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Original Research

Association Between Intracompartmental Pressures in the Deep Posterior Compartment of the Leg and Conservative Treatment Outcome for Exercise-Related Leg Pain in Military Service Members

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List of abbreviations: BOS, biomechanical overload syndrome; CECS, chronic exertional compartment syndrome; ERLP, exercise-related leg pain; ICP, intracompartmental pressure; MTSS, medial tibial stress syndrome; SANE, Single Assessment Numeric Evaluation.

Ethics Approval and Consent to Participate: For this study design, concerning evaluation of standard care, national law does not require permission from an ethical committee. All patients provided written consent for aggregated and encoded use of their treatment data.

Consent for Publication: All participants provided written consent for aggregated and encoded use of their treatment data.

Availability of Data and Materials: Deidentified participant data are available via the corresponding author (M.W.) on reasonable request.

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KEYWORDS
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Running

Abstract *Objective:* To evaluate the relationship between intracompartmental pressure (ICP) values of the deep posterior compartment and the outcomes of a comprehensive conservative outpatient treatment program in service members with chronic exercise-related leg pain.
Design: Historic cohort study.
Setting: Department of sports medicine at a military secondary care facility.
Participants: During the 5-year study period, 266 military patients completed a treatment program for chronic exercise-related leg pain. Eighty-three service members with 145 affected legs met all inclusion criteria (N=83; 59 men, 24 women; median age, 22 years).
Main Outcome Measures: The primary outcome measure was return to active duty. The secondary outcome measure was development of acute on chronic compartment syndrome. A generalized linear mixed model was used to identify predictor variables associated with return to active duty, including ICP values of the deep posterior compartment and Single Assessment Numeric Evaluation (SANE) score.
Results: Sixty service members (72%) successfully returned to active duty. No association between ICP values of the deep posterior compartment and treatment outcome was found (odds ratio, 1.02; 95% confidence interval, 0.97-1.07; *P*=.50). A low SANE score (ie, more severe symptoms at baseline) was negatively associated with primary outcome (odds ratio, 0.95; 95% confidence interval, 0.90-0.99; *P*=.01). None of the patients developed acute on chronic compartment syndrome during the treatment program.
Conclusions: There was no association between a single postexercise ICP value of the deep posterior compartment of both legs in military service members and return to active duty after a comprehensive conservative outpatient treatment program. None of the patients developed acute on chronic compartment syndrome. In this population, ICP measurement of the deep posterior compartment can be safely postponed until conservative treatment fails and surgical treatment is considered.

Chronic exertional compartment syndrome (CECS), a common and poorly understood cause of exercise-related leg pain (ERLP)—a group of overuse injuries of the lower leg, is among the more challenging diagnostic and management dilemmas that confronts the sports- and military medicine providers.[1] CECS, like other ERLP diagnoses including medial tibial stress syndrome (MTSS), bone stress injuries, nerve entrapments, tendinopathies, and vascular entrapment syndromes, is related to repetitive leg loading activities, such as running, marching, and jumping.[2] Literature in the running and military medicine communities has demonstrated that the most prevalent disorders in the ERLP group are MTSS and CECS.[3]

In the Royal Netherlands Armed Forces, MTSS, anterior compartment CECS and a combination of these 2 make up 21%, 32%, and 31% of chronic ERLP diagnoses, respectively.[4] Other armed forces report incidences ranging from 7.2%-35% for MTSS and an incidence rate of 0.49 cases per 1000 person-years for CECS.[5,6] Stress injuries of the tibia and fibula, commonly described in American and British military literature, are very rare in the Royal Netherlands Armed Forces.[4] The incidence of deep posterior compartment CECS is unknown. Combined, these ERLP diagnoses have a serious effect on basic military training and elite military training, where attrition due to musculoskeletal injuries may be as high as 25% of starters.[6,7]

Biomechanical overload syndrome (BOS) is a diagnostic term that may be applied in case patients present symptoms that mimic CECS, but pressure measurements are below the diagnostic cutoff value for CECS.[4] To discriminate between anterior compartment CECS and BOS, but also between deep posterior compartment CECS and MTSS, intracompartmental pressure (ICP) manometry of both the anterior and deep posterior compartment is still routinely performed in the Royal Netherlands Armed Forces. Moreover, the measurement is used to evaluate whether consideration for early surgical treatment is warranted and to estimate the risk of transition from chronic to acute compartment syndrome.[8,9]

In the Royal Netherlands Armed forces, conservative treatment protocols, mainly focusing on gait retraining, have yielded promising outcomes and were shown not to be influenced by absolute ICP values in the anterior compartment or ERLP (sub)diagnosis in a previous study by our research group.[10] Therefore, the initial current treatment paradigm in the Royal Netherlands Armed Forces with ERLP is conservative, regardless of the clinical subdiagnosis or ICP values.[11-13]

The relationship between absolute ICP values in the deep posterior compartment and ERLP symptoms in the posteromedial part of the leg, however, remains poorly described, with 2 studies finding no correlation.[4,14] To our knowledge, there are no studies reporting on the association between ICP in the deep posterior compartment and outcome of conservative treatment. Moreover, only 1 study suggested ICP could predict surgical outcome in patients with CECS of the deep posterior compartment,[15] while 2 other studies contradicted this.[16,17]

We postulate that if absolute ICP values in the deep posterior compartment are of no predictive value for conservative treatment and patients do not develop acute on chronic compartment syndrome during a conservative treatment program, ICP manometry might be safely postponed until conservative therapy fails and evaluation for surgical treatment is warranted.

Moreover, ICP manometry is an invasive diagnostic technique, associated with complications such as neurovascular injury and hematoma, especially in the deep posterior compartment.[18] The aim of this study therefore was to evaluate, irrespective of clinical subdiagnosis, the association between the absolute ICP values in the deep posterior compartment of the legs and return to active duty in a cohort of military service members with posteromedial ERLP, who participated in a comprehensive conservative outpatient treatment program. Second, we aimed to evaluate the occurrence of acute on chronic compartment syndrome during the treatment program.

Methods

Study design and setting

The current study uses the design and methods of a previous study by our research group.[10] A retrospective historic cohort study was performed at a secondary care facility of the Royal Netherlands Armed Forces (Utrecht, the Netherlands). All patients provided written consent for aggregated and encoded use of their treatment data. Dutch law does not require additional formalities for evaluation of standard care.

Study population

Military service members with posteromedial ERLP for more than 6 months, who completed the outpatient treatment program at a Military Sports Medicine department for secondary care in the years 2015 through 2019, were eligible. All patients were screened before the start of the treatment program, using a detailed intake template for history, physical examination, and diagnostic testing, including an ICP measurement.

Patients were included if they reported ERLP over the posteromedial border of the tibia (clinically suspect for MTSS or deep CECS) with or without concomitant anterior pain (suspected for anteriorCECS), and the clinical diagnosis was MTSS, CECS, BOS, or a combination of these disorders. Patients who reported posterior superficial calve pain (suspect for superficial posterior CECS) or posterior deep calve pain (suspect for Popliteal Artery Entrapment Syndrome [PAES]) were not included. Additional prerequisites for inclusion were availability of the following data in the medical records: treatment duration, treatment outcome, and ICP of the posterior compartment of both legs at intake. Patients were also eligible for inclusion if concomitant anterolateral pain symptoms were present. Exclusion criteria were absence of posteromedial exertional pain, a fasciotomy in the history, ICP values of the deep posterior compartment not ordered and therefore not measured, and treatment outcome unavailable (loss to follow-up).

Intracompartmental pressure measurement

All ICP measurements were performed by a single senior sports medicine physician (W.Z.), according to a previously described protocol.[4] A previously described standardized exercise test and pain scoring system for exertional leg pain was used to provoke symptoms in all patients.[4,19] This Running Leg Pain Profile is a diagnostic tool developed and used in the Royal Netherlands Armed Forces for several years, but it has not been formally validated yet.[20]

Patients were also asked to rate the function of their affected leg(s) using the Single Assessment Numeric Evaluation (SANE) score. The SANE score is a single-question instrument evaluating patients' subjective injury status with the following question: "How would you rate your lower leg(s) today as a percentage of normal, on a 0-100 scale, with 100 being normal." The SANE score is validated in a military health care setting.[21] A SANE score $\geq$70 usually coincides with the moment the sports medicine physician and the patient feel return to baseline, to resume active duty in a few weeks, is opportune.[10,11]

Subsequently, ICP manometry was performed with a measurement device with a sideport needle,[a] 1 minute post exercise. With an anterior approach, ICP in both the anterior compartment and deep posterior compartment were measured, penetrating the skin only once per leg. So, if the clinical goal was to obtain an ICP of the deep posterior compartment (to differentiate between deep posterior CECS and MTSS), the ICP value of the anterior compartment was also available, without additional invasive procedures. During ICP measurement, patients were supine, with the knees at the edge of the table and the legs hanging vertically toward the floor. The criterion for the diagnosis of CECS, in any compartment, was $\geq$35 mmHg, obtained with a single measurement in the first minute post exercise for the symptomatic compartments.[4] This is an arbitrary cutoff value, based on earlier work in the Royal Netherlands Armed Forces: ICP values $\geq$35 mmHg 1 minute post exercise are considered elevated ICP; values <35 mmHg are considered normal ICP.[22]

Conservative treatment program

All participants completed a comprehensive conservative outpatient treatment program, as previously described.[10,11] Treatment was individualized, based on patient characteristics and military occupational specialty, but ICP of the deep posterior compartments was not taken into account. In general, service members with physically more demanding jobs received more weeks of rehabilitation.

Gait retraining was standardized. Patients received at least 4 and maximally 6 individual gait retraining sessions during a period of 6-12 weeks. Three common gait retraining cues were repeated at each training session: (1) change from a heel strike to a fore foot strike landing; (2) increase cadence to 180 steps/min; and (3) stand up taller, don't bend over at the waist (trunk and pelvic position). In addition, patients received uniform homework assignments,

increasing running time and distance gradually, with 2-3 sessions per week, emphasizing acquisition of the new running technique.[10]

Data collection

For this study, and the previous study on the anterior compartment, the same encoded database was created.[10] Return to active duty (yes/no) was the primary outcome measure. Demographic data (fixed-effects) included: age (years), sex (male/female), height (meters), weight (kilograms), body mass index, duration of symptoms (months), recurrent ERLP episode (yes/no), laterality of complaints, concomitant presence of posteromedial pain, military job category (before and after treatment), and clinical diagnosis. The values of the ICP measurements of the deep posterior compartments and the SANE score at intake and after completion of the conservative treatment program were retrieved. Duration of treatment (days) was also recorded. Patient safety was evaluated by monitoring development of acute on chronic compartment syndrome during the period of conservative treatment.

The primary outcome measure was return to active duty (yes=0, ie, treatment success/no=1 ie, treatment failure). The secondary outcome measure was development of acute on chronic compartment syndrome. SANE score improvement (return to active duty vs. no return to active duty) and duration of treatment (return to active duty vs. no return to active duty) were also described.

Statistical analysis

Statistical analysis was performed using SPSS Statistics.[b] Results are reported in 2 groups (return to active duty yes/no) with appropriate measures of central tendency and dispersion.

Differences in covariates of the 2 outcome groups (return to active duty/no return to active duty) were evaluated by univariable logistic regression analysis. In addition to ICP values of affected deep posterior compartments, covariates were selected based on background knowledge from literature and experts.

Given the multilevel structure of the data (ICP values of the deep posterior compartments nested in patients), a generalized linear mixed model was used to determine if baseline ICP values were associated with the return to active duty (yes=0/no=1). The model was built with the previously mentioned fixed-effects estimates (Data Collection) and a random intercept and slope. Presence of multicollinearity was evaluated, and robust covariances were used to handle violations of model assumptions. The (adjusted) odds ratio with 95% confidence limits of this analysis was used to report the strength of the associations. Values of P (2-sided) $\leq .05$ were considered significant. A Box-Tidwell test was performed to test the assumption of linearity between predictor variables and the logit of the treatment outcome variable.

A Mann-Whitney U test was performed to test differences in Δ SANE scores (SANE score after treatment minus SANE score at intake) between the 2 groups (return to active duty yes/no). The difference in duration of treatment between the 2 groups was also evaluated using an independent samples t test.

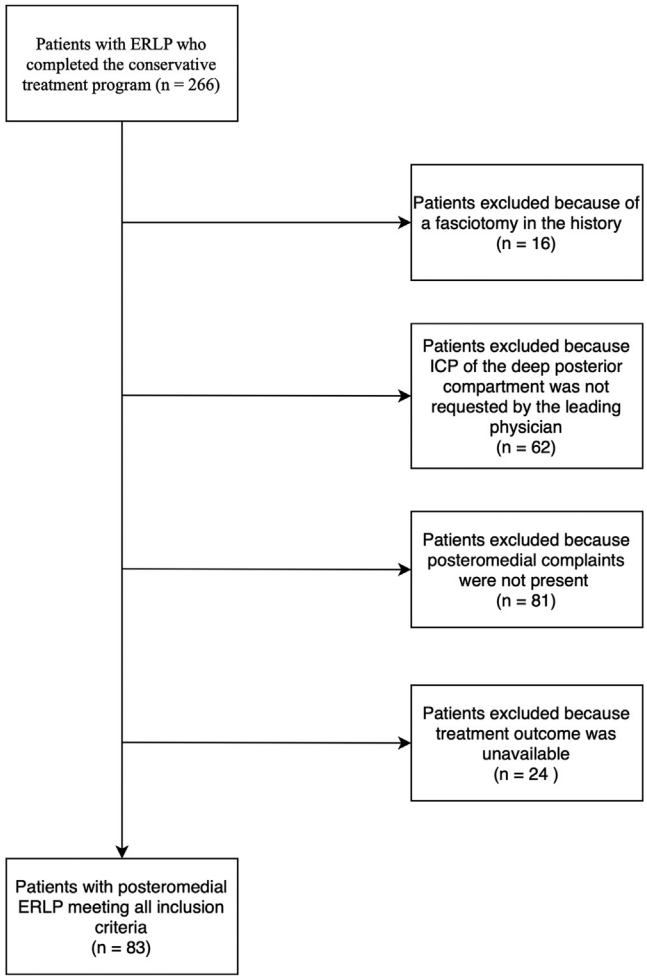

Fig 1 Flowchart of patient inclusion.

Results

Patient demographics of the study population

The treatment program was completed by 266 patients with ERLP during the 5-year study period. A total of 183 patients did not meet inclusion criteria (fig 1). A total of 83 patients with 145 affected legs met all inclusion criteria (table 1).

Absolute ICP values in the deep posterior compartment of all affected legs at intake ranged from 9 mmHg to 76 mmHg. Patients who did and did not return to active duty had comparable ICP values in the deep posterior compartment (see table 1). However, patients not returning to active duty reported significantly lower SANE scores at intake. The groups did not differ regarding all other characteristics.

Treatment outcome

After completion of the treatment program, 60 (72%) of the included service members returned to military base to resume active duty, whereas 23 (28%) were not recovered

Table 1 Baseline characteristics of the study population

Characteristic	All Patients (n=83)	Return to Active Duty (n=60)	No Return to Active Duty (n=23)	Unadjusted Model	
				OR (95% CI)	*P* Value
Age (y), median (IQR min-max)	22 (20-24)	22 (20-24)	22 (20-25)	1.02 (0.91-1.14)	.73
Sex (male), n (%)	59 (71)	44 (73)	15 (65)	0.68 (0.24-1.91)	.47
BMI, mean ± SD	26±4	26±4	27±3	1.03 (0.90-1.17)	.70
Recurrent episode (yes), n (%)	32 (39)	25 (42)	7 (30)	0.61 (0.22-1.71)	.35
Fascial hernia (yes), n (%)	3 (4)	1 (2)	2 (9)	5.62 (0.48-65.22)	.17
Duration of symptoms, (mo), median (IQR min-max)	8 (6-14)	8 (6-16)	8 (5-12)	0.98 (0.93-1.03)	.48
Laterality of posteromedial complaints, n (%)				1.31 (0.42-4.11)	.65
Bilateral	62 (75)	44 (73)	18 (78)		
Concomitant presence of anterolateral pain, n (%)					
None	24 (29)	20 (33)	4 (17)	-	Ref
Unilateral	16 (19)	10 (17)	6 (26)	3.00 (0.69-13.12)	.14
Bilateral	43 (52)	30 (50)	13 (57)	2.17 (0.62-7.60)	.23
ICP affected deep posterior compartments at intake, mmHg, mean ± SD	33±14	32±15	35±14	1.01 (0.99-1.04)	.32
SANE score at intake, mean ± SD	47±17	50±17	39±17	0.96 (0.93-0.99)	.01

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval; IQR, interquartile range; OR, odds ratio; Ref, reference.

sufficiently and needed further treatment. Of the 60 service members who could return to active duty, 47 (78%) could resume their previous occupational specialty, 11 (18%) were allocated a physically less demanding position, and 2 (3%) were able to pursue physically more demanding positions.

The Box-Tidwell test indicated that the assumption of linearity between the predictor variables and treatment outcome (return to active duty) was not violated ($P>.05$).

The multivariable analysis evaluating predictive factors for the treatment outcome (return to active duty) showed a random effect ($P<.01$) (table 2). No association between absolute ICP values of the deep posterior compartment and treatment outcome was shown by multilevel analysis. For 2 participants with a difference in ICP of 1 mmHg, the odds to leave duty was 1.02 (95% confidence interval, 0.97-1.07; $P=.50$). A lower SANE score (ie, more severe symptoms at baseline) was associated with a negative treatment outcome. For 2 patients with a difference of 1 point in SANE score at intake, the odds to leave duty was 0.95 (95% confidence interval, 0.90-0.99; $P=.01$). During the treatment program, none of the participants developed an acute on chronic compartment syndrome.

The change in SANE score (ie, difference between SANE score post treatment and at intake) was shown to be significantly higher in the patients returning to active duty (median, 35; interquartile range, 20-50) compared with those not returning to duty (median, 0; interquartile range, 0-25) ($P<.001$).

The mean duration of the treatment program for all patients was 164 days, ranging from 21 to 463 days. Treatment time was significantly different for the outcome groups

Table 2 Multilevel logistic regression analysis for successful treatment outcome of the comprehensive conservative treatment program for service members with chronic exercise-related leg pain in the posteromedial region of the leg

Variable	Adjusted Model	
	OR (95% CI)	*P* Value
Age	1.12 (0.90-1.39)	.30
Sex, male	0.57 (0.12-2.71)	.48
BMI	0.98 (0.80-1.21)	.86
Recurrent episode	0.53 (0.13-2.24)	.39
Fascial hernia	7.66 (0.15-403.03)	.31
Duration of symptoms (mo)	0.99 (0.92-1.06)	.81
Laterality of posteromedial complaints	1.61 (0.16-16.19)	.68
Unilateral		
Bilateral		
Concomitant presence of anterolateral tibial pain		
None	-	Ref
Unilateral	5.85 (0.62-54.75)	.12
Bilateral	1.54 (0.16-15.10)	.71
ICP affected deep posterior compartments at intake (mmHg)	1.02 (0.97-1.07)	.50
SANE score at intake	0.95 (0.90-0.99)	.01

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval; OR, odds ratio; Ref, reference.

(return to active duty 179±80 days, no return to active duty 127±58 days; t=−2.873, df=81, P<.01).

Discussion

This retrospective analysis evaluated the association between a single ICP value of the deep posterior compartments of the legs and treatment outcome of a comprehensive conservative outpatient program in military service members with posteromedial ERLP. ICP values (1-minute post-exercise) at intake were found not to be associated with successful return to duty after the treatment program. None of the patients in this cohort developed acute on chronic compartment syndrome during the treatment program. These findings suggest that ICP assessment of the deep posterior compartment is not warranted in the initial evaluation of ERLP in military service members to include patients suspected of CECS and may be safely postponed pending a trial of a conservative treatment.

This study is the first to evaluate the association between ICP values of the deep posterior compartment and outcomes of a conservative treatment program. Earlier studies reported a lack of evidence for conservative interventions in patients with deep posterior compartment CECS or described a relationship between ICP values and surgical outcome.[15,23] An earlier cohort study by our research group evaluated the relationship between ICP and outcomes of conservative treatment in a subset of patients with anterolateral ERLP.[10] The current study is an analysis of a subset of patients with posteromedial complaints, extracted from the same cohort as the previous study. Therefore, the methodology, including the conservative treatment program, were equivalent. The current study found no association between postexercise ICP values of the deep posterior compartment and return to active duty in a cohort of military service members who received conservative treatment for chronic ERLP. These findings support a change in the diagnostic protocol in that ICP measurements of the deep posterior compartment may be postponed prior to the start of a conservative treatment program in this group of military services members with ERLP. Previously, the same was found for ICP manometry of the anterior compartment.[10] Postponing ICP measurements of the deep posterior compartment until after conservative treatment has failed may reduce ICP manometry complications such as hematoma and neurovascular injuries. Furthermore, in our estimation, omitting ICP manometry from the diagnostic workup of ERLP entirely may reduce the number of ICP measurements performed in our military health care system by 70%. This can result in a substantial reduction in provider time and associated costs.

While no association was found between ICP values of the deep posterior compartment and return to active duty after conservative treatment, multivariable analysis did show a negative association between SANE score at intake and return to active duty (see table 2), similar to the results of our previous study regarding the anterior compartment.[10] Conversely, the change in SANE score (at intake vs post treatment) was higher in the group returning to active duty. In addition, treatment time was significantly longer in service members who returned to active duty. A possible explanation for these findings may be earlier termination of conservative treatment and referral to surgical evaluation if early conservative treatment results were unsatisfactory.

To continue to improve the care for military service members with chronic ERLP and minimize retirement from active duty, further research should focus on clarifying the relationship between SANE scores at intake and the outcome of conservative treatment for ERLP. The SANE score could be a simple instrument to estimate treatment outcome. Possibly, military patients with ERLP with very low SANE scores should not be offered conservative treatment first but a fasciotomy plus gait retraining approach. In addition, the association between absolute ICP values in the anterior and deep posterior compartment and return to duty after surgical treatment should be addressed. If ICP is not related to severity of symptoms,[4] does not predict the outcome of conservative treatment,[10] and does not predict outcome of surgical treatment, then routine ICP measurement may be omitted from the military diagnostic paradigm of ERLP entirely. Further research could focus on novel, noninvasive diagnostic modalities for ERLP. Ideally, these novel diagnostic modalities should discriminate between different subdiagnoses of ERLP and help to assign patients to the best possible treatment, conservative or surgical, or a combination of the 2. Furthermore, these modalities should aid in assessing outcomes of surgical treatment. Also, future research should evaluate the effectiveness of a conservative treatment outcome in civilian patients with deep posterior CECS because evidence is currently lacking.

Study limitations

Several limitations of this study must be addressed. Although none of the participants developed an acute on chronic compartment syndrome during the treatment program, this rare but devastating complication[9,24,25] cannot be ruled out as a possible complication by this study because of its small sample size. The possibility of generalization of results to civilian patients is limited because military training is not easily comparable to civilian sports. Military service members may have different intensity levels and frequency of training, and road marching and carrying a heavy backpack are not common civilian activities. In addition, female participants are often underrepresented in military populations. Also, a retrospective cohort study is always prone to selection bias, and military-specific outcome measures were used (eg, return to duty), which are highly relevant for military populations but may be less relevant for civilian populations. The findings are relevant for a subset of patients with ERLP; extrapolation to other ERLP populations must done with caution. Furthermore, PAES and superficial posterior CECS were not included as possible causes of posteromedial ERLP. These 2 entities are a well-known cause of posterior ERLP. However, in the Royal Netherlands Armed Forces, superficial calve pain, suspect for superficial posterior CECS, and deep calf pain, suspect for PAES, is reported in only very few cases. Patients suspect for superficial deep posterior CECS and PAES based on symptoms during history and provocation were excluded from this study, which focused on posteromedial complaints specifically. Future studies may focus on treatment optimization for other patients with ERLP, although their numbers in our setting are few. Despite these clear limitations, the authors feel that they can expand on

earlier recommendations regarding routine measurement of ICP; this is not necessary before initiating conservative treatment for military service members with ERLP.[10,26]

Conclusions

Absolute ICP values in the deep posterior compartment of military service members with ERLP participating in a comprehensive conservative outpatient treatment program were not associated with return to active duty. None of the patients developed acute on chronic compartment syndrome during the conservative treatment program. Routine ICP manometry in the deep posterior compartment is not required before commencement of conservative treatment in military service members with chronic ERLP, irrespective of subdiagnosis.

Suppliers

a. Stryker Intracompartmental Pressure Monitor System; Stryker, Kalamazoo, MI.
b. SPSS Statistics version 26; IBM, Armonk, NY.

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