia overlying the gastrocnemius and soleus muscle. Electrocautery is used for soft tissue hemostasis, and a circumferential field block is injected in the subcutaneous tissue.

The skin and subcutaneous tissue is mobilized off of the fascia overlying the gastrocnemius and soleus muscles. Local anesthetic is injected subfascially, and a large window of fascia is excised along with the underlying epimysium from both the gastrocnemius and soleus muscle. A 10 flat Jackson-Pratt (CR Bard Inc, Covington, Ga) drain is placed in each incision and brought out through a separate wound. The incisions are closed with subcuticular absorbable suture and Steri-Strips (3M Healthcare, St. Paul, Minn), and the leg is wrapped in a compressive dressing from toe crease to the knee.

The FPAE release technique. This is performed under general anesthesia using an upper medial 4-cm calf incision similar to that used to expose the distal popliteal artery. Through this incision, the fascial attachments of the gastrocnemius and soleus muscle to the medial tibia are incised, and a large posterior flap of fascia is removed along with the underlying muscular epimysium. The plantaris tendon and distal third of the plantaris muscle, which can be exposed between the gastrocnemius and soleus muscle, are transected and excised. The medial attachments of the soleus muscle are cautered off of the medial tibial border in the same fashion used to expose the distal popliteal and proximal tibial vessels for infrageniculate bypass surgery. Under direct vision, the rigid band of anterior soleal fascia that forms the distal outlet of the popliteal fossa is excised from its tibial attachment laterally to the fibula. This fibrous band is the fulcrum against which the neurovascular bundle is laterally compressed causing the symptoms of FPAES. The calf incision is closed in the same fashion described for the compartment release procedure.

Postoperatively, patients were placed in compression dressings and kept at bed rest with bathroom privileges for 48 hours. Crutches were used as required for 3 to 4 days. At 1 week, patients started a nonimpact aerobic rehabilitation program that included swimming, stationary biking, the use of cross-country ski exercise machine or stair-step exerciser. Patients were instructed to stretch before exercise and to ice over the surgical wounds afterwards. If no problems developed with nonimpact aerobic conditioning, patients were started on an injured runners program at 4 to 6 weeks after surgery. After completing this rehabilitation requirement, patients were allowed to resume full athletic ability.
RESULTS

Between 1987 and 2000, 240 patients (102 men, 138 women) underwent evaluation and surgical treatment for atypical symptoms of lower extremity claudication associated with CRECS or FPAES. Characteristics of this group included long-standing symptoms before treatment (mean, 18 months, range 6-24), isolated muscle group cramping and swelling, or occasional paresthesia on the plantar or dorsal aspect of the foot. Most were young, physically fit adolescents or adults (mean age, 28 years, range 12-65) with no obvious musculoskeletal injury or arteriovenous disease. In only seven patients (2.9%) were the results of noninvasive vascular testing normal (2 venous, 5 arterial). These seven patients were ultimately diagnosed with anatomic popliteal entrapment syndrome.

Of the remaining 233 patients, 30 were treated for FPAES and 203 for CRECS. In the CRECS patients, 734 symptomatic compartments were treated with fasciectomy, 138 were unilateral, and 298 were bilateral. The mean compartment pressure in symptomatic compartments was \( \geq 29 \) mm Hg (normal was considered to be \( \leq 15 \) mm Hg). The most commonly treated compartments were the anterior lateral in 72%, the distal deep posterior in 16%, and the posterior superficial in 12%.

The seven patients (mean age, 44 years, range 19-50) with anatomic popliteal entrapment (5 men, 2 women) presented with symptoms of ischemic claudication or digital ischemia or both (5), or intermittent venous occlusive symptoms (2). Imaging studies in these patients demonstrated medial displacement and focal compression of vascular structures and the presence of anomalous musculotendinous bands (Fig 1). During this same treatment interval, 30 patients (25 women, 5 men) with a mean age of 24.5 years (range 19-35), presented with neuromuscular symptoms suggesting FPAES. All complained of focal, proximal deep calf cramping (soleal pain), particularly when running on inclines or upon repetitive jumping, and occasional paresthesia on the plantar surface of the foot. Lateral long segment displacement and compression of normal appearing popliteal vessels in the absence of obvious musculotendinous anomalies was characteristic of stress imaging studies with MRI (Fig 2).

Since 2000, 614 patients (195 men, 419 women) with a mean age of 28.5 years have been surgically treated for CRECS or FPAES. During this time, 1196 (255 unilateral, 471 bilateral) compartment releases (fasciectomies) were performed, with a dramatic change in the distribution of compartment release procedures. The number of anterior
lateral and posterior superficial releases are now nearly equal—564 (47%) vs 525 (44%)—whereas distal releases remain uncommon, at 107 (9%). Only 20 patients since 2000 have been diagnosed and treated for popliteal entrapment (7 anatomic, 13 functional). Demographic differences between the two forms of entrapment syndrome have remained consistent. Anatomic entrapments uniformly presented with ischemic symptoms in older men (5 of 7 [71%]; mean age, 46 years, range 21-55), whereas FPAES was manifest by soleus muscle cramping and plantar paresthesia in young healthy, athletic women (11 of 13 [85%]; mean age, 26 years, range 21-41).

Despite the small number of 20 patients with symptomatic popliteal entrapment treated since 2000, routine screening tests for popliteal impingement were positive in 141 patients (23%); of these, 104 (74%) were bilateral and 37 (26%) were unilateral. Of the remaining 121 positive entrapment tests with no obvious symptoms of FPAES, 56 occurred in patients with symptoms referable to the posterior superficial or distal deep posterior compartments, and in 65 the symptoms were referable to the anterior or lateral compartments (Tables I and II).

The similarities between FPAES and posterior superficial CRECS patients were much closer than the comparison between anatomic and functional entrapment patients. Both FPAES and CRECS patients tended to be young, athletically fit women. FPAES patients tended to be older (mean, 26.7 years, range 19-41) than the CRECS patients (mean, 20 years, range 16-28). Both had upper calf muscle cramping. Paresthesia was more common in the FPAES group than in the CRECS group (100%) vs 7 (50%). The most common preoperative problem in the FPAES group was misdiagnosis, with a negative surgical exploration by the posterior approach at another institution, which occurred in six of 43 (14%). Postoperative morbidity associated with the FPAES procedure was related to wound complications (seroma, 4.6%; infection, 2%). The most common indirect problem of the FPAES treatment group was development of new CRECS complaints (38%) in previously asymptomatic compartments. Follow-up entrapment studies in those patients treated for FPAES normalized and the specific complaints of soleal cramping and plantar paresthesias resolved. Furthermore, no redo was required for a functional popliteal entrapment release during extended follow-up. In contrast, wound problems were a much greater problem in the posterior superficial compartment procedures. Recurrence of symptoms requiring surgical revision occurs in 6.4% of patients because of seromas or scar formation. Minor wound complications or nerve entrapment (sural nerve, lateral branch of superficial peroneal nerve) occurred in 2.2%. This collective morbidity is much lower than reported in the literature (48%).8,9
Table IV. Demographic data

<table>
<thead>
<tr>
<th>Variable</th>
<th>FPAES</th>
<th>Posterior superficial CRECS</th>
</tr>
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<tbody>
<tr>
<td>Sex, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>10 (23)</td>
<td>70 (30)</td>
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<tr>
<td>Females</td>
<td>33 (77)</td>
<td>165 (70)</td>
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<tr>
<td>Age, mean y</td>
<td>26 (19-24)</td>
<td>20 (16-28)</td>
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<tr>
<td>Bilateral, No. (%)</td>
<td>6 (14)</td>
<td>186 (80)</td>
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<tr>
<td>Symptom, No. (%)</td>
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<tr>
<td>Caudication (upper calf)</td>
<td>43 (100)</td>
<td>235 (100)</td>
</tr>
<tr>
<td>Parasthesia</td>
<td>17 (40)</td>
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<td>Digital ischemia</td>
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<tr>
<td>Calf swelling</td>
<td>3 (7)</td>
<td>20 (8.5)</td>
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<td>Positive entrapment test</td>
<td>43 (100)</td>
<td>56 (24)</td>
</tr>
<tr>
<td>Abnormal compartment pressure</td>
<td>22 (51)</td>
<td>235 (100)</td>
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<tr>
<td>Morbidity/procedures, No. (%)</td>
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<tr>
<td>Scar</td>
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<tr>
<td>Seroma</td>
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<td>Hematoma</td>
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<td>Recurrence</td>
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<td>25 (6.4)</td>
</tr>
<tr>
<td>Mortality</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
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</table>

CRECS, Chronic recurrent exertional compartment syndrome; FPAES, functional popliteal artery entrapment syndrome.

The mean follow-up for patients treated since 2000 was 46 months (range, 8–84 months). Most treated patients (94%) have returned to their previous athletic level of activity. Approximately 6% have not returned to their expected athletic activities because of other musculotendinous sports injuries or because of new or recurrent compartment syndromes. The most common clinical problems associated with failure to return to full athletic activity have been stress fractures, perisititis, recurrent tendonitis, and muscle tears, all associated with overuse injury. Patients with recurrent symptoms in the distribution of a previous release site underwent repeat compartment measurements. If results were normal, the other diagnoses previously mentioned were entertained. Of the 6.4% patients with documented recurrent symptoms of compartment syndrome, only 2% elected to stop their sports activities instead of reinvesting in surgical treatment.

**DISCUSSION**

Atypical claudication associated with a CRECS or FPAES most commonly affects well-conditioned and physically active adolescents or young adults and results from overuse injury. During the course of the two study periods, no substantive changes occurred in the workup or surgical treatment of patients with atypical claudication. In the 1980s, gender distribution for atypical claudicant patients was nearly equivalent (58% women, 42% men). During the past decade, however, a dramatic shift has occurred, with women much more commonly affected than men (69% vs 31%). This shift in gender distribution coincides with a dramatic increase with women’s participation in competitive sports. Coincident with this dramatic change in gender distribution has been a significant change in the distribution of atypical claudication symptoms and the muscle groups affected.

Early in our experience, anterior compartment releases were most commonly performed in male track and cross-country runners. Posterior claudication complaints were uncommon in these patients (28%), and when present, popliteal entrapment had to be excluded as a possible etiology. In addition, only 37 of 240 patients (15%) presented between 1987 and 2000 with complaints that were ultimately attributed to popliteal entrapment syndrome, and the functional form of entrapment (30 of 37 [81%]) was much more common than the anatomic form (7 of 37 [19%]). Vascular complications did not develop in patients who had FPAES. They were much younger and also fit the same activity profile that characterizes individuals with CRECS.10,11 The major difference between the functional and anatomic entrapment syndrome was the absence of musculotendinous anomalies or vascular complications and the proportion of women affected (25 of 30 [83%]).

During the past 8 years, the most common atypical claudication patient has been the adolescent female soccer player (73%) who complains of upper posterior calf symptoms associated with the posterior superficial muscle compartment. Furthermore, nearly half of our patients treated for atypical claudication now complain of symptoms that could be confused with those originating from posterior superficial CRECS or FPAES.

The major point of this article is to suggest that the most common cause for atypical claudication in these young athletes remains the chronic recurrent compartment syndrome and not the functional popliteal entrapment syndrome. Despite the dramatic increase in the number of patients treated for atypical claudication during the past 8 years, only a small proportion of patients—20 of 614 patients (3.3%)—were treated for popliteal entrapment syndrome. The number of these 20 cases, functional entrapment remains the more prevalent (13 of 20 [65%]).

The increase in prevalence of posterior calf complaints has created a diagnostic challenge because symptoms of compartment syndromes and functional entrapment syndromes are very similar and tend to overlap. Symptoms specific to the posterior superficial compartment syndrome include focal gastrocnemius and soleus cramping or swelling, or both, that can affect both the medial and lateral components of these muscles. Pressures in the symptomatic compartment are usually >25 mm. Paresthesias are uncommon and if present are usually associated with sural nerve irritation. Posterior superficial compartment complaints are most commonly associated with muscle hypertrophy due to over training or impact stress, or both, which causes thickening and scarring of the gastrocnemius and soleal fascia. These changes inhibit the capacity of the muscles for expansion to accommodate increased arterial flow with exercise.12

Most compartment complaints are bilateral and symmetric in nature (769 patients). Unilateral complaints are usually associated with chronic orthopedic problems causing protective gating anomalies and overuse injury to a
solitary limb (393 patients). Approximately 20% of patients with unilateral compartment complaints have elevated contralateral compartment pressures in a similar distribution. Surgery is not recommended in these asymptomatic limbs, but patients are advised that clinical problems may develop at a later date and need treatment.

The FPAES is another form of overuse injury that is associated with hypertrophy of the medial gastrocnemius, plantaris and soleus muscles. With forced plantar flexion, the neurovascular bundle as it traverses the popliteal fossa is compressed against the lateral condyle of the femur by the plantaris and gastrocnemius muscles more proximally and distally by soleus muscle contraction against the lateral soleal band. The clinical symptoms include deep soleus calf cramping with plantar paraesthesia when running on inlines or with repetitive jumping. The broad segment compression of the neurovascular bundle laterally against the popliteal fossa margins is quite distinct from the findings encountered with anatomic entrapment where the neurovascular bundle is displaced medially and focally compressed by a musculotendinous band. FPAES tends to occur in the same cohort of patients that develop CRECS; however, it is much less common.

Surgical treatment for FPAES is also quite different from that of CRECS or treatment of the anatomic entrapment syndrome. Failure to relieve atypical claudication complaints in patients with CRECS or FPAES most commonly results from errors in diagnosis. In our series, 14% of the patients treated for FPAES had undergone posterior knee explorations at other institutions that were not successful. Of the patients treated for FPAES, 51% had undergone compartment release procedures before or after functional entrapment release. The confounding variable in establishing the correct diagnosis is a positive result on the entrapment screening test.13-15

Although the incidence of positive entrapment studies varies from year to year, results were positive in an average of 23% of patients (range, 9%-30%) annually tested for entrapment in our series during the last decade.16 Only 3.3% of all patients tested and 14% of all patients with a positive entrapment study had appropriate posterior calf symptoms and confirmatory MRI/MRA studies suggesting popliteal entrapment syndrome. The lower occurrence of FPAES in the more recent study period of 2000 to 2007 appears to be a random event and not related to a change in work up or treatment.

Eighty-six percent of the positive entrapment studies did not correlate with presenting symptoms, suggesting that popliteal impingement in patients with atypical claudication does not necessarily constitute a pathologic condition.17 In general, if FPAES and CRECS symptoms overlap, we tend to do the compartment release surgery first. Popliteal release surgery is performed as a primary procedure if compartment pressures are normal and MRI/MRA studies demonstrate neurovascular compression patterns with functional or anatomic entrapment (Fig 3). We have no evidence to suggest that asymptomatic patients with positive entrapment tests, lateral neurovascular impingement, and absent musculotendinous anomalies require surgical intervention.

AUTHOR CONTRIBUTIONS
Conception and design: WT
Analysis and interpretation: WT

Fig 3. Decision flow chart for treatment in patients who present with atypical calf claudication. ABI, Ankle-brachial index; MRA, magnetic resonance angiography.
Data collection: WT
Writing the article: WT
Critical revision of the article: WT
Final approval of the article: WT
Statistical analysis: WT
Obtained funding: WT
Overall responsibility: WT

REFERENCES


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