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Diagnosis of chronic anterior compartment syndrome in the lower leg

Intramuscular pressure was recorded in 80 patients suspected of suffering from chronic anterior compartment syndrome in the lower leg; the diagnosis was verified in 22 of these patients. The history and clinical findings of the chronic compartment syndrome patients were compared with those of the 58 patients without the syndrome. Pain induced only by athletic activity and only in the anterior lower leg forcing the patient to interrupt running indicated chronic compartment syndrome. The history and clinical findings alone were found to be insufficient to establish the diagnosis. In relation to generally accepted pressure parameters at rest, the muscle relaxation pressure during exercise was found to be a reliable parameter for diagnosing chronic compartment syndrome, whereas mean muscle pressure and muscle contraction pressure were found to be unreliable.

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Introduction

The chronic compartment syndrome (CCS) is defined as a recurrent exercise-induced increase of pressure in skeletal muscle accompanied by pain, swelling, and impaired muscle function. In all pressure studies of CCS, increased intramuscular pressure (IMP) at rest after exercise, and a prolonged time for normalization of the increase pressure have been used as criteria for the diagnosis (Reneman 1985). Recently, different IMP parameters during exercise have also been considered in the diagnosis of the syndrome, e.g., mean muscle pressure (Puranen & Alavaikko 1981), muscle contraction pressure (McDermott et al. 1982), and muscle relaxation pressure, that is, the pressure in the relaxed muscle between contractions (Styf et al. 1986).

We have compared the accuracy and possible errors of different IMP parameters during exercise in establishing the diagnosis of CCS. The symptoms and signs of the patients were evaluated with reference to the possibility of diagnosing the condition on clinical grounds only.

Patients and methods

Patients. Eighty patients with recurrent exercise-induced pain in the anterior aspect of the lower leg were investigated prospectively from July 1981 through 1983. These 50 men and 30 women had been referred to us because they were thought to have CCS in the anterior compartment of the lower leg. Their ages averaged 28 (17–55) years. Forty-six had bilateral pain and 34 unilateral pain. All had tried various conservative treatments, including rest, reduced training, anti-inflammatory drugs, diuretics, physical therapy, ultrasound, stretching, local heat and cold, modification of shoes, different training programs, and orthotic applications; nothing had relieved their pain.

Sixty-three patients were competitive athletes, the remaining 17 were not athletes, but performed heavy physical work. Five of the athletes were marathon runners. Eleven of the 80 subjects had a history of previous major trauma to the lower leg.

The anterior aspect of the lower leg was defined as the anterior compartment, including the anterior ridge of the tibia and the anterior intermuscular septum. In 32 patients the pain occurred only in this location, whereas another 22 patients described concurrent pain over the peroneal compartment; another 21 patients had mild pain over the middle and distal thirds of the posteromedial ridge of the tibia, and 5 patients described mild pain in the calf. On our first examination, the pain had persisted for an average of 3 (1–15) years.

History and clinical examination. Each patient answered 22 questions before entering the study. The questions concentrated on pain analysis, neurologic deficits in the foot, and other symptoms; levels of physical activity, previous injuries, the development of physical capacity, and training technique. The patient was asked to indicate the location of symptoms in the lower leg in three illustrations. A physical examination was made of 16 items in the knee, lower leg, ankle, and foot. The location of tenderness, muscle herniation, and disturbed sensibility were indicated in three illustrations.

Pressure recordings. Intramuscular pressure (IMP) was recorded bilaterally in each of the 80 patients in the anterior tibial muscle at rest and during and after exercise. The patient was lying supine with the feet in shoes of an ergometer. The pedals of the ergometer were loaded with 4–7 kg depending on the patient's muscle strength. The patient was asked to dorsiflex her/his feet once a second until muscle fatigue, pain, or impaired muscle function developed. The work load was kept constant and symmetrical.

IMP was measured by the microcapillary infusion method with a saline infusion rate of 1.5 ml/h (Styf & Körner 1986). A specially prepared teflon catheter (Myopress®, Atos Medical, PL 309, S-242 00 Hörby, Sweden) with four side holes at its tip was filled with saline solution and introduced into the muscle. The catheter was connected to an electromagnetic transducer (Siemens Elema 746) with a displacement of 0.06 mm^3/0.014 MPa ($=0.57\times10^{-6}$ ml/mm Hg) and a multichannel ink recorder (Siemens Elema, Mingograph 82). The method has high dynamic properties, and it allows recording of intramuscular pressure during exercise (Styf & Körner 1986).

Bilateral recordings of IMP were also performed in the peroneal compartment of 22 patients who experienced concurrent pain in the lateral aspect of the lower leg. The exercise test consisted of dorsiflexion and eversion of the ankle joint. In 11 patients the pressure was measured at rest before and after exercise only.

Finally, IMP was measured during exercise bilaterally in the deep posterior compartment in 12 of the 21 patients with current pain over the posteromedial ridge of the tibia. These patients were asked to plantar flex the ankle joint with the feet in shoes attached to an ergometer with a 9 to 10 kg load.

The following pressure parameters were recorded in all the patients: pressure at rest before and after exercise, muscle contraction pressure (MCP) and muscle relaxation pressure (MRP) during exercise, the time for normalization of the increased pressure at rest after exercise, and the amplitude of pulse-synchronous oscillations of the IMP at rest after exercise.

The pressure amplitude during exercise was calculated by subtracting MRP from MCP. The mean muscle pressure (MMP) during exercise was calculated according to the formula:

$$MMP=[(MCP-MRP)/2]+MRP$$

Diagnosis of CCS. The diagnosis of CCS was established if pain and impaired muscle function developed during the exercise test, the IMP at rest after exercise exceeded 30 mm Hg, and the time for normalization exceeded 6 minutes.

Pressure values are given as means with one standard deviation (M±SD). The two-tailed Student's *t*-test and chi-square test were used for statistical analysis.

Results

Chronic compartment syndrome was diagnosed in 22 patients (36 legs). The syndrome followed major trauma to the lower leg in 2 of them; in 1 patient unilateral CCS followed a fracture of the proximal shaft of the tibia and in the other it followed repeated severe contusions to the lower leg. The remaining 58 patients showed no pathologic increase in the IMP. By extensive investigations, most of them eventually were given other diagnoses.

History (Table 1). The pain occurred only in the anterior aspect in 15/22 CCS patients and in 17/58 non-CCS patients ($P<0.05$) (Table 1). Pain was induced only by athletic activity in 12 of the 22 CCS patients, and in 6 of the 58 non-CCS patients ($P<0.01$). None of the CCS patients could continue running when pain eventually developed, but 27 of the 58 non-CCS patients could do so ($P<0.01$). The CCS patients stopped running after 4.5(±3.8) km and the non-CCS patients after 0.6±(0.8) km. No difference in training techniques was found between the two groups.

Table 1. The histories of 22 patients with chronic anterior compartment syndrome in the lower leg (CCS) and 58 patients with pain for other reasons (non-CCS)

History	CCS n=22	Non-CCS n=58
Localization of pain:		
anterior aspect only	15	17
anterior and medial	3	18
anterior and lateral	4	18
anterior and dorsal	0	5
Pain induced by running only	12	6
Pain after running only	0	7
Pain necessitating interruption of running	12	6
Pain during walking	6	17
Distance that induces pain (km)	4.5 (0.2–10) n=12	0.6 (0.01–3) n=30
Level of athletic activity:		
national elite	1	0
local elite	7	11
athletes	14	30
non-athletes	0	17
Maximum sports activity before the start of pain (h/wk)	8.4 (SD=4.0)	5.9 (SD=4.1)
Present sports activity (h/wk)	1.5 (SD=1.4)	2.4 (SD=1.9)
No sports activity now because of pain	8	11
Disturbance of foot sensibility	5	6
Previous major trauma to the lower leg	2	9

Table 2. Clinical findings in 22 patients with CCS legs compared with 58 patients with non-CCS legs

Clinical findings	CCS n=22	Non-CCS n=58
Tenderness over the anterior margin (Am) of the tibia:		
none	12	14
Am only	7	11
Am and lateral compartment	2	17
Am and posteromedial margin	1	11
Am and calf	0	5
Tenderness over the anterior tibial muscle	4	10
Muscle hernias:		
anterior compartment	5	2
lateral compartment	0	3
Positive Tinel's sign over the superficial peroneal nerve	1	9
Positive compression test for the superficial peroneal nerve during muscle contraction	2	12
Pes cavus	1	1
Pes pronatus	2	7

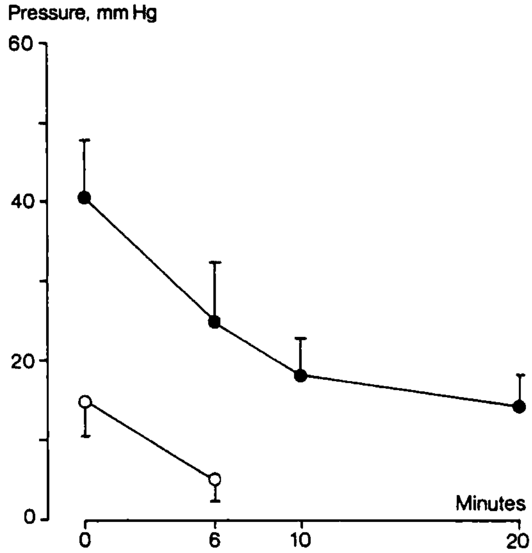

Figure 1. Intramuscular pressure during the first 20 minutes after exercise in 36 CCS legs (filled circles) and 90 non-CCS legs (open circles). The vertical bars indicate 1 SD.

Physical examination (Table 2). Swelling of the lower legs and induration of the anterior compartment was observed in a few patients in both groups. Three CCS patients and 44 non-CCS patients ($P<0.05$) were tender elsewhere in the lower leg. Foot deformities were few in both groups. Neurologic deficits were found in both groups of patients. The time necessary for pain and impaired muscle function to develop during the exercise test, and the working capacity on the ergometer did not differ between the two groups of patients.

Intramuscular pressures (Figure 1, Table 3). IMP at rest was 9.8±1.8 (7.2–13) mm Hg in CCS legs and 6.2±2.2 (2.9–14) in non-CCS legs ($P<0.001$). MRP increased to 42±7.8 (33–55) during exercise in CCS legs and 14±5.9 mm Hg in non-CCS legs ($P<0.001$) In CCS legs the pressure at rest immediately after exercise was 40±7.2 mm Hg and did not normalize during 20 minutes of rest. In all painful non-CCS legs, pressure decreased to a level of the initial pressure within 6 minutes.

At rest after exercise, pulse-synchronous oscillations of the IMP recording could be clearly detected in some patients. The amplitude of oscillations was 5.8±2.7 mm Hg in CCS legs, but less than 1 mm Hg in 31 non-CCS legs (Figure 2). In 54 non-CCS legs, no oscillations in the IMP curve could be detected. The amplitude of the

Table 3. Different intramuscular pressure parameters in 22 CCS patients and in 58 non-CCS patients. Values are mean (SD), mm Hg

Pressure parameter	CCS patients		Non-CCS patients	
	Painful legs (n=36)	Asymptomatic legs (n=8)	Painful legs (n=90)	Asymptomatic legs (n=26)
IMP at rest	9.8 (1.8)	7.7 (2.0)	6.2 (2.2)	5.0 (1.6)
Muscle contraction pressure (MCP)	158 (47)	143 (40)	131 (39)	121 (41)
Muscle relaxation pressure (MRP)	41.3 (7.8)	24.4 (4.4)	14.4 (5.9)	13.5 (4.2)
Mean muscle pressure (MMP)	99	83	72	68
IMP amplitude during exercise	121	118	117	107
IMP at rest after exercise	40.2 (7.2)	25.4 (5.7)	15.1 (5.7)	13.5 (4.2)
IMP at rest 6 min. after exercise	24.0 (9.5)	15.3 (5.9)	7.3 (2.5)	7.0 (1.6)
IMP at rest 10 min. after exercise	18.0 (6.1)	10.7 (5.5)	-	-
IMP at rest 20 min. after exercise	14.6 (5.0)	10.3 (1.5)	-	-
Amplitude of the IMP oscillations at rest after exercise	5.8 (2.7)	3.0 (2.2)	<1	<1

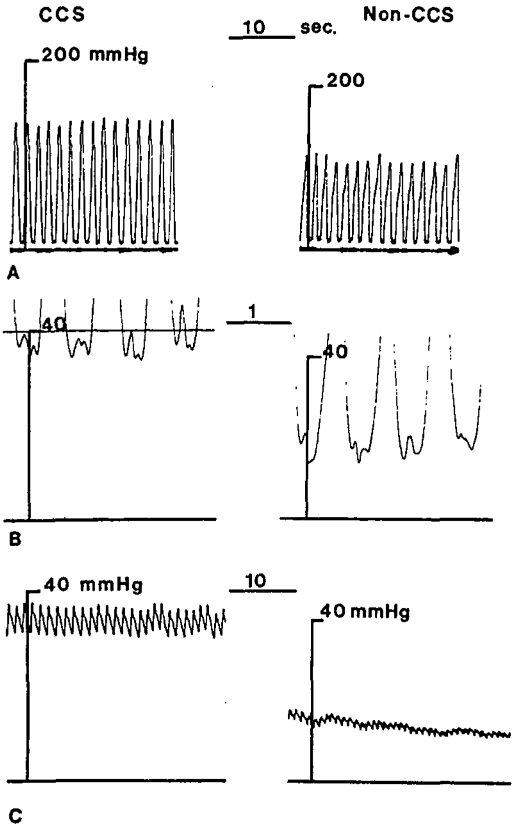

Figure 2. Original IMP recording from the anterior compartment. Left race: CCS leg. Right trace: painful non-CCS leg. A. During exercise. B. The MRP during exercise. C. IMP at rest after exercise. The increased amplitude of the pulse-synchronous oscillations in the CCS legs after exercise is an expression of the decreased compliance of the muscle tissue caused by the volume load.

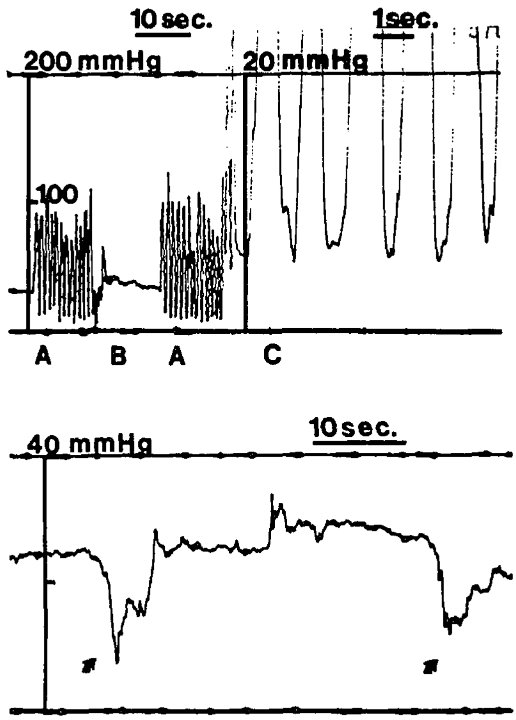

Figure 3. Original IMP recording from anterior compartment in a patient with muscular hypertension syndrome. Upper trace: A. MCP and MRP during exercise. B. IMP at rest in a painful leg between two exercise tests. C. MRP during exercise. Lower trace: Pressure at rest after exercise. When the patient's calf was stroked by hand, the muscle would relax for a short while, leading to a decrease of IMP recorded.

oscillations decreased to 1 mm Hg in CCs legs after 16.3±5.7 minutes; in non-CCS legs they were not visible after 3 minutes.

MMP was 99 mm Hg in the CCS legs and 72 mm Hg in the painful non-CCS legs (n.s.). MMP was 83 mm Hg in the asymptomatic legs of CCS patients and 68 mm Hg in the symptomatic legs of non-CCS patients (n.s.)

In 3 non-CCS patients the IMP at rest was 5.0±2.4 mm Hg; MRP rose to 14±3.9 mm Hg by the end of exercise, that is, to the same level as the other non-CCS patients; at rest between repeated exercise tests, it was 26±2.0 mm Hg (Figure 3). The pressure at rest after exercise did not normalize within 6 minutes. One of these patients was examined three times over 18 months with similar results each time.

One of the patients with CCS in the anterior compartment also had CCS in the lateral compartment. No pathologic increase in the IMP in the lateral or the deep posterior compartment was recorded in any of the other patients.

Discussion

We could confirm the diagnosis of chronic compartment syndrome in only 22 of 80 patients referred to us. Pain induced only by athletic activity, and occurring only in the anterior aspect, and requiring the patient to interrupt running, suggested the diagnosis of CCS; so did the lack of tenderness elsewhere in the leg. Multilocated pain induced by a short running distance, but allowing the patient to continue running despite the pain, was not a sign of the syndrome. Increased muscle relaxation pressure during exercise was found to correlate well with the increased IMP at rest after exercise. The mean muscle pressure and muscle contraction pressure were found to be unreliable as indicators of increased intramuscular pressure at rest after exercise.

The finding of increased IMP at rest before exercise in the CCS patients accords with previous reports (Reneman 1975, Veith 1980). However, the wide range of IMP values at rest in our study and the fact that the IMP in the anterior compartment depends on the position of the ankle joint (Gershuni et al. 1984) make the use of this parameter alone unsuitable in the diagnosis of CCS.

The increase of MRP during exercise in our study correlated well with the increased pressure at rest after exercise and to the prolonged time for normalization of the increased pressure. The pathologic increase of MRP also correlated well with the development of pain, swelling, and impaired muscle function during the exercise test. The impaired muscle function at the end of exercise did not affect the increased MRP, indicating that this value depends on the volume load of the muscle tissue. No perfusion of skeletal muscle occurs during contraction (Follow et al. 1970). The progressive increase of MRP to values exceeding 34 mm Hg in CCS legs during constant exercise has shown to decrease muscle blood flow (Styf et al. 1986). Thus, MRP is a parameter clearly related to the pathophysiologic events causing the symptoms of CCS.

Mean muscle pressures exceeding 50, 80, and 85 mm Hg during exercise have been used as criteria in diagnosing CCS (McDermott et al. 1982, Puranen & Alavaikko 1981). We found no significant difference in MMP between painful and asymptomatic legs in unilateral CCS or between CCS and non-CCS patients (Table 3). This may be explained by the fact that the MCP is related to the force output of skeletal muscle (Körner et al. 1984, Sejersted et al. 1984). When pain develops during exercise in CCS legs, the force output and thus the MCP decrease due to pain. By definition the MMP value depends on both the MCP and the MRP. Therefore, the MMP is secondary to the changes of these parameters. Further, MCP, and thus MMP, depends on the depth of the pressure catheter in the muscle tissue (Kirkeboe & Wisnes 1982, Sejersted et al. 1984). The MMP value also depends on the contraction frequency if the dynamic response of the pressure recording system is slow (Styf & Körner 1986). Finally, changes of muscle blood flow in CCS legs during exercise could not be correlated with changes of the MMP value (Styf et al. 1986). We therefore conclude that the MMP and MCP are unreliable parameters in diagnosing CCS.

Our finding of an increased amplitude of the pulse-synchronous oscillations of IMP at rest after exercise in the CCS legs has not been reported previously. This parameter can be used as an additional pressure parameter in the diagnosis of the syndrome; it reflects the compliance and probably depends on the volume load of the muscle tissue immediately after exercise.

However, there is a risk of making a false CCS diagnosis if the pressure at rest after exercise is used as the only diagnostic criterion. This is illustrated by the 3 patients showing increased IMP at rest after exercise and increased time for normalization of the pressure, but with normal MRP during exercise (Figure 3). The pressure increase after exercise in these 3 patients could not be related to any volume load of the tissue, and they all had a relatively low physical capacity during the exercise test. Following the results of pressure monitoring, we labelled this condition "muscular hypertension syndrome." The increased pressure in these patients may be due to a coactivation of agonistic and antagonistic muscle groups induced by pain. The history of these patients showed some similarity to the patients with tension myalgia described by Stonnington (1977).

Most patients had been referred to us by experienced colleagues, mot of them orthopedic surgeons, who had suspected the existence of CCS. Nevertheless, only one fourth of the patients fulfilled generally accepted criteria for CCS, confirming the findings of Qvarfordt et al (1983). The results of our questionnaire and clinical examination gave us no absolute clinical grounds on which to establish the diagnosis of CCS, although certain observations were more common among the CCS patients. We conclude that symptoms and signs may be helpful in screening patients for pressure recording, but not for the diagnosis of CCS. This conclusion is in contrast to other investigations, which have placed low diagnostic value on IMP recording in the anterior compartment (Sudmann 1979) and in the lateral compartment (Reneman 1975), or used only clinical criteria in the diagnosis of CCS (Leach & Hammond 1967, Kennelly & Blumberg 1968). Some of the differences in opinion may be due to the use of unreliable pressure parameters for diagnosis and/or methods with unsatisfactory dynamic properties for pressure recording during exercise.

CCS following major trauma to the lower legs has not been reported previously. None of our patients had exhibited signs of acute compartment syndrome, nor were any signs of ischemic contracture found in any of the 11 trauma cases. A recent case report of CCS of the forearm following trauma (Kutz et al. 1985) supports our findings.

We conclude that recording of intramuscular pressure during and/or after exercise is necessary for establishing the diagnosis of chronic compartment syndrome. The muscle relaxation pressure during exercise, increased pressure at rest after exercise, and a prolonged time for normalization of the pressure after exercise are the most reliable parameters and should all be used. The use of mean and contraction pressures was found to be unreliable in the diagnosis of the syndrome. Clinical observations are helpful in selecting patients for pressure recording, but not for the diagnosis of chronic compartment syndrome.

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