Injury, Int. J. Care Injured 50 (2019) 1242–1246

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Epidemiology, treatment and outcome after compartment syndrome of the thigh in 69 cases – Experiences from a level I trauma centre

Philipp Rameder[a], Reinhard Schmidt[a], Wolfgang Machold[a], Thomas M. Tiefenboeck[a,*], Adam Bukaty[b], Wolfgang Huf[c], Sandra Boesmueller[a]

[a] Medical University of Vienna, Department of Orthopaedics and Trauma Surgery, Waehringer Guertel 18-20, A-1090, Vienna, Austria
[b] Medical University of Vienna, Division of General Anaesthesia and Intensive Care Medicine, Waehringer Guertel 18-20, A-1090, Vienna, Austria
[c] Karl Landsteiner Institute for Clinical Risk Management, Wolkersbergenstraße 1, A-1130, Vienna, Austria

ARTICLE INFO

Article history:
Accepted 4 April 2019

Keywords:
Compartment syndrome of the thigh
Epidemiology
Diagnostics
Treatment
Complications

ABSTRACT

Background: Compartment syndrome of the thigh (CST) is a rare condition, and its delayed diagnosis and therapy may lead to devastating adverse effects. Thus, the aim of this study was to present the amassed clinical experiences, regarding diagnosis and treatment of CST at a level I trauma centre.
Materials and methods: The database was reviewed for all patients with a manifest CST treated surgically between 1995 and 2014.
Results: 69 patients (61 males and 8 females) met the inclusion criteria, with a mean age of 42.9 years (range: 11–87 years). Forty-four patients (64%) presented with an isolated CST. There was a significant association between complication rates and high impact vs. blunt trauma (12/32, 38% vs. 0/20, 0%; $p = 0.0022$; Fisher's exact test). The number of surgeries in patients with a concomitant femur fracture was significantly increased (in mean: 2.8 vs. 4.9 surgical interventions; $p < 0.001$; *U* test).
Conclusion: Patients after high impact trauma showed the highest complication rate. Concomitant femur fractures were associated with an increased number of surgical interventions. The synopsis of trauma mechanism, clinical presentation, age, anticoagulation status and clinical experience of the trauma surgeon seem to be the best tools to correctly diagnose CST.

Introduction

Compared to compartment syndrome of the lower leg, compartment syndrome of the thigh (CST) represents a rare entity among trauma patients – and as such clinicians have relatively little experience with it. CST can occur within all closed osseo-fascial compartments when the pressure rises above the capillary perfusion gradient – leading to cellular anoxia, muscle ischemia and potentially life-threatening events. Concomitant injuries such as fractures, anticoagulation, haemorrhagic shock and blunt trauma are likely to be associated with CST [1–6]. Due to its high morbidity and mortality rates, CST requires immediate surgical intervention [1].

Therapy includes surgical intervention via fasciotomy, with a single incision on the lateral side of the thigh – sometimes even from the greater trochanter to the lateral epicondyle [6–10]. However, the critical threshold for CST still remains unknown [7].

Although CST is often identified as severe injury, literature yields only a few studies including a mere handful of cases [1]. A systematic review has underlined the lack of reliable data concerning causes, treatment options and complications [1].

Thus, the aim of this study was to present our experience with CST at a level I trauma centre. The mechanisms leading to CST, prognostic factors, isolated CST cases, diagnostic methods, method of treatment, complications and the clinical outcome of surgical treatment have been evaluated. Furthermore, we investigated the impact of the number of surgical interventions and the time to treatment on clinical outcome.

Material and methods

This study was performed as a retrospective data analysis, including all patients with a manifest CST treated surgically at a

* Corresponding author at: Medical University of Vienna, Department of Orthopaedics and Trauma Surgery, Waehringer Guertel 18-20, A-1090, Vienna, Austria.
E-mail addresses: philipp.rameder@chello.at (P. Rameder), office@sport-chirurgie.at (R. Schmidt), wolfgang.machold@meduniwien.ac.at (W. Machold), thomas.tiefenboeck@meduniwien.ac.at (T.M. Tiefenboeck), adam.bukaty@meduniwien.ac.at (A. Bukaty), wolfgang.huf@gmail.com (W. Huf), sandra.boesmueller@auva.at (S. Boesmueller).

https://doi.org/10.1016/j.injury.2019.04.001
0020-1383/

Table 1
Classification of trauma mechanisms.

Blunt trauma	Low impact	High impact
Contusion	Trivial fall (<1.5 m)	Motorcycle accident
Weight training	Stab wound	Car accident
	Postoperatively	Bicycle accident
		Fall from great height (>1.5 m)
		Burial
		Gunshot wound
		Heavy Item

single institution (here, a level I trauma centre) between 1995 and 2014. All database files and medical records were reviewed for demographic data (age, sex, trauma history), clinical and functional outcome, intra-compartmental pressure (ICP), coagulation status and treatment modality.

Inclusion criteria were as follows: (a) patients treated surgically for a manifest CST, (b) availability of a complete data set. Trauma mechanisms leading to the CST were classified into (1) blunt trauma (i.e., contusion), (2) low impact trauma (e.g., falls from standing height) and (3) high impact trauma (e.g., gunshot wounds, motorcycle accidents). A detailed overview is presented in Table 1.

Two patients with incomplete data set were excluded, leading to the final number of 69 patients.

This study was conducted in strict adherence to a protocol approved by the local ethics committee, as well as the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines. Prior to study investigation the corresponding ethic review board approved the study (EK/No. 1304/2013).

Diagnostics

CST was diagnosed clinically according to the following criteria: presence of a tense swollen thigh, pain out of proportion and a positive passive stretch test. Additional symptoms noted were paraesthesia and paresis. Pulselessness was also noted but not used as a criterion, as it is known to be diagnostically ambiguous [5,11,12]. The institutional diagnostic algorithm for conscious patients is presented in Fig. 1. Additionally, the ICP was measured by the compartment pressure measurement device Stryker S.T.I.C 295-1 Monitor (Stryker, Kalamazoo, MI (USA) 49001) in all unconscious patients or patients with ambiguous symptoms.

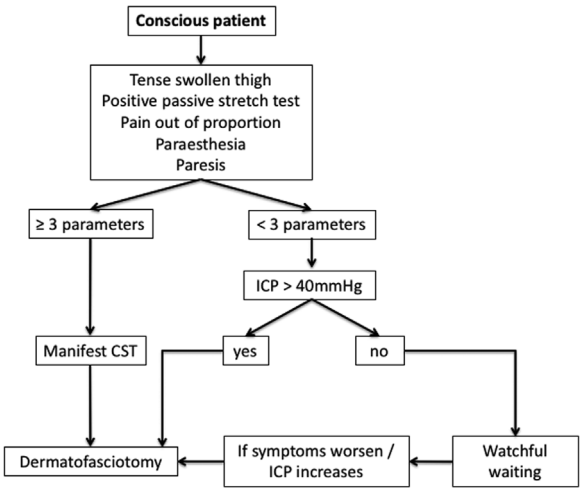

Fig. 1. Institutional diagnostic algorithm for conscious patients.

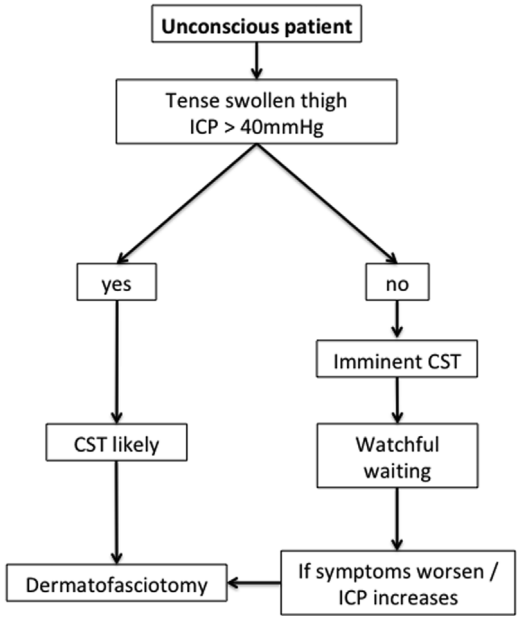

Fig. 2. Institutional diagnostic algorithm for unconscious patients.

The institutional diagnostic algorithm for unconscious patients is presented in Fig. 2.

If ICP measurement was necessary and reached levels above 40 mmHg, a manifest CST was diagnosed. If the patient was unconscious, the ICP and a tense swollen thigh were pathognomonic. If the symptoms were incomprehensible and the ICP was below 40 mmHg the clinical situation was closely evaluated. If the symptoms worsened and ICP increased fasciotomy was carried out.

Therapy

All patients underwent dermatofasciotomy with a single lateral skin incision as described by Tarlow et al. [7]. Muscle contractility was evaluated intraoperatively by electrocautery or forceps. In cases of necrosis or muscle vitality being at risk, cautious debridement was performed. Whenever possible, primary delayed wound closure was attempted and, if necessary, secondary wound closure with a meshed split thickness skin graft was applied. Temporary wound closure was regularly performed by the use of a synthetic skin replacement (Epigard®) and vessel loops. Epigard® changing was carried out routinely within the first 48 h after primary incision, as it represents standard procedure at our department. In 1 case (1%), there was the need for Negative Pressure Wound Therapy (NPWT), rather than Epigard®.

Complications

Complications were divided into minor and major complications. Minor complications were defined as temporary or insignificant impairment such as limited range of motion (ROM) in the knee joint for more than 4 weeks (but less than 6 months), temporary, superficial wound infection, minor secondary haemorrhage without the necessity of red cell concentrate (RCC) and temporary hypaesthesia.

Major complications were defined as considerable impairment (less than 100 degrees flexion in the knee joint more than 6 months postoperatively), permanent paresis, muscle hernia in need of surgical treatment, deep wound infection/fistula, amputation, massive formation of muscle necrosis, severe

secondary haemorrhage requiring large amounts of RCC and Crush syndrome. Muscle contracture also counted as a severe complication.

Statistics

Descriptive and inferential statistics were calculated using IBM SPSS® (SPSS Software Inc.) Version 24. Chi-squared test and Fisher's exact test (in case of cell counts < 5) were used to test for association between categorical variables. For cardinally scaled variables, Student's *t*-test and Mann-Whitney *U* test were used to test for group differences as appropriate. In particular, Mann-Whitney *U* test was used where deviation from normality could be detected using either Kolmogorov-Smirnov test or Shapiro-Wilk test. Mann-Whitney *U* test was also used for cardinally scaled variables with an effective number of realisations < 10, and to test for group differences in ordinally scaled variables. P-values < 0.05 were deemed statistically significant.

Results

Demographics

Sixty-nine patients (61 male and 8 female) with a mean age of 42.9 years (median: 36.5 years; range: 11–87 years) finally met the inclusion criteria. 5 patients (7%) were under 18 years of age and eleven patients (16%) were over the age of 70 years at time of injury. Age significantly affected the proportion of CST patients that presented following a trivial fall (36.2 vs. 69.6; $p < 0.001$; *t*-test). The median age at time of a trivial fall was 72 years. An additional parameter related to age was anticoagulation: Anticoagulation was present in 57% of cases in the trivial fall cohort, whereas only 9% of patients were anticoagulated in the remaining population. At time of injury 13 of 69 patients (19%) were taking anticoagulant drugs and among them 46% were aged above 70 years.

31 cases of CST were on the left side, 36 on the right, and in 2 patients CST was bilateral. There were 44 isolated CST (64%) and 25 non-isolated CST (36%), of which 13 (19%) occurred in the context of polytrauma. 58 patients (84%) were conscious and 11 were unconscious at time of presentation. The assigned aetiologies are presented in Table 2.

Clinical presentation

The time from injury to presentation in the outpatient department was less than 24 h in about 70% (n = 49) and showed no significant influence on the complication rates (21.4 h vs. 35.3 h; *U* test). The majority of patients visiting the outpatient department later than 24 h after injury had suffered a blunt trauma or contusion and only realized the consequences the day after injury. For detailed information about the clinical presentation in conscious and unconscious patients see Table 3.

Table 2
Causes of CST.

	Number	%
Contusion	18	26.1
Trivial fall (<1.5 m)	14	20.3
Motorcycle accident	8	11.6
Car accident	7	10.1
Fall from great height (>1.5 m)	6	8.7
Heavy item	4	5.8
Bicycle	3	4.3
Weight training	2	2.9
Burial	2	2.9
Gunshot wound	2	2.9
Postoperatively	2	2.9
Stab wound	1	1.4
Total	**69**	**100.0**

In 22 cases (32%) the ICP was greater or equal to 40 mmHg. In 10 patients, no pulses were found via palpation. After performing Doppler ultrasound, only two of these 10 patients actually had no pulses – and in both, a concomitant femoral arterial injury was detected by computed tomography angiography (CTA).

An ipsilateral femur fracture was present in 9 patients (13%). Femur fracture was associated with significantly more surgical interventions required until definitive wound closure than patients without (2.8 vs. 4.9; $p < 0.001$; *U* test). The number of severe complications was increased in patients with concomitant femur fractures compared to patients with isolated CST, however, not statistically significant (4/9, 44% vs. 6/44, 14%; $p = 0.11$; Fisher's-exact test).

In 30% (n = 21) of the patients macroscopic muscle necrosis were found during surgery, leading in two patients to a progressive one counting for a major complication.

Surgical procedure

All patients were treated according to the institutional algorithm for CST presented in Figs. 1 (conscious patient) and 2 (unconscious patient).

The standard lateral incision from the trochanteric region to the lateral femur condyle was sufficient for pressure relief. Interestingly, intraoperative findings revealed a predilection site for localized haematomas in the lateral vastus muscle (41/69, 60%), which was particularly present in young patients with contusion injuries. In 49

Table 3
Clinical presentation.

Total of 69 patients		
Conscious patients (n = 58; 84%)		Unconscious patients (n = 11; 16%)
	Swollen and tense thigh (n = 69; 100%)	
Pain out of proportion (n = 58; 100%)		–
Positive passive stretch test (n = 58; 100%)		–
Ambiguous symptoms (n = 12; 21%) with ICP ≥ 40 mmHg		ICP ≥ 40 mmHg (n = 10; 91%)
	No pulses found via palpation (n = 10; 14.5%) / After Doppler ultrasound (n = 2; 2.9%)	
Paraesthesia (n = 3; 5.2%)		–
Paresis (n = 1; 1.7%)		–
Ipsilateral femur fracture (n = 4; 7%)		Ipsilateral femur fracture (n = 5; 45%)

n = number; percentages in relation to the patient population/cohort.

patients (71%) a localized haematoma and in 20 patients (29%) a diffuse haemorrhage was found intraoperatively causing the CST.

Only in 2 cases an additional medial incision was made. In all but one fasciotomy wound, Epigard® and vessel loops were used to cover and gradually reduce the wound size. The number of surgeries needed varied between 1 and 11 (median: 3) surgical interventions. 90% of all patients needed 6 or less surgical interventions. The number of surgical procedures was significantly increased in the non-isolated study population (2.75 in isolated vs. 4.4 in non-isolated; $p < 0.001$; *U* test).

Wound closure

Delayed primary closure was performed in 56 of 69 patients (81%), secondary wound closure with meshed split thickness skin graft was performed in four patients (6%), one leg (1%) was amputated below the groin, one patient (1%) was transferred to another hospital before wound closure and six patients (9%) died before wound closure caused by their initial injury.

Skin suture only was carried out in 23 cases (33%), whereas the combination of fascial suture and skin suture was accomplished in 33 cases (48%). The time to wound closure averaged 7.26 days (median: 5 days).

Complications

Complications were noted in 32 patients (46%). Of these, 14 (20%) suffered minor and 18 (26%) major complications. For detailed information regarding the types of complication see Table 4. The time to diagnosis significantly influenced the development of infections (20.9 h vs. 98.4 h; $p = 0.04$; *U* test). There was a significant association between isolated CST and severity of complications found. Isolated CST tends to develop no or only minor complications, whereas non-isolated CST tends to develop major complications (6/44, 13% in isolated vs. 12/25, 48% in non-isolated CST; $p = 0.02$; chi-squared test). The rate of major complications was significantly higher in patients involved in high-impact and low-impact accidents compared to CST after blunt trauma (12/32, 38% and 6/17, 35% vs. 0/20, 0%; $p = 0.002$; Fisher's exact test). The highest rate of major complications took place after motorcycle accidents (4 major complications out of 8 motorcycle accidents). Of the nine patients (13%) who died during follow-up, only one case (1%) was directly linked to the CST.

The relationship between the kind of wound closure and complication rate showed no significant difference (chi-squared test); however, isolated skin closure tended to lead to more minor and major complications (7 + 6/22, 59% vs. 7 + 5/33, 36%). The only two (3%) muscle hernias occurred in patients with isolated skin closure.

Table 4
Complications in detail.

	Minor	Major
Restriction knee ROM (> 4 weeks < 6 months)	8	
Superficial, temporary wound infection	5	
Minor secondary haemorrhage	1	
Severe secondary haemorrhage		4
Deep wound infection/fistula		3
Crush syndrome		3
Muscle hernia		2
Permanent paresis		2
Severe muscle necrosis		1
Amputation		1
Death related to CST		1
Paresis and severe muscle necrosis		1
Total (n = 32)	**14**	**18**

n = number.

The rate of major complications was significantly increased if the patient underwent more than 3 surgeries (11 major complications in patients > 3 surgeries vs. 7 major complications in patients ≤ 3 surgeries; $p = 0.008$; chi-squared test).

Follow-up

The length of hospitalization in patients with non-isolated CST was significantly longer compared to isolated CST (in mean 36.9 vs. 15.2 days; $p < 0.001$; *t*-test).

Discussion

CST is a rare but severe condition and its aetiology, therapy and outcome has been insufficiently reported. As of this writing, ICP threshold guidelines for diagnosing CST have simply been borrowed from those used for CS of the lower leg (though they have only been well evaluated in the latter setting). Whether or not these thresholds can be effectively applied to CST still remains unknown. This statement is supported by the varying methods and recommendations concerning ICP thresholds seen in the literature [2,4,5,13,14]. Adequate treatment, possible complications and outcomes are all influenced by a number of factors – such as anticoagulation or coagulopathies, patient age, the cause of the CST (in terms of the type of energy generating the trauma), and even the method of wound closure.

Summarizing, our main results we found significantly higher rates of complications in patients with concomitant injuries compared to isolated CST. Traffic accidents cause the highest complication rates. However, it has to be mentioned, that these patients often suffer a polytrauma and therefore complications might be related to other-, or the combination of multiple injuries.

There was a trend towards a higher rate of severe complications in patients with a concomitant femur fracture and surgical interventions were significantly more needed. However, this collective was underestimated compared to literature (13% vs. 58%) [6,9,15]. Time between injury and hospitalization did not influence the overall complication rate – which stands in contrast to literature [16]. Mithoefer et al. [6] presents a complication rate of 18%, which is slightly lower compared to the 25% rate in our study.

In this patient cohort, the most common symptom was a tense, swollen, painful thigh, which is well described throughout the literature [2,4,6,8]. The presence of pain during passive stretching was 100% sensitive; however, its specificity is difficult to assess, since other concomitant injuries, including simple muscle contusions, yielded similar ranges of pain. Even though paraesthesia is listed as one of the cardinal signs for diagnosing CST [1,6,9], we only found this in 5% of our patients (n = 3).

The evaluation of Δ p has been proposed by some authors to establish more valuable data compared to absolute cut-off values in order to sort out the more ambiguous cases regarding the indication for fasciotomy [14,17–19]. However, there still exist no absolute cut-off values for the CST and Δ p for the thigh has to be developed in future studies. In this study the measured ICP itself had no significant influence on the complication rate or the number of muscle necrosis. In only two of our patients severe muscle necrosis occurred during the follow-up period.

We observed an association between time to diagnosis and infection in our study, which is well in line with the results of Kanlic et al. [9] who presents an increased risk of infection and probable need for amputation in patients where the diagnosis has been delayed for more than 12 h.

Referring to our experience with CST, we highly recommend skin and fascial suture to avoid muscle hernia and complications in

general. The good results observed using Epigard® and vessel loops for curbing wound edges are convincing.

Limitations

Limitations of this study include its retrospective single centre design, the heterogeneous patient group, and the investigation of the patients over a long-time period. However, to the best of our knowledge, this is the largest study population with CST treated surgically at a single level I trauma centre – and as such, we are able to present a broad experience. Future prospective studies will have to address the specific ICP thresholds for CST in order to form tools for decision-making.

Conclusions

CST presents a rare entity, however, in case of delayed diagnosis and therapy it might be associated with severe impairment. Patients after high impact trauma showed the highest complication rate. Concomitant femur fractures were associated with an increased number of surgical interventions. The synopsis of trauma mechanism, clinical presentation, age, anticoagulation status and clinical experience of the trauma surgeon seem to be the best tools to correctly diagnose CST.

Level of evidence

Level IV, retrospective study.

Consent for publication

All included patients in this study gave informed consent.

Availability of data and material

The datasets generated and/or analysed during the current study are not publicly available due to data privacy but are available from the corresponding author on reasonable request.

Funding

There was no funding regarding this manuscript.

Authors' contributions

According to the definition given by the International Committee of Medical Journal Editors (ICMJE), the authors listed above qualify for authorship based on making one or more of the substantial contributions to the intellectual content of:

(i) Conception and design [PR, RS, WM, AB, TT, SB]; and/or,

(ii) Analysis and interpretation of data [PR, RS, WM, AB, TT, WH, SB]; and/or

(iii) Participated in drafting of the manuscript [PR, RS, WM, AB, TT, WH, SB]; and/or

(iv) Critical revision of the manuscript for important intellectual content [PR, RS, WM, AB, TT, WH, SB].

Competing interests

The authors declare that they have no competing interests.

Acknowledgements

Not applicable.

References

[1] Ojike NI, Roberts CS, Giannoudis PV. Compartment syndrome of the thigh: a systematic review. Injury 2010;41:133–6.
[2] Echtermeyer V, Horst P. Compartment syndrome. Exclusively the result of increased pressure in the muscular compartment? Der Unfallchirurg 1997;100:924–37.
[3] Rorabeck CH. The treatment of compartment syndromes of the leg. J Bone Joint Surg Br 1984;66:93–7.
[4] Tiwari A, Haq AI, Myint F, Hamilton G. Acute compartment syndromes. Br J Surg 2002;89:397–412.
[5] Mubarak SJ, Owen CA, Hargens AR, Garetto LP, Akeson WH. Acute compartment syndromes: diagnosis and treatment with the aid of the wick catheter. J Bone Joint Surg Am 1978;60:1091–5.
[6] Mithofer K, Lhowe DW, Vrahas MS, Altman DT, Altman GT. Clinical spectrum of acute compartment syndrome of the thigh and its relation to associated injuries. Clin Orthop Relat Res 2004;223–9.
[7] Tarlow SD, Achterman CA, Hayhurst J, Ovadia DN. Acute compartment syndrome in the thigh complicating fracture of the femur. A report of three cases. J Bone Joint Surg Am 1986;68:1439–43.
[8] Schwartz Jr JT, Brumback RJ, Lakatos R, Poka A, Bathon GH, Burgess AR. Acute compartment syndrome of the thigh. A spectrum of injury. J Bone Joint Surg Am 1989;71:392–400.
[9] Kanlic EM, Pinski SE, Verwiebe EG, Saller J, Smith WR. Acute morbidity and complications of thigh compartment syndrome: a report of 26 cases. Patient Saf Surg 2010;4:13.
[10] Mithoefer K, Lhowe DW, Vrahas MS, Altman DT, Erens V, Altman GT. Functional outcome after acute compartment syndrome of the thigh. J Bone Jt Surg 2006;88:729–37.
[11] Ashton H. Critical closing pressure in human peripheral vascular beds. Clin Sci 1962;22:79–87.
[12] Holden CE. Compartmental syndromes following trauma. Clin Orthop Relat Res 1975;95–102.
[13] Matsen 3rd FA, Winquist RA, Krugmire Jr RB. Diagnosis and management of compartmental syndromes. J Bone Joint Surg Am 1980;62:286–91.
[14] McQueen MM, Court-Brown CM. Compartment monitoring in tibial fractures. The pressure threshold for decompression. J Bone Joint Surg Br 1996;78:99–104.
[15] Hope MJ, McQueen MM. Acute compartment syndrome in the absence of fracture. J Orthop Trauma 2004;18:220–4.
[16] Sheridan GW, Matsen 3rd FA. Fasciotomy in the treatment of the acute compartment syndrome. J Bone Joint Surg Am 1976;58:112–5.
[17] Whitesides TE, Haney TC, Morimoto K, Harada H. Tissue pressure measurements as a determinant for the need of fasciotomy. Clin Orthop Relat Res 1975;43–51.
[18] White TO, Howell GE, Will EM, Court-Brown CM, McQueen MM. Elevated intramuscular compartment pressures do not influence outcome after tibial fracture. J Trauma 2003;55:1133–8.
[19] von Keudell AG, Weaver MJ, Appleton PT, Bae DS, Dyer GSM, Heng M, et al. Diagnosis and treatment of acute extremity compartment syndrome. Lancet (London, England) 2015;386:1299–310.