

Role of Repeat Muscle Compartment Pressure Measurements in Chronic Exertional Compartment Syndrome of the Lower Leg

Aniek P. M. van Zantvoort,^{*†} MD, Johan A. de Bruijn,^{*†} MD, Michiel B. Winkes,^{*†} MD, PhD, Adwin R. Hoogeveen,[‡] MD, PhD, Joep A. W. Tejjink,^{†§} MD, PhD, and Marc R. Scheltinga,^{*||} MD, PhD
Investigation performed at Máxima Medical Center, Veldhoven/Eindhoven, the Netherlands

Background: The diagnostic gold standard for diagnosing chronic exertional compartment syndrome (CECS) is a dynamic intracompartmental pressure (ICP) measurement of the muscle. The potential role of a repeat ICP (re-ICP) measurement in patients with persistent lower leg symptoms after surgical decompression or with ongoing symptoms after an earlier normal ICP is unknown.

Purpose: To study whether re-ICP measurements in patients with persistent CECS-like symptoms of the lower leg may contribute to the diagnosis of CECS after both surgical decompression and a previously normal ICP measurement.

Study Design: Case series; Level of evidence, 4.

Methods: Charts of patients who underwent re-ICP measurement of lower leg compartments (anterior [ant], deep posterior [dp], and/or lateral [lat] compartments) between 2001 and 2013 were retrospectively studied. CECS was diagnosed on the basis of generally accepted cutoff pressures for newly onset CECS (Pedowitz criteria: ICP at rest ≥ 15 mmHg, ≥ 30 mmHg after 1 minute, or ≥ 20 mmHg 5 minutes after a provocative test). Factors predicting recurrent CECS after surgery or after a previously normal ICP measurement were analyzed.

Results: A total of 1714 ICP measurements were taken in 1513 patients with suspected CECS over a 13-year observation period. In all, 201 (12%) tests were re-ICP measurements for persistent lower leg symptoms. Based on the proposed ICP cutoff values, CECS recurrence was diagnosed in 16 of 62 previously operated compartments (recurrence rate, 26%; 53 patients [64% female]; median age, 24 years; age range, 15-78 years). Recurrence rates were not different among the 3 lower leg CECS compartments (ant-CECS, 17%; dp-CECS, 33%; lat-CECS, 30%; $\chi^2 = 1.928$, $P = .381$). Sex ($\chi^2 = 0.058$, $P = .810$), age ($U = 378$, $z = 1.840$, $P = .066$), bilaterality ($\chi^2 = 0.019$, $P = .889$), and prefasciotomy ICP did not predict recurrence. Re-ICP measurements evaluating 20 compartments with previously normal ICP measurements (15 patients [53% female]; mean age, 31 ± 10 years) detected CECS in 3 compartments (15%, all ant-CECS).

Conclusion: Previous fasciotomy for lower leg CECS or previously normal muscle pressure (ICP) do not rule out CECS as a cause of persisting lower leg symptoms. Repeat ICP measurement may have a potential role in the evaluation of patients with persistent lower leg complaints. However, other reasons for lower leg exertional pain must always be considered prior to secondary surgery.

Keywords: intracompartmental pressure measurement; muscle compartment pressure; repeated ICP; CECS; chronic exertional compartment syndrome

^{||}Address correspondence to Marc R. Scheltinga, MD, PhD, De Run 4600, PO Box 7777, 5500 MB Veldhoven, the Netherlands (email: m.scheltinga@mmc.nl).

^{*}Department of Surgery, Máxima Medical Center, Eindhoven/Veldhoven, the Netherlands.

[†]Caphri Research School, Maastricht University, Maastricht, the Netherlands.

[‡]Department of Sports Medicine, Máxima Medical Center, Eindhoven/Veldhoven, the Netherlands.

[§]Department of Surgery, Catharina Hospital, Eindhoven, the Netherlands.

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Chronic exertional compartment syndrome (CECS), if present, is usually observed in the lower leg.¹¹ Typically, patients report muscle pain during sports such as running or soccer that may briefly persist after cessation of exercise.^{12-14,19,33} Cramps, tightness, weakness, and altered skin sensation may also be present. Symptoms usually subside within half an hour of rest after exercise.⁴¹

Consensus regarding the pathophysiology of CECS is lacking, but elevated intracompartmental pressures (ICPs) are believed to play a central role.²⁷ If history and physical examination suggest CECS, results of a dynamic ICP measurement determine management. Most patients with elevated ICP are initially treated with conservative therapies such as rest, pain medication, or adjustment of running technique.¹⁶ However, some CECS patients do not respond

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favorably to such treatment regimens and require fasciotomy.⁹

The most frequently used muscle compartment cutoff points are the modified Pedowitz criteria, which confirm CECS if pressures are elevated up to ≥ 15 mmHg in rest, and ≥ 30 mmHg and/or ≥ 20 mmHg 1 and 5 minutes after provocation, respectively.²⁷ Recently, the pivotal role of a dynamic ICP and these criteria have been subject of debate, as correlations with therapeutic efficacy, including surgical outcome, were never demonstrated.²⁵⁻²⁷ Furthermore, a recent magnetic resonance imaging (MRI) study on lower leg deep posterior CECS found that ICP pressure catheters were often positioned suboptimally, also indicating a more relative than absolute role of ICP in the diagnostic process.⁴⁰

After fasciotomy, some patients continue to report symptoms possibly associated with ongoing CECS. Other patients might experience CECS-like symptoms although earlier ICP tests were normal. The diagnostic value of a repeated ICP measurement (re-ICP) in these patient populations is unclear. A re-ICP may be considered once alternative diagnoses for persistent lower leg complaints (eg, medial tibial stress syndrome [MTSS], popliteal artery entrapment syndrome [PAES], stress fracture, tarsal tunnel syndrome, common peroneal nerve entrapment) are excluded.²¹

The general aim of this study was to examine the potential role of a re-ICP measurement in the management of patients with suspected CECS in the lower leg. To answer this question, we studied 2 patient groups that underwent re-ICP measurement of a lower leg compartment. The first population presented with recurrent or persistent lower leg pain after an earlier fasciotomy for CECS. The second population demonstrated persistent lower leg symptoms suggestive of CECS despite earlier normal ICP.

METHODS

Patient Selection

Our hospital is a teaching facility with a catchment area of 200,000 individuals. The Department of Sports Medicine serves as a national referral center for exercise-induced pain syndromes of the extremities. All individuals who underwent ICP measurement for CECS between January 2001 and December 2013 because of a history (exertional lower leg symptoms such as pain, feeling of tightness, cramps, and/or muscle weakness) and physical examination (painful or tense compartment on palpation before exercise) suggestive of CECS were prospectively entered in a database. Patients were included in the present study if they received a re-ICP measurement for recurrent or ongoing CECS-like symptoms after fasciotomy of the same lower leg compartment(s) or if they experienced persisting symptoms in a lower leg muscle compartment after an earlier normal ICP measurement of that same compartment. Patients were excluded if they had undergone conservative treatment after a positive ICP measurement, if they did undergo a fasciotomy after an initial normal ICP measurement, or if the re-ICP measurement was performed in a

different/contralateral compartment. The hospital's medical ethical committee judged that the regulations dictated in the Medical Research Involving Human Subjects Act (WMO) did not apply to the study protocol. No informed consent was required according to local directives for retrospective studies. The study complies with the Helsinki Declaration on research ethics.

Consultation and Intracompartmental Pressure

Patients were standardly consulted by 1 of 2 sports physicians with several years' experience in diagnosing CECS. The muscle compartment was tested for tenderness, distal arterial pulsations were palpated, a pedal pulse test was executed, and medial portions of the lower medial tibial rim were palpated to exclude MTSS. If history and physical examination were possibly consistent with recurrent or persisting CECS, a re-ICP measurement was proposed to the patient.

A re-ICP measurement of the anterior tibial muscle compartment, the deep posterior compartment, the lateral compartment, or a combination thereof was performed by 1 of 2 experienced sports medicine physicians. In cases of bilateral complaints, the most symptomatic leg was measured. A slit catheter was connected to an arterial line manometer and display (Indwelling Slit Catheter Set; Stryker Instruments and pressure monitor device 783547; Hewlett Packard).^{2,23} The catheter was inserted in the compartment using a hollow needle while the patient was in a supine position with 20° plantar flexion of the ankle and 10° to 30° flexion of the knee joint. Before insertion of the needle in the bulky portion of the muscle, the skin was infiltrated with 2 mL of 1% lidocaine. After removing the needle, the catheter was left in situ and connected to the manometer. Correct placement was confirmed by movement of the ankle joint against resistance. After recording a resting ICP value, the catheter was disconnected from the monitor and taped onto the skin. Patients were then instructed to run on a treadmill until maximal provocation of symptoms. Directly after cessation of exercise, patients returned to the supine position, the catheter was reconnected to the monitor, and pressures were recorded. Patients were diagnosed with recurrent or newly-onset CECS on the basis of a suggestive history, physical presentation, and elevated ICPs according to the modified Pedowitz criteria (ICP ≥ 15 mmHg at rest, ≥ 30 mmHg after 1 minute, or ≥ 20 mmHg 5 minutes after a provocative test).²⁷

Data Collection and Statistics

Data were obtained from 2 sources. Between January 2001 and March 2010, data were retrieved from a custom-made Microsoft Access database supplemented by information from hardcopy files from the archive. Between April 2010 and December 2013, electronic hospital patient files were used. Analysis was performed using SPSS Statistics, Windows version 22.0.0.0 (IBM Corp). Normality of distribution was determined using the Shapiro-Wilk test. When distributed normally, data are expressed as mean \pm SD. If not, data are expressed as median and range. Potential group differences in prefasciotomy ICP values were

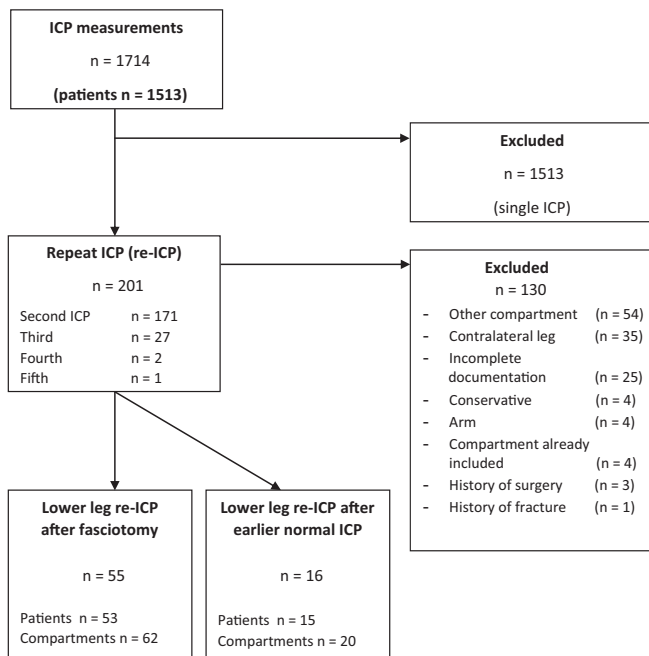


Figure 1. Intracompartmental pressure (ICP) measurements for chronic exertional compartment syndrome between January 2001 and December 2013.

assessed using an independent-samples *t* test. We used the chi-square test to assess differences in recurrence rates in the 3 lower leg CECS types. Equality of variances in these groups of patients was assessed using the Levene test. Factors potentially predicting CECS recurrence (age, sex, bilaterality, affected compartment) were also evaluated using a chi-square test (parametric) or Mann-Whitney *U* test (nonparametric). The Kruskal-Wallis *H* test assessed differences in preoperative ICP values during rest regarding anterior (ant), deep posterior (dp), and lateral (lat) compartments. Because ICP values 1 and 5 minutes after a provocative test were not systematically reported, these variables could not be statistically evaluated as predicting factors. A *P* value $\leq .05$ was considered significant.

RESULTS

General

During the 13-year study period, a total of 1714 ICP measurement sessions were performed in 1513 patients. Of these, 201 tests were re-ICPs of all extremity compartments. After exclusions, 71 re-ICP measurements of the lower leg in 68 patients were eligible for analysis (after fasciotomy, *n* = 55; after a previously normal ICP, *n* = 16) (Figure 1). The most frequently reported symptoms prior to re-ICP measurement were pain (53/55, 96%; *n* = 13 missing) and a feeling of tightness (30/47, 64%; *n* = 21 missing). Most patients reported symptoms during exercise (42/61, 69%; *n* = 7 missing) whereas 20% (12/61; *n* = 7 missing)

TABLE 1
Characteristics of Populations Undergoing Lower Leg Re-ICP Measurement for CECS^a

	Re-ICP After Previous Fasciotomy	Re-ICP After Previously Normal ICP
Patients, <i>n</i>	53	15
Compartments, <i>n</i>	62	20
Anterior, <i>n</i> (+) ^b	28 (5)	13 (3)
Deep posterior, <i>n</i> (+) ^b	24 (8)	5 (0)
Lateral, <i>n</i> (+) ^b	10 (3)	2 (0)
Sex, <i>n</i> (%)		
Female	34 (64)	8 (53)
Male	19 (36)	7 (47)
CECS at first ICP measurement, <i>n</i> (%)		
Unilateral	22 (42)	3 (20)
Bilateral	31 (58)	12 (80)
Age at first ICP, <i>y</i> , median (range)/mean \pm SD	22 (14-77) (95% CI, 23.88-32.46)	29 \pm 10
Age at re-ICP, <i>y</i> , median (range)/mean \pm SD	24 (15-78) (95% CI, 25.80-34.12)	31 \pm 10
Time since start of symptoms at re-ICP, mo, median (range)	17.5 (1-140)	14 (6-120)

^aCECS, chronic exertional compartment syndrome; ICP, intracompartmental pressure; re-ICP, repeat ICP measurement.

^b+ indicates elevated intramuscular pressure according to Pedowitz criteria.²⁷

experienced symptoms during normal daily activities. Two-thirds (26/39; *n* = 29 missing) of all patients had to stop their sports activities or lower their sports activity level because of their exertional symptoms.

Re-ICP Measurement for Suspected Recurrent CECS After Fasciotomy

A total of 53 patients (62 compartments; female, 34/53; median age, 24 years; range, 15-78 years) had previously undergone fasciotomy for ant-CECS (*n* = 28), dp-CECS (*n* = 24), or lat-CECS (*n* = 10) (Table 1). At remeasurement, 16 compartments (26%), met the criteria for CECS. Differences in rates of elevated compartment pressures were not statistically significant for the 3 lower leg CECS types (*P* = .38, $\chi^2 = 1.93$; ant-CECS, 17%; dp-CECS, 33%; lat-CECS, 30%). Sex ($\chi^2 = 0.058$, *P* = .810), age (*U* = 378, *z* = 1.840, *P* = .066), bilaterality ($\chi^2 = 0.019$, *P* = .889), and prefasciotomy ICP at rest also did not predict elevated pressures during re-ICP measurement of either CECS subtype (ant-CECS, *P* = .290; dp-CECS, *P* = .136; lat-CECS, *P* = .905).

Re-ICP Measurement for Ongoing Suspicion of CECS After a Previously Normal ICP

A total of 15 patients (20 compartments; female, *n* = 8; mean age, 31 \pm 10 years) underwent re-ICP measurement

for an ongoing suspicion of CECS despite a normal first ICP measurement (Table 1). Diagnostic criteria for CECS were found in 3 compartments in 3 patients (15% of measured compartments, all ant-CECS). In the remaining 12 patients, re-ICP values did not meet the criteria for CECS in anterior (n = 10), deep posterior (n = 5), and lateral compartments (n = 2).

DISCUSSION

The aim of this study was to evaluate the yield of a repeat dynamic ICP measurement in the management of lower leg CECS. Patients who are suspected of having CECS again after a seemingly successful fasciotomy or having CECS after a previously normal ICP result may undergo a repeat ICP measurement if other exertional pain syndromes such as PAES, MTSS, and intermittent claudication are ruled out.^{1,8,10,21,22,24,31,35} However, it remains unknown whether re-ICP measurement has any potential diagnostic value in these patients, especially since the diagnostic value of an ICP measurement per se is nowadays frequently questioned.^{5,17,29} If one continues to assume that ICP measurement is the gold standard of CECS testing (in the absence of a better one), results of the present study may indicate that a re-ICP measures pressures that are consistent with CECS in up to 23% (19/82) of all compartments. Moreover, these data also suggest that an earlier fasciotomy for CECS, or previously normal ICP measurements, do not exclusively rule out CECS as a cause for persisting lower leg symptoms.

The present study is the first to report on re-ICP measurements, either after a fasciotomy or an earlier normal ICP measurement. The study has a number of limitations associated with its retrospective nature. It is possibly flawed by the risk of information bias as data on patient history and clinical evaluation were occasionally missing. Moreover, some of the patients were not operated on at our hospital. As a consequence, details on experience of surgeons as well as surgical procedure and follow-up were not available. Therefore, a future study including data such as re-ICP measures and surgical details of patients that were prospectively obtained in a single institution will possibly provide more valuable information on the role of re-ICP measurements in CECS.

Both in patients with a previously normal ICP measurement and in patients with ongoing lower leg complaints after a fasciotomy for CECS, causes for exercise-induced symptoms other than CECS must always be ruled out prior to the execution of a re-ICP test. This differential diagnosis includes intermittent claudication (ankle brachial index <0.9, drop after exercise >0.15), PAES (abnormal pedal pulse test, abnormal Duplex after provocation), or MTSS (painful palpation ≥ 5 cm along distal medial tibial rim). If these diagnoses are excluded, conservative treatment regimens such as rest, cooling, orthotics, compression stockings, adjustments in running technique, as well as manual, prolo-, and shockwave therapy may be considered, although the evidence is not strong.^{6,7,15,16} When these conservative regimens fail, the diagnosis CECS may once

again be considered. A re-ICP measurement may aid in the differential diagnostic approach, but one may also, somewhat pragmatically, decide to directly proceed to surgery in a patient with a typical clinical presentation. For instance, Verleisdonk et al³⁸ performed a fasciotomy in 18 patients possibly having a de novo CECS of the anterior compartment based on a typical medical history and physical examination in the presence of normal ICP and found a 66% success rate. In the present study, 26% (16/62) of all compartments showed elevated pressures at re-ICP measurement, either after a fasciotomy or after an earlier normal ICP. Postoperative elevated re-ICPs may possibly be explained by an incomplete fasciotomy, postoperative development of excessive fibrous tissue, or reformation of the fascia.^{4,20,30} An elevated re-ICP after an earlier negative ICP measurement is potentially caused by either an initial false-negative ICP result due to inadequate provocation at first ICP measurement, prolonged inactivity leading to muscle atrophy and consequent low muscle pressures, or it is just a false positive result in itself. A normal re-ICP measurement, despite ongoing complaints, may be explained by a false-negative measurement result or, for instance, by a muscle strain caused by an ongoing changed gait pattern, previously provoked by the CECS symptoms, explaining the accurate normal compartment pressures. Moreover, the possibility of another unknown syndrome other than CECS (or the aforementioned differential diagnosis) must be considered. We strongly feel that the diagnosis of CECS and subsequent decision for invasive surgery should never be made based on results of ICP measurements alone. We recommend a combined approach including detailed history taking, physical examination, and exclusion of other lower leg pathologies, with or without elevated re-ICP measurements.

Timed ICP values obtained during rest and immediately after a provocative test (running, hopping, tip-toeing) are considered the diagnostic gold standard for CECS.^{32,34} The modified Pedowitz criteria are widely accepted as cutoff points to confirm or reject this diagnosis.²⁷ However, a correlation between these cutoff values and treatment outcomes has never been demonstrated, fueling a discussion regarding its absolute role in the diagnostic process as well as its prognostic value.^{5,17,29} Moreover, ICP pressure catheters may be positioned suboptimally when introduced using a "blind" technique, especially in the deep posterior compartment.⁴⁰ It is therefore not a surprise that fasciotomy after a positive ICP test does not always confer success.⁴¹ It must be appreciated that a suboptimal clinical outcome is the end result of all management steps, including faulty diagnostic tests and suboptimal conservative and/or surgical techniques. Conversely, if only clinical characteristics are used as the basis of CECS management, overdiagnosis and treatment may be as frequent as 50%.³ Whether a 23% elevated re-ICP rate, as detected in the present population, really represents CECS or just reflects a high false-positive rate is unclear. A prospective study initiated in our institution from January 2013 onward including all patients with a history and physical examination suggestive of CECS and ICP values may allow for the determination of the relationship between ICP and clinical outcome. Alternative diagnostic tools such as MRI and near-infrared spectroscopy are

under investigation but are not yet generally accepted.^{28,36} Unless alternative diagnostic tools for CECS become available, a dynamic ICP will continue to be regarded as the diagnostic gold standard.

In general, fasciotomy is successful in 33% to 90% of operative patients.^{18,37,39} Success largely depends on CECS type, with treatment in the deep posterior compartment frequently reported to be the least successful. Therefore, reoperations are not unusual.^{4-6,13,18,30,39} In the present study population, 1 of 4 patients undergoing a re-ICP measurement demonstrated elevated compartment pressure. Assuming an unknown false positivity rate and having reservations regarding the absolute discriminative value of the Pedowitz criteria, it is reasonable to assume that some of these patients do suffer from (recurrent) CECS. Interestingly, rates of repeat elevated compartment pressures were not different across the 3 compartments (ant-CECS, 17%; dp-CECS, 33%; lat-CECS, 30%). Possible reasons for high ICP after surgery are an incomplete fasciotomy or development of excessive fibrous tissue.^{4,20,30} A “fifth compartment” consisting of the tibialis posterior muscle with its own fascia that is left intact during the surgical exploration probably also contributes to an inferior outcome after surgery in patients with dp-CECS.^{18,41} In our opinion, a surgeon should always explore all muscles of the affected compartment to make sure the fasciotomy is complete.

CONCLUSION

A re-ICP measurement may be considered in patients with persisting lower leg symptoms after surgery for CECS as well as after a previously normal ICP, since both scenarios do not rule out CECS. However, other reasons for lower leg exertional pain must always be considered prior to embarking on repeat ICP and secondary surgery.

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