Systematic Review

Surgical Management for Chronic Exertional Compartment Syndrome of the Leg: A Systematic Review of the Literature

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Purpose: To review published literature to characterize the at-risk demographic, operative indications, surgical techniques, functional outcomes, and reoperation and complication rates after operative management of chronic exertional compartment syndrome (CECS) of the lower leg. **Methods:** We searched PubMed, Embase, Cochrane Database, and CINAHL (Cumulative Index to Nursing and Allied Health Literature) through February 1, 2015, using the terms "chronic exertional" and/or "exercise induced compartment syndrome." The inclusion criteria were studies of Level I to IV evidence in English, published in 1970 or later, involving human subjects, reporting clinical outcomes of operative management of CECS of the lower leg, including at least 5 patients, and having follow-up of at least 80% and 6 months. **Results:** Among the 204 original articles, 24 primary studies with 1,596 patients met the inclusion criteria. The mean age was 26.6 years (standard deviation, 8.9 years), and the majority of patients were male patients (70%). The total study population mostly comprised military service members (54%) and athletes (29%). Of the athletes, 83% were recreational; 9% were college level; and 8% were either national, international, or professional. The most commonly involved compartment was the anterior compartment (51%; 95% confidence interval [CI], 48.6% to 52.3%), followed by lateral (33%; 95% CI, 31.4% to 34.9%), deep posterior (13%), and superficial posterior (3%). The cumulative posterior involvement rate was 16% (95% CI, 15.1% to 17.8%). Mean follow-up was 48.8 months (standard deviation, 22.1 months; 95% CI, 47.1 to 50.5 months). Six percent underwent revision surgery. The overall complication rate was 13% (due to postoperative neurologic dysfunction, infection, and so on). **Conclusions:** Primary operative management of lower-extremity CECS was successful in approximately two-thirds of all young athletic patients, and 84% were satisfied with their surgical outcomes at short- to mid-term follow-up. Open fasciotomy remains the predominant surgical technique, although its comparative efficacy relative to newer endoscopic or other minimally invasive techniques is not currently known. These data may be used to guide the orthopaedic community on accurate preoperative counseling and benchmark patient outcomes for future quality-improvement initiatives. **Level of Evidence:** Level IV, systematic review (studies ranging from Level I to Level IV).

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Chronic exertional compartment syndrome (CECS) of the lower extremity was first described in 1956 in a 24-year-old professional football player who presented with bilateral leg pain related to increased training intensity.[1] Although the contemporary incidence of CECS in the general population is unknown,[2] it has been described in athletic subpopulations at a rate of 0.49 cases per 1,000 persons-years.[3] The lower extremity is most commonly involved,[4] with as many as 13.9% to 34.4% of patients with leg pain attributable to CECS.[5,6]

Although the exact mechanism has not been fully elucidated, the pathology is thought to arise from transient muscular ischemia and progressive neurovascular dysfunction due to the increased intramuscular pressures experienced during endurance

exercise.[7,8] Clinical manifestations include pain on exertion that subsides with rest, typically from chronic repetitive use, and a history of failed nonsurgical treatment.[9] As a result, CECS has been seen and described chiefly among the athletic[2,7-20] and military[21-27] populations, although it may also occur in nontraditional, sedentary individuals.[28]

Conservative management of CECS involves rest, physical therapy, and activity modification involving avoidance of inciting activity, gait retraining, and forefoot running.[29,30] With evidence of increased intracompartmental pressures during exertion,[31] refractory pathology is most often addressed by compartment-specific fasciotomy.[32]

Literature is mixed on the clinical outcomes of operative management in active individuals. Furthermore, the complication profile varies across the existing literature, with incidences ranging from 4% to 19%,[2,17] and the recurrence rate has also been reported as high as 45%.[27]

To this end, we performed a systematic review of the published literature to characterize the at-risk demographic, operative indications, surgical techniques, functional outcomes, and reoperation and complication rates after operative management of CECS of the lower leg. We hypothesized that operative management of CECS of the lower leg would offer moderate symptomatic relief but with a significant rate of complications and reoperation among the young athletic demographic.

Methods

Literature Search

We conducted a systematic review of the literature to identify all publications regarding CECS of the lower leg. A comprehensive literature search was performed using an Internet-based search beginning with queries of the PubMed, Medline, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Cochrane, and Embase databases for all articles between January 1, 1970, and March 1, 2015. A total of 5 search terms were used and were entered into the title and keyword search fields: (1) "chronic exertional compartment syndrome," (2) "compartment syndrome," (3) "chronic compartment syndrome," (4) "exertional compartment syndrome," and (5) "exercise-induced compartment syndrome." This yielded a total of 204 original articles that were isolated for screening.

Study Selection and Inclusion and Exclusion Criteria

The abstracts of all identified articles were subsequently analyzed to determine relevance to CECS (Fig 1). Articles were initially excluded if they involved 1 or more of the following criteria: animal model or basic science research, acute compartment syndrome, compartments other than those of the leg, non–English language, nonsurgical treatment, or publication before 1970. The full-text articles on the remaining investigations were then reviewed for the following inclusion criteria: peer-reviewed clinical studies of Level I to IV evidence, case series including at least 5 patients, and clinical follow-up of at least 80% and 6 months. The references of all articles were reviewed as well for any additional articles that were not found on the initial search.

Patient demographic characteristics (age, sex, occupation), activity profile (athlete, military, other), and level of competition (recreational, collegiate, professional) were extracted from each article. We further assessed the duration of symptoms, operative indications, surgical technique, compartment involvement, reported preoperative and postoperative clinical outcomes, presence of revision surgery or unplanned reoperation, and perioperative complication profile. "Clinical success" was defined as 1 or more of the following: a good or excellent patient-reported outcome, postoperative patient satisfaction, an indication that the patient would elect to undergo the surgical procedure again, complete resolution of pain or exertional symptoms, or a return to full preoperative levels of activity.

Statistical Analysis

For continuous data, the weighted averages were calculated and reported including 95% confidence intervals (CIs) for the population age, success rate, composition (military, athletes, and so on), compartment involvement, and overall follow-up. The cumulative standard deviation (retrieved from included studies) for age and follow-up is reported in this article.

Results

Literature Selection

Of the 204 articles discovered on our initial search, 164 articles were eliminated based on abstract review based on clear irrelevance and exclusion criteria. For the 40 articles remaining, full abstracts were reviewed in depth by the 2 lead investigators (D.C., J.A.R.) and confirmed for inclusion by the independent senior authors (J.C.D., N.K., B.R.W.), as were the references for additional studies. After retrieval and review of these 40 full-text articles, 27 were eliminated based on redundancy of data between studies (5 studies), inadequate sample size (fewer than 5 patients) (13 studies), focus on pathologies aside from CECS (3 studies), and/or emphasis on surgical technique with no clinical outcomes reported (6 studies). A review of included article references yielded an additional 11 publications that were not found on the initial search (Fig 1). The final review included 24 publications: 1

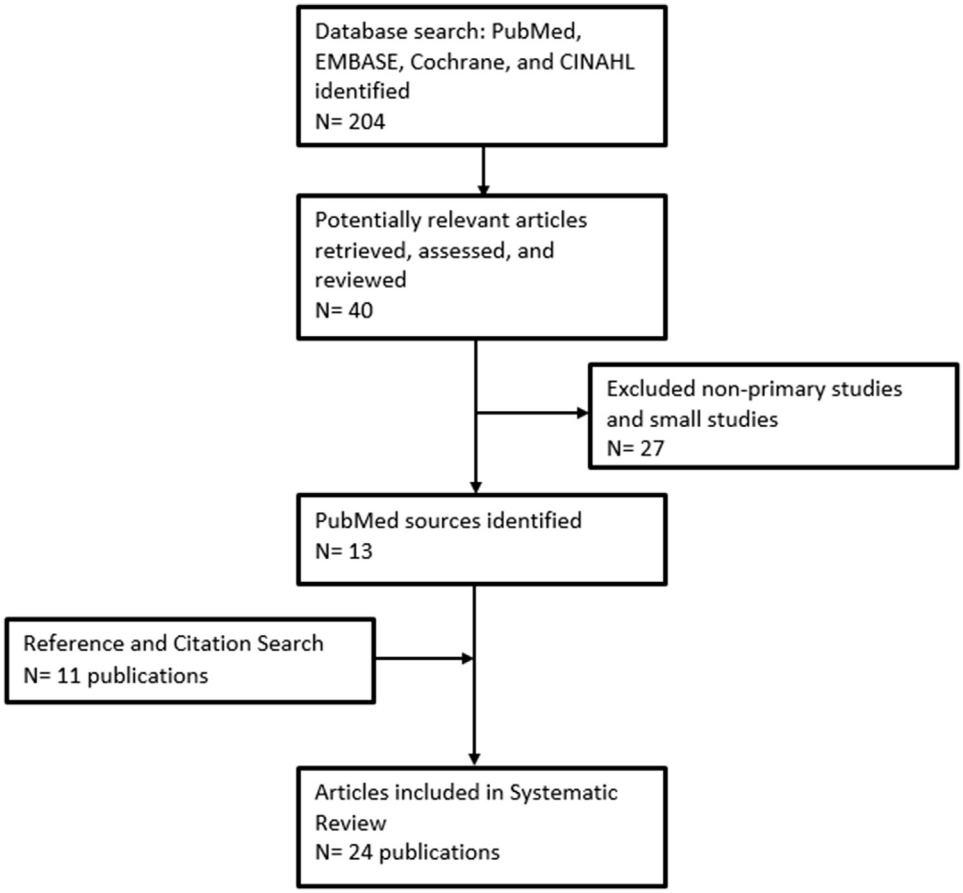

Fig 1. Studies identified by searching PubMed, Embase, Cochrane, and CINAHL (Cumulative Index to Nursing and Allied Health Literature) databases.

Level I, 1 Level II, 4 Level III, and 18 Level IV, according to established criteria for evaluating the level of evidence.[33]

Data Extraction and Analysis

Patient Demographic and Injury Characteristics. The 24 studies included in this systematic review comprised 1,596 patients with an average sample size across studies of 67 ± 120 patients (range, 9 to 611 patients). The weighted average age was 26.6 years (range of study means, 16.7 to 35 years; overall standard deviation [SD] for age, 8.9 years; 95% CI, 25.9 to 27.3 years), and the majority of patients were male patients (70%). Nearly one-half of the population consisted of military service members (54%, n = 855; 95% CI, 51.1% to 56.0%), and almost one-third (29%, n = 468; 95% CI, 27.1% to 31.6%) were specified as athletes, of whom 43% (n = 201) were competitive or endurance runners. Of the athletes identified across 15 publications,[2,8-20,34] 9% (n = 42) were collegiate level and 8% (n = 36) competed on a professional, national, or international level.

Bilateral involvement was reported in 79% of patients (431 of 544 patients) in 14 studies.[9-13,16-18,20-22,25,29,35] Compartment involvement was reported in 16 studies (1,222 patients)[2,8-12,14-16,19,20,26-28,34,35] and consisted most commonly of the anterior compartment (50%, n = 1,454; 95% CI, 48.6% to 52.3%), followed by lateral (33%, n = 954; 95% CI, 31.4% to 34.9%), deep posterior (14%, n = 385), and superficial posterior (3%, n = 89). The cumulative posterior compartment involvement rate was 16% (95% CI, 15.1% to 17.8%). The average follow-up was 48.8 months (SD, 22.1 months; 95% CI, 47.1 to 50.5 months).

Operative Indications. On clinical presentation, CECS was consistently described as pain during exertion that was alleviated by rest, with variable complaints of tightness, cramping, and/or paresthesia.[10,23] Indications are shown in Table 1.

Intracompartmental pressures were measured in 21 of the 24 studies (88%). Nine studies (42%) used the criteria of Pedowitz et al.[5] to confirm the clinical diagnosis of CECS,[8,9,12,16-18,20,28,29] constituting symptomatic compartment pressure of 15 mm Hg or more before exercise, 30 mm Hg or more at 1 minute after exercise, or 20 mm Hg or more at 5 minutes after exercise. Five studies (21%) reported using conventional radiography and bone scans for exclusion of other diagnoses.[8,14,15,22,28] Two studies performed vascular tests to rule out vascular obstruction.[10,35]

Table 1. Indications for Surgical Operation

	No. of Studies (% of Studies)
Pain on exertion that subsides with rest	20 (83)[8,10-19,21-23,25-27,29,34,35]
Paresthesia	14 (58)[8,10,12-19,22,23,28,29]
Failure of nonsurgical treatment	9 (38)[11,13,16,19,22,23,25,27,34]
Ischemia	9 (38)[8,10,16-18,23,26,28,35]
Tightness	7 (29)[9,10,12,15,19,22,29]
Weakness	4 (17)[12,15,17,19]
Overuse	4 (17)[9,26,28,34]
Cramping	4 (17)[13,17,19,35]
Foot drop	1 (4)[10]

Surgical Technique and Rehabilitation Protocol. Of the entire population included, 1,495 (94%) underwent eventual surgical management, including compartment-specific open fasciotomy (86%), fasciotomy with partial fasciectomy (12%), and endoscopic fasciotomy (<2%). The anterior compartment was most commonly released by a single-incision technique (10 studies consisting of 455 patients),[12,16-19,22,23,25] involving a single longitudinal incision through the skin and subcutaneous tissue midway between the anterior tibial crest and fibula overlying the intermuscular septum. The range of techniques included the approach of Rorabeck et al.,[13] which was cited in 4 studies[9,10,15,34]; the approach of Mubarak and Owen[36] in four[2,12,15,16]; a "blind" technique[35] in 1; and a technique with multiple small horizontal incisions in 1.[2] In addition, a 2-incision technique was reported in 6 studies, involving 127 patients.[8,10,13-15,34] The deep posterior compartment was approached in all cases through a single longitudinal incision just medial to the tibial crest through which the soleal bridge was released from the tibia to access the deep fascia.[13]

Postoperative rehabilitation protocols varied. Immediate weight bearing as tolerated was most common (9 studies).[8,11,13,14,16,17,21,26,28] Only 1 study reported a more conservative approach, consisting of bed rest and elevation for 4 days before weight bearing.[18] Two studies advised ankle range-of-motion exercises as part of the immediate rehabilitation.[14,17] However, most studies did not specify any specific rehabilitation protocol.

Clinical and Functional Outcomes. There was a lack of standardized outcome measures for determination of success after operative management of CECS. Outcomes were classified using a Likert scale (excellent, good, fair, or poor) in 11 studies, 2 of which measured outcomes by leg (44 excellent, 24 good, 13 fair, and 5 poor; 79% excellent or good),[16,21] 3 by compartment (63 excellent, 65 good, 32 fair, and 11 poor; 75% excellent or good),[12,17,28] and 6 by patient (98 excellent, 62 good, and 85 fair/poor or needing revision; 65% excellent or good).[11,15,18,19,28,29] The defined cumulative success rate was 66% (range, 48% to 100%; SD, 15%; 95% CI, 63.9% to 68.6%). There were 9 studies measuring patient satisfaction ("would have surgery again," "satisfied," or "very satisfied") with the surgical procedure, reporting a combined 84% satisfaction rate at final follow-up.[2,8-10,14,22,23,29,34] Eleven studies reported an overall rate of return to previous or full activity of 75%,[2,8-10,13,14,18,20,22,29,35] at time points ranging from 6 weeks[10] to 4.7 months.[20] Half of the studies (n = 12) in this systematic review had success rates between 70% and 84%.[2,9,12,13,15,17,21,22,26,28,29,34] More recent data specifically evaluating more homogeneously high-demand individuals across 6 studies,[11,18,19,23,25,27] from 2002 to 2015, suggest much more moderate success (48% to 65%).[27,37]

The success rates for specific compartment releases (not isolated) were 86% with involvement of the anterior compartment (207 of 240); 90%, lateral (67 of 77); 61%, deep posterior (44 of 72); and 100%, superficial posterior (3 of 3). These were tabulated from 9 studies,[8,12-14,16,17,20,28,34] 5 studies,[8,13,16,20,34] 9 studies,[8,10-14,17,20,34] and 1 study,[20] respectively.

The duration of symptoms was reported in 8 studies, among which the weighted average was 23 months.[2,8,10,12,16-18,22] Three studies particularly found better outcomes associated with a shorter duration and worse outcomes with a longer duration.[11,18,19]

Recurrence of Symptoms and Reoperation. The rate of recurrence of symptoms ranged between 0%[20] and 44.7%.[27] Overall, 103 patients (8%) underwent all-cause reoperations. Where reported, 72% of reoperations (49 of 68) were successful. Three patients underwent successful revision by fasciectomy.[2] Reoperation rates ranged from 0% to 19% of patients[18,20] as described in 14 studies.[2,9,11,14,15,17-19,22,23,25-27,34]

Complication Rates. The overall complication rate was 13% (n = 197), with most complications being postoperative neurologic dysfunction such as superficial peroneal neuritis (5%, n = 72), followed by infection (4%, n = 66), hematoma or seroma (2%, n = 25), and wound dehiscence (1%, n = 16) (Table 2). The remainder of complications included deep venous thrombosis (n = 3), lymphocele (n = 1), and other nonspecified complications (n = 14).

Discussion

At an average follow-up of 48.8 months, we found that primary surgical management of CECS of the lower leg showed a cumulative clinical success rate of 66%, with a risk of reoperation and a risk of perioperative complications in the young athletic population of 6% and 13%, respectively.

Table 2. Surgical Complications

	% of Overall Population (% of Total Complications)	n
Complication		
Nerve-related injury	5 (37)	72
Infection	4 (33)	66
Hematoma or seroma	2 (13)	25
Wound dehiscence	1 (8)	16
DVT	<1 (2)	3
Lymphocele	<1 (0.5)	1
Other	<1 (7)	14
Overall	13	197

DVT, deep venous thrombosis.

Demographic Characteristics

The affected patient demographic consisted of predominantly active high-demand young male patients. The prevalence of CECS among military service members is well established, and 7 studies involved a military demographic.[21-23,25-27,35] Among athletes, runners and soccer players were most prone to development of CECS.[12,16,19] Presumably, the frequent and high-demand lower-extremity endurance activities in these groups may predispose at-risk individuals to the development of CECS. Three studies on college athletes achieved high success rates from 83% to 100%, with all the failures being in patients with involvement of the deep posterior compartment (5 failures in 46 patients).[13,14,20] Winkes et al.[19] stated that sex characteristics were not significantly related to surgical outcomes, although conflicting opinions exist. Four studies provided evidence of better outcomes in younger populations (Table 3).[10,13,14,19,29]

Diagnostic Criteria

There is a lack of unity in accepted diagnostic criteria. CECS is often established based on a pathognomonic history and physical examination. Pedowitz et al.[5] described the more recent and widely accepted criteria, which were used in 9 of the studies.[8,9,12,16-18,20,28,29] These criteria have been shown to have poor specificity, albeit very high sensitivity.[9] More recently, Roscoe et al.[31] (among other authors) have challenged these criteria and found a higher sensitivity and specificity using a dynamic monitoring system, as compared with the Pedowitz criteria. The high variation in measurement depth and location creates difficulties in establishing the diagnostic and prognostic value of nonstandardized intracompartmental pressure measurements.[23] To date, a strong correlation between compartment pressures and prognosis has not been established,[19,25,26,29,34] and as a result, compartment pressure is used diagnostically and does not carry prognostic value. However, given the lack of a diagnostic gold standard, physicians must also weigh the potential for other lower-extremity pathology common to athletic persons, such as medial tibial stress syndrome,[2] tibial stress fractures,[8] fascial hernia,[23] periostitis,[28] nerve entrapment syndromes, and popliteal artery entrapment syndrome.[17] With more vague exertional complaints, CECS may also become a diagnosis of exclusion.

Technique

The traditional surgical technique as described by Rorabeck et al.[13] was a 2-incision technique through which all 4 compartments were released. Since then, less invasive and more focused variations such as partial fasciectomy[25] and endoscopic approaches[11,20] have been described. Endoscopic fasciotomy has been thought to decrease wound healing time, decrease scarring, and minimize wound dehiscence[20] (Table 4). To date, few studies have been performed to investigate the equivalence of the endoscopic approach with traditional open fasciotomy. A long-term follow-up study of 34 cases of CECS that underwent partial fasciotomy found that the 3 failures in the series were due to incomplete fasciotomy,[21] which is a likely cause for revision.[15] On the basis of animal models (swine), a minimum 90% fascia release is necessary.[32] Detmer et al.[2] saw symptoms return at approximately 2 months postoperatively suggesting initial adequate decompression, followed by a recurrence, often in a different compartment; recurrences apparently occurred due to excessive healing of scar tissue.[9] In cases with both anterior and lateral involvement, some surgeons preferred not to release the lateral compartment[16,29] because it appeared to be due to anterior

Table 3. Studies Showing Better Outcomes in Younger Populations

Author, Level of Evidence	Findings
Packer et al.,[29] Level III	College and high school populations (aged < 23 yr) had better outcomes than the post-college population (aged > 23 yr); satisfaction was 89% for the high school population, 94% for the college population, and 66% for the post-college population.
Garcia-Mata et al.,[10] Level IV	Increased success was reported in a study of younger patients (mean age, 17 yr); symptoms were eliminated completely in all surgical cases.
Rorabeck et al.,[13] Level IV	Of 12 patients (college athletes; mean age, 25 yr), 10 were cured and asymptomatic; both unsuccessful cases had deep posterior compartment involvement.
Rorabeck et al.,[14] Level IV	Of 25 patients (college athletes; mean age, 22 yr), 22 were satisfied; the 3 cases of failure had deep posterior compartment involvement.

Table 4. Endoscopic Surgical Technique Risks Versus Benefits

Risks
Inferior results with numerous complications for deep posterior involvement[11]
Risk of venous injury and hematoma formation, necessitating postoperative drain use[11,20]
Limited comparative literature
Tight working space for retractor placement and manipulation of scissors and arthroscope
Benefits
Safe for anterior and lateral compartments[20,38,39]
Improved endoscopic visualization of neurovascular structures and extent of fascial release when compared with other semi-blind or minimally invasive techniques[20,40]
Efficacious with predictable relief of symptoms and decreased risk of recurrence because of inadequate release[20]
Good cosmesis with limited incisions; theoretically diminished postoperative fibrosis, healing time,[39] and surgical morbidity[20]

compartment syndrome.[35] Simultaneous treatment was performed in all studies, and 1 study advocated against staged treatment for an earlier return to activity: simultaneous fasciotomy patients returned at an average of 10.7 weeks versus 22.7 weeks for staged treatment.[8] Scar tissue can entrap the nerve, causing pain and necessitating a revision; the nerve must then be dissected out of the scar tissue on revision.[15] Endoscopic approaches are being explored because they have improved visualization through smaller incisions that may limit postoperative fibrosis seen in larger incisions.[20] However, results appear no better than those of standard open fasciotomy at this point.[11]

Success Rates

After operative management, we found an overall clinical success rate of 66% (although each study's metrics varied), with rates in the published literature ranging from 48% to 100%. Early studies reported greater improvement after surgery,[14,16,35] although this is most likely a function of the varied outcome metrics. In a long-term study by Winkes et al.,[19] only a 48% success rate was found among athletes, and Roberts et al.[25] found 48% of patients showing no improvement or worsening. Conversely, 3 other studies resulted in a vastly greater success rate of 100%.[8,10,20] However, these findings also suggest limited improvement in treatment strategies over the past few decades, despite modifications of surgical technique and improvements in diagnostic modalities. Subgroup analysis has yielded various groups among which success might be stratified, including age,[10] level of athletic participation,[18] compartment involvement,[8,11-14,16,17,19] duration of symptoms,[11,18,19] height,[31] and sex.[12]

Compartment Involvement

Many studies tried to investigate the prognostic value and correlation of outcome with compartment pressures, but this has not been effective.[10,13-15,19,23,25,26,29] Compartment involvement has been perhaps the chief determinant of outcome among the aforementioned subgroups and has a strong backing of evidence across many studies in which the deep posterior compartment has resulted in inferior outcomes compared with the anterior compartment. The duration of symptoms[11,18,19] seems to have promising data for prognosis without any conflicting studies to date. In addition, there was some discussion on level of competition before surgery being a factor in level of success, but outcomes seemed to be on par with or higher than those in other studies in the literature among college and higher-level athletes[13,14,19,20] and this is yet to be adequately studied. Moreover, chronicity of symptoms has been associated with worse outcomes[19] (Table 5).

Compartment involvement has also been shown to be a prognostic factor. Whereas anterior compartment involvement was most common in this review and associated with the best outcomes,[12-14,17] results after release of an involved deep posterior compartment have been poor.[8,17] Winkes et al.[19] reported only 48% good or excellent outcomes in the deep posterior compartment, where 87% of those involved were isolated deep posterior compartment syndrome. This study focused on compartment pressures, noting that the static pressure measured directly after exercise appeared to be the most important. In another study, Micheli et al.[12] reported that deep posterior compartment release yielded only a 40% success rate despite an overall success rate of 76% (59 of 78). However, Pasic et al.[9] noted no appreciable differences in outcomes for

Table 5. Support for Chronicity of Symptoms Associated With Worse Outcomes

Author, Level of Evidence	Findings
Winkes et al.,[41] Level IV	Success was noted in 8 of 24 cases with duration of symptoms lasting > 24 mo, 5 of 13 cases with duration of 12-24 mo, 7 of 10 cases with duration of 6-12 mo, and 5 of 5 cases with duration of 0-6 mo.
Slimmon et al.,[18] Level III	Patients treated within 12 mo of symptom onset showed increased satisfaction over those who underwent surgery > 12 mo after symptomatic onset.
Lohrer and Nauck,[11] Level IV	Patients who had symptoms for ≥ 2 yr had a success rate of 20%, whereas those with a preoperative history of < 2 yr had a much greater success rate (75%).
Waterman et al.,[27] Level IV	In a large study of 611 patients, univariate analysis found an odds ratio of 8.46 for the association of persistent symptoms with surgical failure; the association was confirmed on multivariate analysis, with an odds ratio of 5.47.

the deep posterior compartment and suggested an issue with the surgeon's expertise. Involvement of an increasing number of compartments was found to influence outcomes, which were worse overall in patients with multiple-compartment involvement.[18] In a study by Packer et al.,[29] patients who underwent combined anterior and lateral releases had a 31% failure rate whereas there were no failures among those with isolated anterior releases. This may be attributable to myriad factors including the possibility of incomplete release associated with an increasing number of compartment releases (outcomes declined in patients with multiple-compartment involvement).[18]

Revision and Complication Rates

Despite variability among metrics by which successful outcomes were measured, rates of complications and, ultimately, revision surgery remained minimal. This review found most complications were classified as neurologic dysfunction, primarily of the peroneal nerve with subjective numbness, altered sensation, regional hypersensitivity, entrapment, and/or neuroma formation. Iatrogenic peripheral nerve injury may occur intraoperatively, marking it as a major source of discussion vis-à-vis differing surgical techniques. There may be extensive postoperative fibrosis, which requires revision because of pain and/or nerve entrapment. Schepsis et al.[15] found 44% of revision patients (8 of 18) to have entrapment of the superficial peroneal nerve. In a study by Wittstein et al.,[20] there were 2 hematomas in the first 2 cases; drains were subsequently used in the next 7 cases for 48 hours without further complications. Although drain use may diminish fluid collection, wound healing complications, and secondary fibrosis, its practice is not routine but may be considered in patients with compromised hemostasis or limited surgical incisions or in high-risk patients (e.g., active chemoprophylaxis).

In the setting of revision surgery, the surgeon should be mindful of the many possible causes of recalcitrant symptoms, including incomplete fasciotomy, fascial hernia, nerve entrapment with the fascial or fibrotic tissue, or incorrect diagnosis masquerading as CECS.[2,8,17,19,23,28] At the time of revision after a failure, Schepsis et al.[15] found that as many as 44% of patients showed evidence of superficial peroneal nerve entrapment with the fascia and scar tissue. Given the high incidence of postoperative nerve entrapment, prophylactic fasciectomy at the time of the index surgical procedure might be an appealing option, although some authors suggest that strength may be sacrificed without a fascial barrier to work against.[2] During surgery, it should be noted that leg muscles may be found herniated through the fascia: One study found fascial defects in 60% of patients[35]; another study found 6 of 22 cases with intraoperative muscle herniation, all in the lower third[10]; and yet another study reported 24 of 106 patients to have fascial hernias.[26] If not identified or treated, these may contribute to clinical failure or incomplete resolution of symptoms. Some controversy exists on increased thickness of the fascia as well[2,10]; 1 study reported an increase in thickness in 25 of 36 symptomatic specimens. However, in 2011 Dahl et al.[42] reported that mean fascial stiffness did not differ among healthy individuals, patients with CECS, and patients with CECS and diabetes.

Limitations

There were a number of inherent limitations to our study. As a systematic review, this investigation is limited by the quality of the constituent studies. Of the studies in the existing literature, few have been able to provide high-quality data with large patient populations. Furthermore, significant variability in patient demographic characteristics (e.g., level of competition), diagnostic criteria, operative indications, surgical techniques, and outcome measures exists among available studies. Similarly, there is a lack of uniformity in outcome reporting and diagnostic measurement techniques. The potential for publication bias must also be acknowledged. In 2 studies by Schepsis et al.,[16,17] there was no overlap in patients because the reported dates were from 1982 to 1990[17] and from 1991 to 1996.[16] However, 2 studies by Rorabeck et al.[13,14] in the same hospital may have contained overlap between 1 study involving dates between 1982 and 1984[14] and an earlier study published in 1983, in which the dates involved were not specified.[13] Finally, another limitation of our study was the possibility of recall bias in the many retrospective studies.

Conclusions

Primary operative management of lower-extremity CECS was successful in approximately two-thirds of all young athletic patients, and 84% were satisfied with their surgical outcomes at short- to mid-term follow-up. Open fasciotomy remains the predominant surgical technique, although its comparative efficacy relative to newer endoscopic or other minimally invasive techniques is not currently known. These data may be used to guide the orthopaedic community on accurate preoperative counseling and benchmark patient outcomes for future quality-improvement initiatives.

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