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ORIGINAL ARTICLE • LOWER LIMB - SPORT

Fasciotomy for chronic exertional compartment syndrome of the leg: clinical outcome in a large retrospective cohort

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Abstract

Background Chronic exertional compartment syndrome (CECS) is an overuse disorder typically affecting an athletic population. CECS is a diagnosis based on history and intracompartmental pressure (ICP) testing. CECS patients can be treated surgically by fasciotomy; however, research on the relationship between ICP and patient symptoms and also between ICP and patient-reported outcome post-fasciotomy is limited. This study aims to (1) assess functional outcome and patient satisfaction post-fasciotomy and (2) identify any potential correlation between ICP and reported levels of pain.

Methods 138 CECS patients who had ICP measurements and subsequently underwent fasciotomy were identified from our regional service for exercise-induced lower limb extremity pain between January 2000 and March 2017. Clinical outcomes were recorded at the time of ICP testing and in the post-operative follow-up clinic. Pain was reported using a verbal rating scale (VRS) ('low', 'moderate' or 'high') or as a visual analogue score (VAS) 0–10 (0 = least painful, 10 = most painful). Spearman's ranked correlation test was used to calculate correlation between ICP and reported pain.

Results A total of 138 patients were eligible for inclusion in this study (mean age 29.7 ± 9.7 years, 110 M, 28 F) of which 109 patients (VRS $n = 61$, VAS $n = 48$) reported pain level at pre- and post-operative stages. Mean pre-operative VAS score was 8.52 ± 0.71, and decreased to 0.77 ± 0.69 post-operatively. An insignificant positive correlation ($r = 0.046$, two-tailed $p = 0.76$) was found between VAS pain and ICP. A significant moderate positive correlation ($r = 0.497$, two-tailed $p = 0.01$) was found between VRS pain and ICP.

Conclusion Fasciotomy significantly reduces pain and increases activity levels in CECS patients. ICP was found to positively correlate with patient-reported pain.

Keywords Chronic compartment syndrome · Patient satisfaction · Patient outcome · Fasciotomy · Compartment pressure

Introduction

Chronic exertional compartment syndrome (CECS) is a condition causing transient leg pain during and after activity [1]. Tightness, swelling and numbness are common symptoms and relieved by rest in most patients [2]. CECS affects mostly young active people and is commonly seen in runners or army recruits [3–6]. The exact pathophysiology is unclear, but the pain is thought to originate from the increase in intramuscular pressure leading to impaired perfusion and therefore causing ischaemic pain [7, 8].

CECS is primarily a clinical diagnosis based on patient demographics and symptoms. Other causes of lower leg pain in active people include medial tibial stress syndrome, stress fracture, nerve and vascular entrapment. CECS can be differentiated by invasively measuring the intramuscular compartment pressure (ICP). There are several proposed ICP criteria, notably Styf et al. [9], van den Brand et al. [10] and Verleisdonk et al. [11]. The most commonly recognised is Pedowitz et al. [12], but all criteria have been shown to be inconsistent in supporting the diagnosis of CECS [13]. ICP is a useful tool in confirming CECS, but it is unknown if ICP correlates with pain [14].

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The most prevalent symptom in CECS is pain [15], which can have a detrimental effect on the level of daily activities and mental health [16, 17]. Conservative management includes rest, stretching, physiotherapy and orthotics [18]. Surgical management is predominantly fasciotomy, with some practice of fasciectomy reported as well [19]. Fasciotomy for CECS is shown to be an extremely successful surgical management for patients with CECS [21–24].

Several studies reported that 70–100% [20–24] of patients showed minimal or no pain after fasciotomy; however, most of these studies involved small cohort of elite athletes or militants, absent-reported pre-operative state or outcome measures. The literature comparing between variables such as ICP, patient-reported symptoms and outcomes of surgery is scarce. Further investigation is warranted to determine possible correlation.

This study aims to assess patient-reported outcomes pre- and post-fasciotomy. A secondary aim is to identify potential relationships between ICP and patient-reported pain. To the author's knowledge, this study involves one of the largest cohort of heterogenous patient population with pre- and post-fasciotomy patient-reported outcomes along with ICP measurements.

Materials and methods

Clinical research and audit department approval was obtained for this study from our local NHS Trust.

A total of 138 patients with a diagnosis of CECS between January 2000 and March 2017 were included.

Inclusion criteria:

1. A clear history of exercise-induced lower limb pain
2. Dynamic compartment pressure testing in keeping with clinical diagnosis
3. Operative treatment with mini-open (not endoscopic) fasciotomy of the affected compartment
4. Post-operative follow-up and outcome measures

Exclusion criteria:

1. A combined diagnosis such as medial tibial stress syndrome
2. Any ipsilateral surgery or trauma within 6 months of fasciotomy
3. Revision fasciotomy cases

Patient-reported pain, activity level and associated symptoms were recorded. Pre- and post-operative pain was recorded using either a three-item categorical verbal rating scale (VRS) ('low', 'moderate' or 'high') or a visual analogue score (VAS) of 0–10 (0 = least painful, 10 = most painful).

Pre-fasciotomy pain scores, activity levels and associated symptoms were collected at ICP testing (see Fig. 1). Post-fasciotomy pain scores and activity levels were measured 6 months post-operatively in a follow-up clinic. All available data were retrospectively extracted from electronic records including patient clinic letters which spanned from 2000 to 2017. There were no attempts to contact patients with missing data to minimise recall bias.

The decision to measure ICP was based on clinical suspicion of CECS, and to provide objective evidence to support the clinical symptoms. ICP testing was performed at the outpatient clinic with the use of a transducer probe (CPMS UNIT 1 probe, manufactured by MIPM GmBH, Germany and distributed by B Braun, UK).

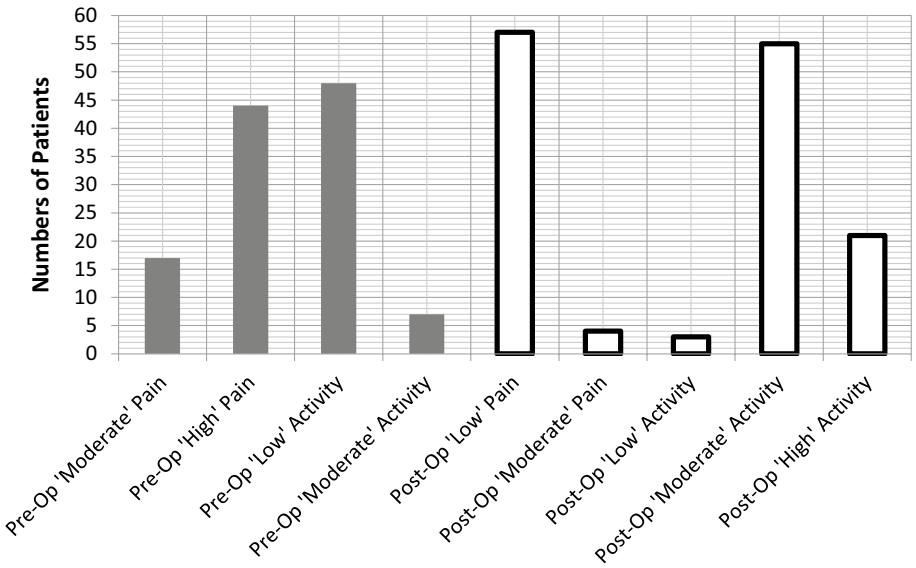

Fig. 1 Bar chart demonstrating patient reported pain level and activity level pre- and post-fasciotomy

During the test, ICP was measured from the compartment suggestive of causing the symptoms. Supine and standing resting ICP were measured, and patients then ran at an incline on a treadmill. Standing ICPs were measured at 1 min, 4 min and 8 min whilst running. Patients then stopped running, and another supine measurement was taken at 0 and 5 min after stopping. ICP cut-off for diagnosis: > 15 mmHg at rest, > 60 mmHg after provocative exercise or > 30 mmHg at 5 min after exercise.

When the diagnosis was confirmed at pressure testing, mini-open fasciotomy of the involved compartment(s) and post-operative rehabilitation were then discussed with the patient.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics software (Version 23, IBM Corp, Armonk, IL, USA). Pain (reported as VRS or VAS) and ICP were assessed for normality using Kolmogorov–Smirnov, and reported as mean ± SDs. Wilcoxon signed-rank test compared outcomes pre- and post-fasciotomy. Gender, laterality of fasciotomy and compartment affected were reported as frequencies. Spearman's ranked correlation test examined the association between the greatest ICP measured for each patient during testing and patient-reported pain (VRS or VAS). Alpha level of significance was < 0.05 and < 0.01 was considered highly significant.

Results

Patient demographics

One hundred and thirty-eight patients were eligible for inclusion in this study, 110 (80%) were males and 28 (20%) were females, mean age was 29.7 ± 9.7 (years). Fifty-three patients (38%) underwent unilateral fasciotomy, whilst 85 (62%) had bilateral fasciotomy. Ninty-six patients (70%) had uni-compartmental disease and 42 patients (30%) with multi-compartmental disease. Two patients required revision bilateral anterior compartment fasciotomy due to recurrence of symptoms (Table 1). There were no significant differences in patient-reported pain, activity levels or associated symptoms between unilateral and bilateral fasciotomy groups.

Pre-operative patient-reported outcomes

Patient-reported pain, activity levels and associated symptoms were recorded at ICP testing at a mean of 12 ± 13.8 weeks (range 1–65 weeks) prior to fasciotomy.

One hundred and nine patients reported pre- and post-operative pain level, of which 61 used a VRS and 48 patients used a VAS. There were no statistically significant differences in VRS and VAS between different compartments (Tables 2 and 3).

Pre-operative activity levels were recorded for 55 patients of which 0 reported 'high activity.' A total of 40 patients reported associated symptoms, 36 reported experiencing a 'tense' lower leg, whilst four reported a 'burning' sensation after running on the treadmill.

Table 1 Patient demographics. 138 patients: 110 males, 28 females

Variables	Gender	Minimum	Maximum	Mean	SD
Age (years)	Male	16	62	29.7	9.5
	Female	16	60	29.0	11.0
Compartments involved					Number of patients
Unilateral anterior					37
Unilateral lateral					0
Unilateral posterior					4
Unilateral anterior + lateral					5
Unilateral anterior + posterior					7
Unilateral anterior + lateral + posterior					0
Bilateral anterior					52
Bilateral lateral					0
Bilateral posterior					3
Bilateral anterior + lateral					7
Bilateral anterior + posterior					22
Bilateral anterior + lateral + posterior					1

Table 2 VRS pain

Patients with pre- and post-fasciotomy pain verbal rating scale ('low', 'moderate' or 'high')	61
Pre-fasciotomy 'low' pain	0
Pre-fasciotomy 'moderate' pain	17
Pre-fasciotomy 'high' pain	44
Post-fasciotomy 'low' pain	57
Post-fasciotomy 'medium' pain	4
Post-fasciotomy 'high' pain	0

Table 3 VAS pain scores

Patients with pre- and post-fasciotomy pain visual analogue scale score (0–10, 0 = least painful, 10 = most painful)	48
Pre-fasciotomy pain score, mean ± SD	8.52 ± 0.71
Post-fasciotomy pain score, mean ± SD	0.77 ± 0.69
Pre-fasciotomy anterior compartment pain score, mean ± SD	8.53 ± 0.73
Post-fasciotomy anterior compartment pain score, mean ± SD	0.76 ± 0.68
Pre-fasciotomy posterior compartment pain score, mean ± SD	8.33 ± 1.15
Post-fasciotomy posterior compartment pain score, mean ± SD	0.67 ± 0.58

Post-operative patient-reported outcomes

Post-operative pain and activity level data were collected during follow-up clinics at a mean 23.0 ± 15.5 weeks (range 4–70 weeks) post-fasciotomy. Overall mean post-operative VAS score was 0.77 ± 0.69 (Tables 2 and 3).

Figure 1 shows a comparison of VRS pain rating and activity levels at pre-operative and post-operative stages. Figure 2 compares VAS pain for different compartments pre- and post-fasciotomy.

Intracompartmental pressure

ICP testing was stopped for eight patients due to severe pain expressed by patients. All ICP measurements were included in the statistical analysis. There were mean increases of 52.7 mmHg (anterior), 47.5 mmHg (lateral) and 32.0 mmHg (posterior—not separated into deep and superficial) between resting and exercise ICP (Table 4).

Post-exertion ICP and pain

Spearman's rank correlation was used to measure the strength of association between pain (reported as VRS or VAS) and ICP (mmHg).

A statistically significant moderate positive correlation ($r = 0.497$, two-tailed $p = 0.01$) was found between patient-reported VRS pain and ICP. Interestingly, VAS-reported pain showed a statistically insignificant weak positive correlation ($r = 0.046$, 2-tailed $p = 0.76$) with ICP.

Figure 3 demonstrates a box and whisker plot for patient-reported VRS pain and ICP. Figure 4 shows a scatter diagram for patient-reported VAS pain and ICP

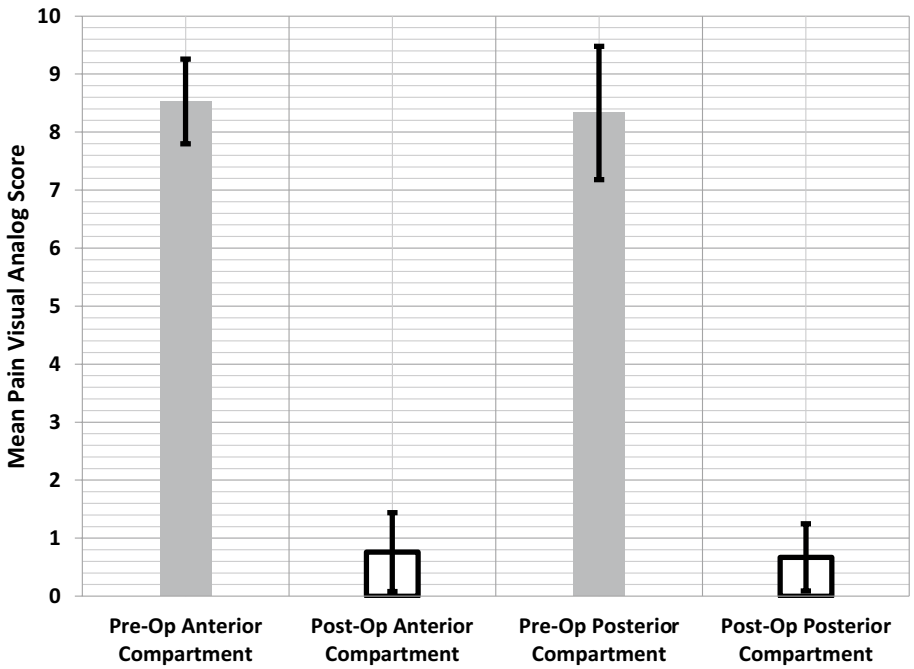

Fig. 2 Bar chart demonstrates mean patient-reported pain (VAS) for different compartments pre- and post-fasciotomy, and error bars show the SD

Table 4 Demographics of CECS and ICP measurements for all compartments

Compartment	Time	ICP (mmHg)			
		Minimum	Maximum	Mean	SD
Anterior	Resting	4	124	44.5	20.1
	Post-exertional	40	200	97.2	32.2
Lateral	Resting	17	106	54.6	28.1
	Post-exertional	40	159	102.1	42.9
Posterior	Resting	5	174	53.4	34.9
	Post-exertional	34	161	85.4	34.8

Discussion

This study aimed to assess CECS patient-reported outcomes pre- and post-fasciotomy, and also any potential relationships between pre-operative ICP and pain. Following strict inclusion and exclusion criteria was important to decrease confounding variables and maximise internal validity of the study.

All patients in this study followed a standardised rehabilitation protocol designed by the treating team in our hospital. A total of 98.5% of patients who underwent fasciotomy reported a lower pain and higher activity level post-operatively compared to the time of ICP testing. Patient-reported VAS pain showed that patients with anterior compartment syndrome had a higher pre-operative pain score than patients with posterior compartment syndrome.

Post-operative VAS pain scores were lower for posterior in comparison with anterior chronic compartment syndromes which is in agreement with Slimmon et al. [25] in a series of 50 CECS patients. The finding of lower pre-operative and post-operative pain in the posterior compartment than anterior compartment syndrome is interesting due to the low incidences of posterior compartment in relation to anterior compartment, with the latter making up around 95% cases of all CECS [26–28]. It has been suggested that posterior CECS

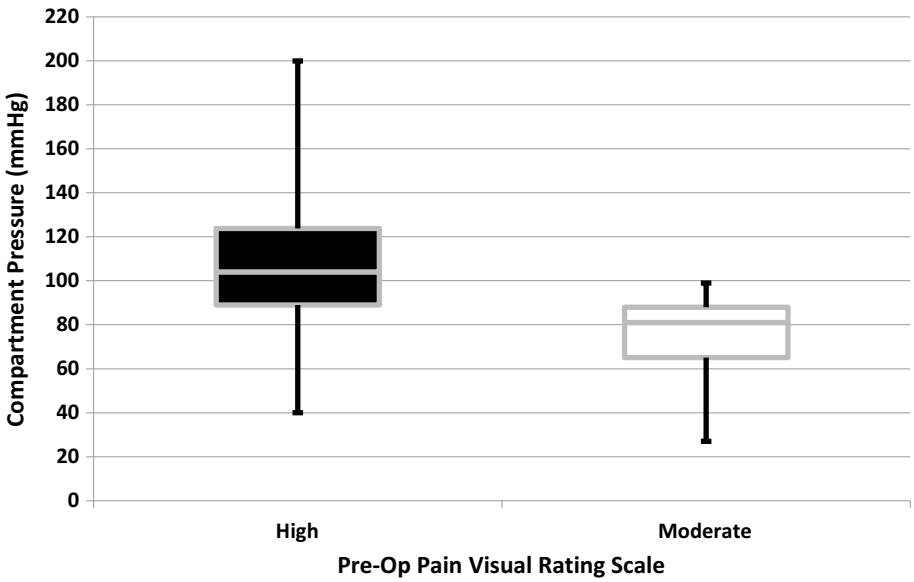

Fig. 3 Box and Whisker plot for pre-op VRS and ICP. *Note*: There were 0 reports of pre-op 'low' pain

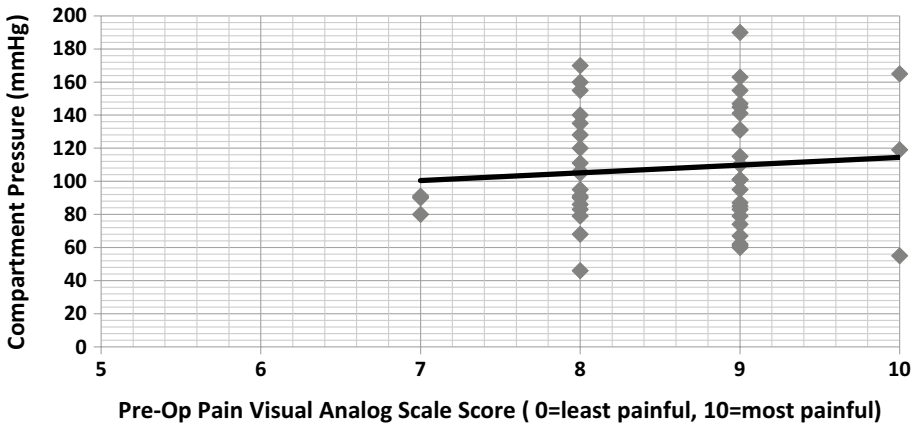

Fig. 4 Scatter plot for pre-op VAS score and ICP. *Note*: A pre-op pain VAS score of ≥ 7 was reported for all patients

is associated with reduced patient satisfaction post-surgery [20]. However, we found that posterior CECS patients were likely to have lower pain post-operatively.

Roberts et al. assessed 98 CECS patients from a military population who underwent fasciotomy and concluded that pre-op ICP was not associated with post-op outcomes [29]. However, this conclusion may not extrapolate to the general non-military population due to population discrepancy [30]. In this current cohort of patients, a very weak positive correlation was found between VAS pain score and ICP, and a moderate positive correlation was found between VRS pain level and ICP. To the authors' knowledge, this has not been reported. The positive correlation between pain and ICP can be interpreted in various ways: (1) The proposed pathophysiology of CECS, a minimally elastic fascia causing an increase in ICP, leading to reduced perfusion and causing ischaemic pain is supported [31, 32] (2) if a patient has a high ICP, they are likely to be suffering from high level of pain, therefore, fasciotomy is likely to relieve their symptoms. ICP measurement is a useful adjunct particularly if the clinical diagnosis is doubtful, and also as a baseline should there be a poor outcome or a recurrence. It is important to note that the diagnosis of CECS should be based on the pattern of symptoms such as nature of pain, distribution, onset pattern, severity, exercises that elicit pain and recovery time post-exercise.

In comparison with other studies, which assessed outcomes for fasciotomy in CECS patients, this study eliminated the possibility of recall bias as patient-reported pain and activity levels were documented contemporaneously at the time of ICP testing and post-operative review in clinic, and not retrospectively using a patient questionnaire. Nonetheless, there were several limitations to this study. The subjectivity of pain is difficult to control as pain perception differs from one patient to another. Although pain is frequently reported using numerical rating scales (NRS), visual analogue scales (VAS), and verbal rating scales (VRS), pain levels cannot be compared between different measuring tools [33]. The use of two different pain-reporting tools makes it difficult to report pain in this cohort because VRS and VAS are not interchangeable [33]. Whilst a validated tool (VRS or VAS) was used to measure patient pain, these rating systems have not been expressly validated in CECS. In addition, we did not have a recognised score for activity levels or associated symptoms. Of the 138 patients included, only 109 (79%) patients reported complete data sets with pre- and post-operative pain levels (VRS or VAS). With respect to activity, there were 79 (57%) patients with recorded activity levels. The incompleteness of this clinical outcomes data is due to missing documentation. Gender, age, height and weight were not controlled for in data analysis.

To further the understanding of the pain and functional limitations of CECS, a validated questionnaire such as the exercise-induced leg pain questionnaire [34] should be used to assess the full spectrum of CECS symptoms, this can reduce the subjectivity and increase the accuracy or reported outcomes. Outcome measures are vital to any surgical study, the majority of current literature-reported outcomes within 1 year of fasciotomy, arguably at the time of the best outcome, thus possibly overestimating the benefits of fasciotomy. Post-operative-reported outcomes should be measured at different times: weeks, months and years. This can assess the effectiveness of different rehabilitation protocols [35] and observe both short- and long-term therapeutic effects of fasciotomy. Such methodology design would increase the likelihood of non-respondents due to loss of contact and loss of interest. Subsequently, this would most likely require a multicentre collaboration to recruit a significant cohort size.

Conclusion

In a large cohort of patients with chronic exercise-induced lower limb compartment syndrome, we demonstrate patient-reported pain and activity levels improved post-fasciotomy using a mini-open approach. We found a significant positive correlation between ICP and VRS-reported pain, and a statistically insignificant, yet positive correlation between ICP and VAS-reported pain.

Compliance with ethical standards

Conflict of interest Dr JPH Tam, Mr AGF Gibson, Mr JRD Murray and Dr M Hassaballa declare that they have no conflict of interest.

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