



Management of acute limb compartment syndrome: A survey of clinical practice among orthopedics and traumatology surgeons in Turkey

Akut kompartman sendromu klinik yaklaşımları: Türkiye'deki ortopedi ve travmatoloji doktorlarının uygulamalarının anket ile değerlendirilmesi

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Abstract

Aim: The aim is to conduct a survey of currently practising orthopedics and traumatology surgeons and residents in Turkey regarding their current practice and perceptions on compartment syndrome management.

Materials and Methods: A structured survey was developed for the study. Diagnosis in alert and unconscious patients, clinical signs of the condition, compartment pressure measurement, optimal time frame and technique for performing a fasciotomy, and preventive measures in patients with limb injuries were assessed.

Results: Due to the evaluation, most significant and earliest symptom thought to be pain in 74% and 82.2% respectively. In diagnostic approach of conscious patients, 59.6% find intense pain and intense pain with passive stretching sufficient for diagnosis. In unconscious patients, 22.6% measure intracompartment pressure in every patient and if high in first measurement, indicates emergent fasciotomy, whereas 59.5% apply emergent fasciotomy in clinical suspicion without measuring intracompartment pressure. 89.7% don't use pressure gauge in case of a compartment syndrome suspicion. 55.5% have not seen manually constructed mechanism before. 25.3% participants have sufficient knowledge to construct the mechanism.

Conclusion: There are controversies in the management of compartment syndrome in Turkey, development of clinical practice guidelines may encourage best practice, reduce variations and reduce the incidence of complications.

Key words: Compartment syndrome, clinical management, fasciotomy, compartment pressure measurement.

Öz

Amaç: Çalışmanın amacı, Türkiye'de halen çalışmakta olan ortopedi ve travmatoloji uzmanları ve asistanlarının, kompartman sendromuna yönelik güncel yaklaşım ve algılarının ortaya konmasıdır.

Gereç ve Yöntem: Çalışma için tasarlanmış anket ile, bilinci açık veya kapalı hastada tanı, kompartman sendromunun klinik bulguları, kompartman basıncı ölçümü, fasiyotomi için uygun müdahale süresi ve tekniği değerlendirildi.

Bulgular: Bu değerlendirmede, en önemli (%74) ve en erken (%82,2) oluşabilecek semptomun ağrı olduğu görüşü hakimdir. Tanısal yaklaşımda, %59,6 aşırı ağrı ve pasif germe ile aşırı ağrıyı tanı için yeterli görmektedir. Bilinci kapalı hastalarda, %22,6 kompartman basıncını her hastada ölçülmesi gerektiğini ve birinci yüksek sonuçta acil fasiyotomi endikasyonunu uygun görmektedir. Öte yandan, %59,6 kompartman basıncı ölçmeksizin klinik şüphenin acil fasiyotomi için yeterli bir endikasyon olduğu görüşündedir. %89,7 kompartman sendromu şüphesinde basınç ölçmeye gerek duymamaktadır. %55,5 manuel kompartman ölçüm düzeneğini hiç görmemiş ve %25,3 düzeneği kurabilecek bilgiye sahip olduğunu ifade etmektedir.

Sonuç: Türkiye'de kompartman sendromu yönetiminde tartışmalı yaklaşımlar olduğu gözlenmekle beraber, klinik yaklaşım rehberlerinin hazırlanması, en uygun yaklaşımın oluşması, değişken yaklaşımların ve komplikasyon insidanslarının azaltılması için fayda sağlayacaktır.

Anahtar Sözcükler: Kompartman sendromu, klinik yaklaşımlar, fasiyotomi, kompartman basınç ölçümü.

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Introduction

Compartment syndrome is a condition in which increased pressure within a limited space compromises the circulation and function of the tissues (1). The condition commonly occurs in the compartments of extremities, especially in the leg (2).

Acute limb compartment syndrome (ALCS) is a surgical emergency and is associated with significant morbidity and legal problems, if not diagnosed promptly and treated effectively. Insufficient management might lead further complications.

Trauma is most common reason for ALCS which reported to occur in 1–10% of all tibia fractures (3). Despite the relative frequency of ALCS, and significant morbidity associated with the condition, there are still controversial opinions in literature regarding optimal management of the condition.

The aim of this study was to conduct a survey of currently practicing orthopedic surgeons and residents in Turkey regarding their current practice and perceptions of what constitutes basic principles and best practice in management of ALCS after traumatic injury.

Materials and Methods

A structured survey tool was developed based on a review of the published reports. The survey tool was designed to assess current practice and perceptions of what constitutes best practice in key areas in management of traumatic ALCS. The key areas assessed were diagnosis of condition in alert and unconscious patients, clinical signs of the condition, compartment pressure measurement, optimal time frame and technique for performing a fasciotomy, and preventive measures in patients with limb injuries. For questions requiring a choice between several options, a check-box item was used.

The survey tool was piloted by three orthopedic surgeons and two residents before being sent to attendees. List of the registered surgeons and residents was obtained from Turkish Society of Orthopedics and Traumatology (TOTBID).

Target group was all currently practicing orthopedic surgeons and accredited orthopedic registrars in Turkey. Because of TOTBID privacy policy, an exact figure for target group could not be obtained. However, TOTBID provided an estimate of 4500 currently practicing orthopedic surgeons and residents in Turkey. Sample population was calculated according to 50% frequency for the unknown frequency status and 8% accepted error with 95% confidence interval as 146 attendees for a 5000 estimated registrars. 250 surveys were handed out in the National Congress of Orthopedics and Traumatology to reach the most homogeneous and the largest number of orthopedic surgeons.

Results

There were 161 returns to the surveys distributed. 15 participants were not a part of the target group or returned surveys tardy, therefore only 146 valid surveys have been used for evaluation. 67.1% of participants were specialists, whereas 32.9% of participants were residents. 61.6% of medical doctors who have participated in the survey have been practicing for at least 10 years. 36.3% of them have been working in a university hospital, 26.2% in a state hospital, 29.5% in a training research hospital. When number of cases was analyzed within the clinics the participants have been practicing, it has come out that there have been more than 1000 operations performed in clinics, in which 55.5% of participants have been practicing.

33.6% of participants have encountered compartment syndrome at least 10 times. 54.8% encountered on leg and 37.7% on forearm most frequently. Most significant symptom of acute compartment syndrome has come out as pain in 74% and earliest symptom as pain again in 82.2%. When it was asked about the group of patients that has highest risk for compartment syndrome, 29.5% answered as tibia segmental fracture, 29.5% as long-lasting crush injury, 8.9% as forearm segmental fracture, 32% as re-vascularized extremity.

In diagnostic approach of acute compartment syndrome in conscious patients, 59.6% of participants find intense pain and intense pain with passive stretching exercises sufficient for diagnosis. In unconscious patients, 22.6% of participants measure in-compartment pressure in every patient and if high pressure in the first measurement, points it out as an indication for emergent fasciotomy, whereas 59.5% of participants apply emergent fasciotomy according to clinical suspicion without seeing it as a requirement to measure in-compartment pressure. 55.5% of participants express that they haven't seen the manual device used for measurement of compartment pressure in their entire medical education period, while 25.3% of participants enounce that they have sufficient knowledge to set up the pre-mentioned manual device. 89.7% of medical doctors, who have taken the survey don't use pressure gauge in case of a compartment syndrome suspicion.

In analysis of treatment and follow-up of acute compartment syndrome, 84.7% of participants apply fasciotomy via long skin incisions over compartment, as 13.9% of them find it sufficient to apply subcutaneous long fasciotomies via short skin incisions. 26.7% of participants express that extremity that's being followed with a diagnosis of compartment syndrome should be kept at higher level than heart level, whereas 73.3% of whom believe that it's better to follow up extremity at a higher level than heart level and/or with cold application (Table-1).

Table -1. Outcomes of the Survey Due to the Evaluation.

Survey Outcomes			
Practice year	<10y	56/146	38.4%
	≥10y	90/146	61.6%
Compartment syndrome experience	≤5 cases	63/146	43.2%
	5-9 cases	34/146	23.3%
	≥10 cases	49/146	33.6%
Most localization	Forearm	55/146	37.7%
	Foot	6/146	4.1%
	Leg	80/146	54.8%
	Thigh	3/146	2.1%
	Other	2/146	1.4%
Most important ALCS symptom	Pain	108/146	74.0%
	Sensory deficit	14/146	9.6%
	Motor deficit	15/146	10.3%
	Paleness	9/146	6.1%
Earliest ALCS symptom	Pain	120/146	82.2%
	Sensory deficit	15/146	10.3%
	Motor deficit	2/146	1.4%
	Paleness	7/146	4.8%
	Other	2/146	1.4%
Most risky condition	Comminuted tibia fracture	22/146	15.1%
	Prolonged crush injury	43/146	29.5%
	Comminuted forearm fracture	63/146	43.2%
	Revascularized extremity	18/146	12.3%
ALCS diagnosis in conscious patient	Wait for 5P	13/146	8.9%
	Severe pain with passive stretch and rest pain	87/146	59.6%
	Pain + high compartment pressure measurement	27/146	18.5%
	Pain + consecutive high compartment pressure measurements	19/146	13.0%
ALCS diagnosis in unconscious patient	Compartment pressure measurement, fasciotomy is indicated if high	33/146	22.6%
	Consecutive compartment pressure measurement for fasciotomy indication, even the first measurement is high	16/146	11.0%
	Clinical suspicion is enough for fasciotomy	87/146	59.6%
	Pressure measurement + clinical signs + Doppler USG verification	10/146	6.8%
Manual compartment pressure measurement	Haven't seen before	81/146	55.5%
	Haven't set before	24/146	16.4%
	Have the knowledge	37/146	25.3%
	Don't have any idea	4/146	2.7%
Fasciotomy technique	Short skin incisions, long subcutaneous fasciotomies	20/146	13.9%
	Long skin incisions and fasciotomies	124/146	84.7%
	Other	2/146	1.4%
Fasciotomy experience	≤5 cases	83/146	56.8%
	5-9 cases	29/146	19.9%
	≥10 cases	34/146	23.3%
ALCS follow-up extremity position	Extremity on heart level	39/146	26.7%
	Extremity over heart level	50/146	34.2%
	Extremity on heart level with cold application	16/146	11.0%
	Extremity over heart level with cold application	41/146	28.1%
Compartment pressure measurement in ALCS Suspect	Yes	15/146	10.3%
	No	131/146	89.7%

ALCS: Acute limb compartment syndrome.

55.5% of participants' clinic more than 1000 operations was reported to be performed, 33.6% of participants have reported to come across compartment syndrome at least 10 times, 54.8% of which on the crural region and 37.7% of which on the forearm and carpal region most

frequently.

Response of participants about the riskiest scenario for displaced comminuted forearm fracture, comminuted tibia shaft fracture, prolonged crush injury and reperfusion after prolonged limb ischemia was 8.9%,

29.5%, 29.5% and 32.3% respectively. 10.3% of participants reported to have used manometer within their clinics in ALCS-suspicious case; 5.5% have used trademark pressure measurement systems and 4.8% have used manually constructed mechanism.

When it has been questioned whether or not the participants have come across previously missing compartment syndrome. 25.3% of participants reported that they have never come across any previously missing compartment syndrome, 62.4% reported they have come across 1-3 times, 12.4% reported have met more than 4 times. Also, in a question, in which participants could choose more than one answers, 32.2% of participants have reported that they haven't seen manually constructed mechanism, 19.2% neither have seen the mechanism nor have sufficient knowledge to construct the mechanism, 4.1% of which have neither seen nor constructed the mechanism, however, have sufficient knowledge to construct the mechanism.

Discussion

Clinical symptoms with varying combinations and severity in sequential examinations set difficulties in the diagnosis of this ALCS, especially in multi-traumatized patients which diverts clinician's attention, even among expert surgeons. So, high degree of suspicion is essential in addition to adequate knowledge and practical exposure to manage these patients to avoid significant morbidity even mortality and also medico-legal issues, due to delayed or missed diagnosis. Unfortunately, there are variations in perception of basic principles and management of ALCS by orthopedic surgeons' clinical practice. Also there is little consensus among authors about appropriate management of ALCS, especially regarding the optimal fasciotomy indication particularly with poly-traumatized and unconscious patients. A recent study showed that incidence of fasciotomy and varied from 2 to 24% highlighting the variability of surgical indications and inconsistency in clinical diagnosis (4,5). In the survey completed within this study, in case of ALCS, it's been aimed to question basic approach to ALCS.

In this study, 54.8% of participants come across ALCS on the crural region and 37.7% of which on the forearm and carpal region most frequently. When we look at literature, tibia shaft fractures are being reported to be responsible for the one-third of all of the ACLS, one-quarter of blunt and crushed soft tissue traumas, and one-fifth of radial and ulnar fractures (6). Also we should keep in mind that, up to 30% of ALCS cases occurs without any evidence of fracture (2,7).

In the survey results, most significant symptom of the ALCS has come out as pain in 74% and the earliest symptom as pain again in 82.2 %. ALCS is a dynamic process in which symptoms evolve progressively. So,

examinations should be done serially more over a period of time unless it's strongly suspected at initial presentation (6,8). The aim must be to diagnose early enough to intervene progression towards irreversible changes. The classically mentioned the five "P" signs have low sensitivity but high specificity for diagnosis according to systematic review and combination of these signs might increase the sensitivity (9). But the cardinal symptom for ALCS in conscious patients is pain out of proportion to known injury and doesn't improve with adequate analgesia (6,10). Also pain at rest and with passive stretch is almost always found in evolving ALCS. Moreover, pain can be absent in regional anesthetized patients and sedated patients in ICU (6). Paresthesia is another early sign indicates early nerve ischemia which is followed by hypoesthesia, anesthesia (6,10). Paresis and paralysis are late symptoms which indicate muscular and/or neural lesions (4,6).

Response of participants about the riskiest scenario for displaced comminuted forearm fracture, comminuted tibia shaft fracture, prolonged crush injury and reperfusion after prolonged limb ischemia was 8.9%, 29.5%, 29.5% and 32.3% respectively. This question of survey was purposed to evaluate perceptions of participants about which case scenario is more prone to develop ALCS. According to clinical practice guidelines, a particularly high index of suspicion is necessary for the patient groups as; males aged <35 years with fracture tibia and/or the radius/ulna (11,12), high-energy injuries such as open fractures and/or severe soft tissue injuries (13), patients <35 years with a bleeding disorder or an anticoagulant with soft tissue injuries (14,15) and crush injuries. Despite distribution of participants' responses are also probably related to their past experiences, selecting the riskiest situations as reperfusion injury in 32% of the respondents suggest that the situation is not fully understood. Revascularization after acute arterial injury or obstruction can result in ALCS and most of the patients need fasciotomy after revascularization (16).

26.7% of participants express that extremity that's being followed with a diagnosis of compartment syndrome should be kept at higher level than heart level, whereas 62.3% believe that it is better to follow up extremity at a higher level than heart level and/or with cold application. Authors reported that although limb elevation decreased compartment pressure, blood pressure to elevated limb also decreased, resulting in an overall reduction in perfusion pressure (17,18) Also according to clinical practice guidelines, affected limbs should be positioned at heart level in patients at high risk of developing ALCS (19). Moreover, the guidelines recommend patient should be kept in normotensive and high flow of oxygen should be administered if oxygen saturation is suboptimal (19).

In a diagnostic ALCS approach to conscious patients, 59.6% of participants report that severe rest pain and severe pain after passive stretch enough to make a diagnosis. According to clinical practice guidelines, ALCS should be diagnosed in presence of clinical signs especially with pain out of proportion, as cardinal sign. But in alert, high risk patients with equivocal clinical findings, compartment pressure should be measured. Furthermore, in the initial absence of clinical signs, alert, high-risk patients should be assessed for clinical signs of ALCS at least every 4 hour for a minimum of 24 hour after precipitating injury (19). As 8.9% of participants expressed, waiting for 5P symptoms and paresis/paralysis developing secondary to neural and/or muscular damage, means late symptoms are to be observed which result in malpractice (19). Supporting clinical diagnosis with compartment pressure measurement could be acceptable to eliminate possible risk of over/under treatment and as result of medico legal reaction, if and only if there would be no loss of time. Rarely reported literature about ALCS in awake and conscious patients without severe pain also cause confusion (20). However, insistence on making follow-up measurements regardless of clinical findings and meaningful high compartment pressure values might result in delay in diagnosis and treatment, accompanied by malpractice.

In a diagnostic approach to unconscious patients, 22.6% of participants report that compartment pressure should definitely be measured, 11.0% thinks that regardless of meaningfully high compartment pressure values, follow-up measurements should definitely be conducted, 59.6% suggests that compartment pressure measurement might not be completed and fasciotomy is sufficient in case of a clinical suspicion, and 6.8% reports that additional to clinical findings and compartment pressure measurements, Doppler USG should be applied. According to clinical practice guidelines, in unconscious patients, ACLS should be diagnosed in the presence of raised compartment pressure. Furthermore, in initial absence of raised pressure, unconscious, high risk patients should have their compartment pressure measured at least every 4 h for a minimum of 24 h after precipitating injury (19). In an unconscious patient, as majority of clinical signs are subjective, the unproportioned pain to injury and pain not relieved by analgesics which are accepted as the cardinal symptoms of ALCS, are nearly impossible to evaluate. Therefore, as 59.6% of attendees have responded, rather than making a diagnosis of ACLS based on clinical findings, in unconscious and uncooperative patients, diagnosis should be made according to compartment pressure measurements (19). In survey, 33.6% of participants point out that diagnosis should be made according to compartment pressure measurement, while one-third of prementioned amount of participants

also suggest that follow-up measurements should be completed, even though there would be meaningful high values of compartment pressures and this reveals the fact that there is confusion in this matter. 6.2% of the responses point out that in addition to clinical findings and compartment pressure measurements, Doppler USG should be used. In literature, there are studies regarding the diagnosis of ALCS through laser Doppler flowmeter. However, this doesn't have a routine use in ALCS diagnosis.

Stryker pressure monitor system, Synthes hand-held compartment pressure monitor, arterial line manometer and Whitesides infusion techniques are methods for measuring compartment pressure (6). More accurate diagnosis is reported with arterial line manometer followed by Stryker device (21). Diversely, Whitesides method gave less accurate results in more than one study. But Whiteside method is lifesaving method if other equipment is unavailable, which consists of simply by intravenous tubing, a three-way stopcock, a syringe and a mercury manometer (22). In our survey, 10.3% of participants reported they have used manometer within their clinics in ALCS-suspicious case; 5.5% have used trademark pressure measurement systems and 4.8% have used manually constructed mechanism. In literature, in two surveys, one dates back to 1998 in the UK (23) and the other one dates back to 2015 in Australia (24), completed regarding ALCS approach, 15% of respondents in study of Williams et al. in UK, compared with 78% in the Wall et al study in Australia routinely used compartment pressure measurement. In our study, only 10.3 % of participants reported they have used manometers in ALCS-suspicious cases and this result is relatively lower than results of other studies conducted. This reveals the fact that medical doctors in our study have an approach to ALCS rather based on clinical experience. However, this might create a risk of missing compartment syndromes especially in unconscious and uncooperative patients (6). The survey, it has been questioned whether or not participants have come across previously missing compartment syndrome. 25.3% of participants reported that they have never come across any previously missing compartment syndrome, 62.4% reported that they have come across 1-3 times, 12.4% reported to have met more than 4 times. Also, in a question, in which participants could choose more than one answers, 32.2% of the participants have reported that they have not seen manually constructed mechanism, 19.2% neither have seen the mechanism nor have sufficient knowledge to construct the mechanism, 4.1% of which have neither seen nor constructed the mechanism, however, have sufficient knowledge to construct the mechanism. All in all, it has been found out that 55.5% of the participants have not seen manually constructed mechanism before. In addition to this, it has been understood that only

32.8% of the participants have sufficient knowledge to construct the mechanism, whereas 7.5% of which have never constructed the mechanism.

In another question, in which participants' general approach to fasciotomy has been questioned, it has been found that 13.7% of participants had an opinion of subcutaneous fasciotomies made through short skin incisions are enough. Skin has been shown to act as a limiting boundary even after a fasciotomy has been performed, that jeopardize limb (15,19,24). So, long skin incisions with full-length fasciotomies are recommended.

In our survey, following controversial subjects are not being questioned; which values should be used, absolute pressure threshold or differential pressure threshold and which values are accepted as cut-off values for fasciotomy, because our real aim has been questioning basic approach to ALCS cases. Therefore, as the questionnaire has been prepared it has been tried to put more emphasis on questions regarding the basic key points in individuals' own practices rather than detailed and tiring theoretical information. As responses reveal, orthopedists do still have some confusions about their approach to ALCS cases. This might put a medical doctor in a guilty position in medico-legal means. It is important to make a reminder that in literature there are two studies, analyzing the accusations come up after

ALCS and in more than half of cases, decisions have been made against medical doctors (25,26).

Conclusion

As a conclusion this survey was distributed to the target group of Turkish orthopedic and traumatology surgeons and residents and, hence, selection bias was avoided. However, because of low response rate, the results may not be representative of the management practice of the entire group. A high proportion of clinicians with an interest in ALCS and a better understanding of current evidence may have responded to the survey, leading to an erroneously narrow spread of results. Variation in management of ALCS in Turkey may be greater than that showed in this study.

The results of this study show that there are controversies in the management of ALCS in Turkey, particularly in the critical areas of compartment pressure measurement in diagnosis and treatment. The development of clinical practice guidelines may encourage best practice and reduce variation in management of ALCS and reduce incidence of complications due to misdiagnosis and inappropriate treatment of patients. Further research is needed in all areas of the management of ALCS to dictate optimal management of the condition in future.

References

1. Matsen FA III, Krugmire RB Jr. Compartmental syndromes. *Surg Gynecol Obstet* 1978;147(6):943-9.
2. McQueen MM, Gaston P, Court-Brown CM. Acute compartment syndrome. Who is at risk? *J Bone Joint Surg* 2000;82(2):200-3.
3. Elliott KGB, Johnstone AJ. Diagnosing acute compartment syndrome. *J. Bone Joint Surg* 2003;85(5):625-32.
4. Via AG, Oliva F, Spoliti M, et al. Acute compartment syndrome. *Muscles Ligaments Tendons J* 2015;5(1):18-22.
5. O'Toole RV, Whitney A, Merchant N, et al. Variation in diagnosis of compartment syndrome by surgeons treating tibial shaft fractures. *J Trauma* 2009;67(4):735-41.
6. Raza H, Mahapatra A. Acute compartment syndrome in orthopedics: Causes, diagnosis, and management. *Adv Orthop* 2015;2015:543412.
7. Hope MJ, McQueen MM. Acute compartment syndrome in the absence of fracture. *J Orthop Trauma* 2004;18(4):220-4.
8. McQueen MM, Court-Brown CM. Compartment monitoring in tibial fractures. The pressure threshold for decompression. *J Bone Joint Surg Br* 1996;78(1):99-104.
9. Ulmer T. The clinical diagnosis of compartment syndrome of the lower leg: Are clinical findings predictive of the disorder? *J Orthop Trauma* 2002;16(8):572-7.
10. von Keudell AG, Weaver MJ, Appleton PT, et al. Diagnosis and treatment of acute extremity compartment syndrome. *Lancet* 2015;386(10000):1299-310.
11. Mar G, Barrington M, McGuirk B. Acute compartment syndrome of the lower limb and the effect of postoperative analgesia on diagnosis. *Br J Anaesth* 2009;102(1):3-11.
12. Kalyani B, Fisher B, Roberts C, et al. Compartment syndrome of the forearm: A systematic review. *J Hand Surg Am* 2011;36(3):535-43.
13. Frink M, Hildebrand F, Krettek C, et al. Compartment syndrome of the lower leg and foot. *Clin Orthop Relat Res* 2010;468(4):940-50.
14. Christenson J, Wulff K. Compartment pressure following leg injury: The effect of diuretic treatment. *Injury* 1985;16(9):591-4.
15. Cohen M, Garfin S, Hargens A, Mubarak S. Acute compartment syndrome. Effect of dermatomy on fascial decompression in the leg. *Jof Bone Joint Surg Br* 1991;73(2):287-90.
16. Busch T, Sîrbu H, Zenker D, et al. Vascular complications related to intraaortic balloon counterpulsation: An analysis of ten years experience. *Thorac Cardiovasc Surg* 1997;45(2):55-9.
17. Wiger P, Styf JR. Effects of limb elevation on abnormally increased intramuscular pressure, blood perfusion pressure, and foot sensation: An experimental study in humans. *J Orthop Trauma* 1998;12(5):343-7.
18. Matsen FA, Wyss CR, Krugmire RB, et al. The effects of limb elevation and dependency on local arteriovenous gradients in normal human limbs with particular reference to limbs with increased tissue pressure. *Clin Orthop Relat Res* 1980;(150):187-95.

19. Wall CJ, Lynch J, Harris IA, et al. Clinical practice guidelines for the management of acute limb compartment syndrome following trauma. *ANZ J Surg* 2010;80(3):151-6.
20. O'Sullivan MJ, Rice J, McGuinness AJ. Compartment syndrome without pain! *Ir Med J* 2002;95(1):22.
21. Uliasz A, Ishida JT, Fleming JK, et al. Comparing the methods of measuring compartment pressures in acute compartment syndrome. *Am J Emerg Med* 2003;21(2):143-5.
22. Whitesides TE, Haney TC, Morimoto K, et al. Tissue pressure measurements as a determinant for the need of fasciotomy. *Clin Orthop Relat Res* 1975;(113):43-51.
23. Williams PR, Russell ID, Mintowt-Czyz WJ. Compartment pressure monitoring -- current UK orthopaedic practice. *Injury* 1998;29(3):229-32.
24. Wall CJ, Richardson MD, Lowe AJ, et al. Survey of management of acute, traumatic compartment syndrome of the leg in Australia. *ANZ J Surg* 2007;77(9):733-7.
25. Bhattacharyya T, Vrahas MS. The medical-legal aspects of compartment syndrome. *J Bone Joint Surg Am* 2004;86-A(4):864-8.
26. Shadgan B, Menon M, Sanders D, et al. Current thinking about acute compartment syndrome of the lower extremity. *Can J Surg* 2010;53(5):329-34.