

Chronic compartment syndrome also affects non-athletic subjects

A prospective study of 63 cases with exercise-induced lower leg pain

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Background Chronic exertional compartment syndrome is most often reported in young and physically active people.

Patients and methods We studied 73 consecutive patients (mean age 39 (16–77) years, 45 women) with a history of exercise-induced pain and suspicion of chronic exertional compartment syndrome (CECS) of the lower leg—clinically, radiographically and with intramuscular pressure measurements.

Results Intramuscular pressure increased with reproduction of symptoms and fulfilled the criteria for diagnosis of CECS in 36 patients (mean age 36 (16–65) years, 22 women), with engagement of 66 anterior, 2 lateral and 7 posterior muscle compartments in 72 legs. The patients with CECS of the lower leg were divided into 4 etiological groups: 18 with overuse, 10 with earlier trauma, 4 insulin-treated diabetics, and 4 others. Two-thirds of the patients had pain during walking. The outcome after fasciotomy was excellent or good in 41/57 of the legs.

Interpretation CECS of the lower leg probably has a multifactorial etiology and is more common in sedentary individuals than has been recognized previously. Fasciotomy appears to be beneficial in these cases also.

Chronic exertional compartment syndrome (CECS) is defined as a condition in which exertion increases muscle compartment pressure, interfering with tissue circulation and causing ischemia,

and even temporary neurological deficits (Mohler et al. 1997, Blackman 2000). Yet, several authors have questioned perfusion deficit and ischemia as main pathogenetic factors linked to pain in CECS (Amendola et al. 1990, Trease et al. 2001). The diagnosis of CECS is based on clinical history, increased intramuscular pressure, and pain during exercise (Pedowitz et al. 1990, Blackman 2000). The anterior compartment of the lower leg is most often affected, and it is the most studied compartment with respect to intramuscular pressure. Accordingly, rather clear-cut pressure criteria have been presented for the diagnosis of CECS in this compartment (Pedowitz et al. 1990, Toulipopolou and Hersman 1999). However, there are conflicting opinions about the setting and activity during which the intramuscular pressure should be measured for diagnostic purposes (Willy et al. 1999). Commonly, the measurements are made before and after exercise and sometimes during exercise (Styf and Körner 1987). Free running or running on a treadmill are also employed for reproduction of symptoms (Willy et al. 1999). Patients with CECS in the lower leg are described as young and physically active subjects—often runners—reporting recurrent exertion-related pain in the affected muscle compartment (Black and Taylor 1993, Abramovitz and Schepsis 1994, Hutchinson and Ireland 1994). Few predisposing factors for CECS have been reported, although a history of trauma has been mentioned (Tubb and Vermillion 2001).

In this prospective consecutive study, we asked general practitioners to send us all patients with exercise-induced lower leg pain and with a clinical picture similar to that of CECS, in order to study the etiology of the disorder and prognosis.

Patients and methods

Patients

73 patients were referred consecutively to our department from 1996 through 2000 because of a suspicion of chronic compartment syndrome in the lower leg, i.e. with a history of pain in the lower leg on exertion (64/73 bilaterally). 51 patients were referred from general practitioners, 12 from other surgical departments, and 10 from a sports clinic. 7 patients refused to participate and 3 had been treated earlier for a similar disorder, and were therefore excluded. Thus, 63 patients (36 women) with a mean age of 39 (16–77) years and mean duration of symptoms of 2.6 (0.5–15) years were included. History, symptoms and clinical signs were noted, with special attention being paid to neurological and circulatory disturbances. We performed bilateral radiographs, scintigraphy, and intramuscular pressure measurement.

Reproduction of symptoms and assessment of intramuscular pressure

To reproduce the symptoms, all patients underwent an exercise test with intramuscular pressure measurement. As the main symptom reported by the patients was pain in the lower leg on running or walking, we used treadmill exercise with increasing velocity. The duration of the test was 10–15 min, and during this period the velocity and slope of the treadmill was adjusted in an attempt to reproduce the patient's lower leg pain. The patients with CECS usually reported "strong" or "very strong pain" (5 or 7 on the 10-point Borg scale) in the lower leg(s) (compartments) and/or rated exertion as "very heavy" (17 on the 20-point Borg scale) at the end of the test (Borg 1973). Intramuscular pressure was monitored using continuous microcapillary infusion technique with isotonic saline infusion at a rate of 1.5 uL/h, (Styf and Körner 1986) via a catheter (Myopress; Athos Medical, Höör, Sweden) which was connected to a pressure

transducer (PMSET 2DT-XO 2TBG; Becton Dickinson, Singapore) and a multichannel ink recorder (Mingograph 7; Siemens Elema, Sweden). An ordinary Teflon cannula was first inserted into the muscle belly with the patient in supine position. Using this cannula, the Myopress catheter was introduced into the muscle (at a depth of at least 15–20 mm beneath the fascia). The cannula was then retracted and the catheter fastened to the skin using adhesive tape.

As most patients had anterior muscle compartment pain, we measured this pressure first. The catheter was inserted either into the anterolateral or—for the lateral compartment—into the lateral aspect of the lower leg about 10–15 cm below the head of the fibula, and for the deep posterior compartment into the medial aspect of the middle of the lower leg. Local anesthetic was used only for the skin and the fascia. We avoided penetration deep into the muscle, and thus avoided influencing the environment around the tip of the catheter to prevent any possible effect of the needle or the anesthetic on the muscle tissue, and on pressure measurement. Measurements were done in both legs, even in patients with unilateral symptoms, with the patient in supine position as soon as possible after exercise, usually after 1–2 min and then after 5, 10, and 15 min. The patients were also asked to rate their pain according to the Borg scale.

A diagnosis of CECS in the anterior tibial compartment required: 1. history of exercise-induced pain/symptoms, 2. appropriate reproduction of symptoms and pain during the exercise test, and 3. intramuscular pressure at rest of > 15 mm Hg and/or intramuscular pressure of > 30 mm Hg 1–2 min after the end of the exercise test, and/or intramuscular pressure of > 20 mm Hg 5 min after the end of the exercise test (Pedowitz et al. 1990).

Standard investigations including intramuscular pressure measurement in the anterior compartment, radiography and scintigraphy were diagnostic in 51 patients: 36 patients had CECS and 15 patients had other disorders. 12 patients without diagnosis underwent additional investigations. All patients with a diagnosis of CECS in the anterior compartment were recommended surgical treatment with fasciotomy of the anterior tibial and peroneal compartment according to Fronek et al. (1987). Patients with CECS of the posterior compartment were rec-

Table 1. Criteria for classification of results

Results criteria	
Excellent:	No pain during or after exercise No limitation of duration and extent of exercise Patient considers himself/herself cured
Good:	Minimal discomfort or soreness during/after exercise No limitation of duration and extent of exercise Significantly improved Glad to have had surgery
Fair:	Pain on running/exercise or afterwards Still has a limitation Recurrent symptoms Only slightly improved
Poor:	Unchanged or worse Complications

ommended surgical treatment as described by Styf (2003). After surgery, the patients used crutches for 3 days and were allowed free weight bearing. A compression bandage was applied for 2 weeks. Most patients reached their previous activity level after 2 months. All surgically treated patients were examined after 3 months. In 4 patients who did not improve after anterior compartment fasciotomy, other diagnoses including chronic compartment syndrome in other compartments of the lower leg were considered. Accordingly, measurement of intramuscular pressure in the deep posterior compartment was performed in 4 patients, and in the lateral compartment in 1 patient.

The study was approved by the Ethics Committee of Umeå University, Sweden.

Follow-up

Follow-up of operated patients was done 12 months after surgery and follow-up of unoperated patients was done 12 months after referral. The results of the operation were evaluated according to Table 1.

Statistics

The statistical package Statistica, version 6.0, was used for statistical analysis using the Mann-Whitney test (Holms' correction of the Bonferroni method).

Results

Patients with CECS

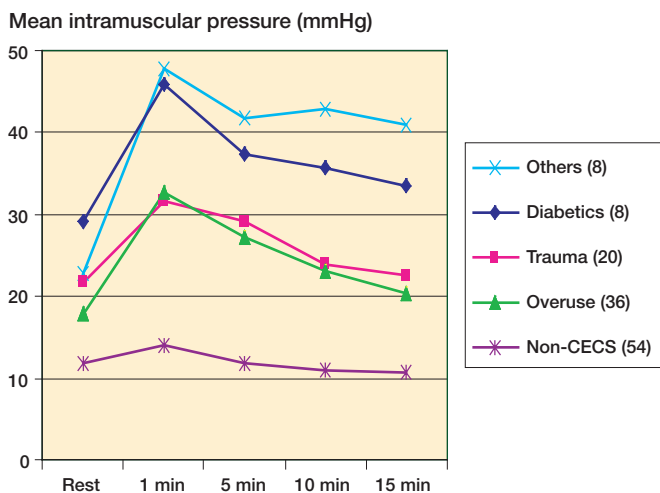
History, clinical findings and postoperative outcome for all patients are given in Table 2. Clinical history suggested a division into 4 etiological groups: 1. overuse (no history of trauma or general disease, cases 1–18), 2. post-trauma (history of major injury of the affected leg, cases 19–28), 3. diabetics (on insulin treatment, cases 29–32), and 4. others (other history, cases 33–36). Interestingly, only 11 patients were active in sport (6 were active athletes and 5 were recreational runners). 1 patient in group 1 (case 9) was diagnosed as having an osteoid osteoma in the left leg, in addition to CECS in the same leg.

Comparing the different groups with each other, the diabetics showed higher intramuscular pressure at rest ($p = 0.008$) and also 15 min after exercise ($p = 0.005$) than the overuse group (Figure). There were no differences in age and sex between the groups.

Follow-up

32 patients (57 legs) were treated with fasciotomy of the anterior and lateral compartments (Fronek et al. 1987). In 3 cases the surgical treatment proposed was not accepted and 1 patient was lost to follow-up. 3 patients treated for CECS of the anterior compartment also had a posterior compartment fasciotomy performed bilaterally, and in 1 subject the left posterior compartment was decompressed (cases 1, 26, 29, and 30 in Table 1). Thus, no patients in our study had a posterior compartment syndrome exclusively.

For 6 of the 57 operated anterior compartments, the results were rated as excellent. They were rated as good for 35, as fair for 15, and as poor for 1. The outcome at follow-up was rated as excellent or good for 24 of 31 operated compartments in the overuse group, for 8 of 14 in the post-trauma group, for 5 of 6 in the diabetes group, and for 4 of 6 operated compartments in the "others" group. 4 patients who were operated on with anterior compartment release were also treated with fasciotomy of the posterior compartment later on (7 posterior compartments), and the overall rating of these treated legs was excellent or good in 6 and fair in 1.



Preoperative intramuscular pressure (mean values in mm Hg) in the anterior tibial muscle at rest and 1, 5, 10, and 15 min after exercise. The diabetics had higher mean intramuscular pressure at rest and 15 min after exercise than the overuse group ($p < 0.05$). Figures in parenthesis indicate the number of compartment pressures measured in each group.

Postoperative complications

2 patients had postoperative hematomas, 2 had superficial infections postoperatively, and 2 showed signs of superficial peroneal nerve affection.

Patients with diagnoses other than CECS

The 27 patients (15 women) without CECS of the leg were diagnosed as periostitis (11 patients), medial tibial syndrome (7), lumbar disc herniation with rhizopathy (2), and 1 each of low back pain, trochanteritis, status post-contusion, polyneuropathy, status post-acute compartment syndrome, venous insufficiency, and Achilles tendinosis. The radiographic and scintigraphic examination confirmed diagnosis in 2 patients with signs of periostitis. The intramuscular pressure was measured in the anterior compartment in 20 patients, while 7 were only measured in the posterior compartment. At follow-up, 22 of the patients reported no change of symptoms whereas 5 had improved—probably due to reduced physical activity.

Discussion

In contrast to most other studies of CECS of the lower leg, we included all patients with suspected CECS, independently of age or other disorders.

Also, most of our cases had a sedentary lifestyle with leg pain even during walking. The overall surgical outcome in our study (with two-thirds good or excellent) is somewhat below the success rates documented earlier (Blackman 2000), although the differences in sampling, evaluation methods, and follow-up make comparison difficult. We used a standardized questionnaire (Abromovitz and Schepsis 1994) that was filled in by the patients before the clinical follow-up. This included questions about both pain and activity levels, thereby reducing any observer bias.

Patients with fair or poor results after 3 months were reassessed to rule out other diagnoses. In 4 patients, the intramuscular pressure

was consequently measured in the posterior compartment bilaterally. 3 also had bilateral posterior compartment syndrome and one had unilateral, and these were treated surgically. We did not routinely measure the intramuscular pressure in the posterior compartment, in order to avoid neurovascular injury. Thus, among our 63 initial cases there may have been patients with involvement of compartments other than the anterior and lateral who were not diagnosed. The clinical re-examination and pressure recordings of the posterior compartment in patients who did not experience any improvement after anterior compartment decompression should have minimized the occurrence of other compartment syndromes in our surgically treated series.

Our results after fasciotomy of the posterior compartment were not evaluated separately, since this procedure was performed in patients treated 6 months earlier with anterior compartment release, so the patients' ratings 1 year afterwards thus included both operations.

The typical patient with CECS of the lower leg is young and physically active, and often a runner, and the differential diagnoses mentioned are often other overuse syndromes. The pathophysiology has been widely discussed, but seems to be largely unknown. The results after surgery for those with

Table 2. Preoperative history of lower leg trauma or disease, symptoms, signs and postoperative results after one year according to patients with chronic compartment syndrome in the anterior m. tibialis

A	B	C	D	E	F		G		H	
					R	L	R	L	R	L
1	F	16	A	No	1–4	1–4	3	3	2	2
2	M	18	A	No	1–5	1–5	1, 4	1	1	1
3	F	18	A	No	1–5	1–5	1	1	2	2
4	M	19	A	No	1, 4, 5	1, 4, 5	1, 3	1, 3	N	N
5	M	20	R	No	1, 2	1, 2	1	1	2	2
6	F	22	A	No	1, 2, 4	1, 2, 4	1	1	3	3
7	F	23	R	No	1, 3, 4, 5	1, 3, 4, 5	1, 3	1, 3	2	2
8	M	23	R	No	1, 2, 5	1, 2, 5	1	1	3	3
9	F	24	R	No	1, 3, 4, 5	1, 3, 4, 5	1, 2	1, 2	2	2
10	F	25	W	No	1–5	1–5	1, 3	1, 3	2	2
11	M	30	R	No	1–5	1–5	1, 2, 5	1, 2, 5	2	2
12	F	31	W	No	1–5	1–5	1, 2	1, 2	2	2
13	M	34	W	No	1, 2, 4	1, 2, 4	1	1	2	3
14	M	38	W	No	1–5	1–5	1	1	2	2
15	M	38	W	No	1–5	1–5	1, 2, 3	1, 2, 3	1	1
16	F	43	W	No	1, 4, 5		1, 2, 6		L	L
17	F	47	W	No	1–5	1–5	1	1	3	3
18	F	51	W	No	1–5		1, 3		2	N
19	M	20	W	MC, ^B	1, 2, 5	1, 2	1, 4	2	2	
20	F	31	W	op. cr. lig. ^L		1–3		1, 2, 4	2	3
21	M	32	W	MC, ^R	1–3		1, 2, 4, 6		2	N
22	F	32	W	FF, ^R	1–4		1		2	N
23	F	32	W	FF, ^R	3		1, 2, 3		3	N
24	F	33	W	MC, ^R	1, 3, 4, 5		1, 2		2	N
25	F	43	W	MC, ^L		1, 4, 5		1, 7	N	N
26	M	54	W	MR, ^R , MC, ^L	1–3	1, 3, 4, 5	1, 2	1, 2, 6	3	3
27	M	58	W	MC, ^B	1–5	1–5	1, 2, 4, 6	1	4	3
28	F	65	W	MC, ^B	1, 2, 5	1, 2, 5	3	3	2	2
29	F	25	W	DM	1, 2	1, 2	1	1	1	1
30	F	40	W	DM	1–5	1–5	1	1, 3	2	2
31	F	41	W	DM	1–5	1–5	1, 2, 3	1, 2, 3	2	3
32	F	48	W	DM	1, 3, 4, 5	1, 3, 4, 5	1, 3	1, 3	N	N
33	M	43	W	PN	1, 2, 4, 5	1, 2, 4, 5	1, 5	1, 5	N	N
34	F	48	W	RA	1, 3, 4, 5	1, 3, 4, 5	1, 2, 5, 6	1, 2, 5, 6	2	2
35	F	53	W	GT	1–5	1–5	1	1	2	2
36	M	61	W	CB	1–5	1–5	1, 2	1, 2	3	3

A Case nr	1. Pain
B Sex	2. Sensory deficit
C Age	3. Edema
D Activity level	4. Muscle fatigue
A Athletes	5. Muscle stiffness
R Recreational	G Preoperative signs lower leg
W Walkers	1. Tenderness over anterior compartment
E Leg trauma or disease	2. Tenderness over anterior tibia
CB Chronic back-pain	3. Muscle hypertrophy
DM Diabetes mellitus	4. Fascial hernia
FF Fibula fracture	5. Sensory deficit
GT Gynecological tumor	6. Edema
MC Muscle contusion	7. Muscle rupture
MR Muscle rupture	H Operative result
PN Polyneuropathy	1. Excellent
RA Rheumatoid arthritis	2. Good
^R right	3. Fair
^L left	4. Poor
^B both	L Lost at follow-up
F Preoperative symptoms lower leg	N Unoperated leg

anterior compartment involvement have been reported to be excellent or good in a high proportion of cases, and are in agreement with our findings (Barnes 1997).

Previous trauma, even if minor, is claimed to be a predisposing factor for CECS according to Tubb and Vermillion (2001). Most of the injuries in our series had happened years previously, and muscle contusion was the most common type of lesion. To be included in this category of cases, we required that the trauma must have resulted in a swollen and painful extremity. Thus, if the injury had an influence on the development of CECS, these patients should have symptoms in the injured legs. This was the case in 4 patients with bilateral symptoms and 5 with unilateral symptoms, while case 25 developed bilateral CECS long after surgery in 1 knee with subsequent edema of the left leg; thus, it may be questionable to have included her in this group. Furthermore, in the 4 patients with bilateral CECS the importance of previous injury may be debatable, since it is possible that these cases would have developed CECS without any injury. In any case, the inclusion criteria were based on a history of a substantial injury to the lower leg.

Other pathomechanisms are possible after trauma. In patients with earlier fracture, callus formation or calcification of the muscle hematoma can be space-occupying. Muscle injury may lead to thickened fascial walls that are unable to enlarge when the muscle volume increases during activity. Furthermore, it is also possible that the muscle injury impairs the venous and lymphatic outflow, leading to increased intramuscular pressure.

CECS has rarely been associated with other diseases. It is, however, probable that in the diabetics the disease was a contributory factor. CECS of the lower leg has been reported in diabetic subjects only occasionally, and it has been acute compartment syndromes secondary to spontaneous muscle necrosis (Chautems et al. 1997, Adornato et al. 2000). In contrast, all 3 of our diabetic patients had typical symptoms of chronic compartment syndrome when walking, and the symptoms were markedly alleviated by surgery in all 3 cases. The pathophysiology may be different in diabetics, with possible explanations such as vasomotor disturbances or soft tissue alterations.

Although most patients improved after surgery, one-third still had pain persisting on exercise. This may be due to diagnostic problems, since definitive criteria for the diagnosis are not yet fully established; also, the pain may be caused by for us undiagnosed other coexisting pathological conditions.

Our patients were older than those in previous studies (Blackman 2000, Brennan and Kane 2003). This is a matter of sampling, but we did not actively recruit older subjects; we only informed our referents about CECS of the lower leg and told them to send all patients whom they suspected of having the syndrome. In contrast, all our athletes were referred from a sports clinic. Thus, the composition of the cases was affected by the information we gave and is not representative of the general population. However, compared to other studies on young, physically active subjects, our study indicates that CECS of the lower leg is more common in non-athletes than realized previously—possibly due to a lack of awareness of the syndrome amongst physicians.

About half of the patients referred to us with suspected CECS of the lower leg were verified as having the syndrome according to the clinical symptoms and the intramuscular pressure criteria. CECS is therefore an important differential diagnosis in exertional leg pain in non-athletes also. The wide range of the final diagnosis in the other half of the patient group emphasizes the importance of a careful clinical investigation.

Contributions of authors

DE: did the measurements, and collected and analyzed the results. GT and PS: planned the study, and contributed to the analysis and the writing of the paper.

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