RESEARCH ARTICLE

Factors Associated with Development of Thigh Compartment Syndrome Following Subtrochanteric and Diaphyseal Femoral Fractures

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Abstract

Objectives: Acute compartment syndrome of the thigh (CST) is an ongoing challenge for orthopaedic surgeons as the diagnosis is often difficult to establish. Currently, there is a shortage of studies investigating risk factors for the development of thigh compartment syndrome following subtrochanteric and diaphyseal femoral fractures. This study aimed to identify risk factors associated with the development of CST following femoral fractures.

Methods: Retrospective review performed in a level one trauma center from January 2011 to December 2020 for all patients with non-pathological acute subtrochanteric or diaphyseal femoral fractures. Variables collected included demographics, injury severity score (ISS) scores, mechanism of injury, classification of femoral fracture, open versus closed injuries, development of compartment syndrome, time to compartment syndrome diagnosis, number of subsequent surgeries, and primary wound closure versus split-thickness skin graft. The statistical analysis of this study included descriptive analysis, simple logistic regression, paired T-test, and Wilcoxon Signed Rank.

Results: Thirty-one (7.7%) patients developed thigh compartment syndrome following 403 subtrochanteric or diaphyseal femoral fractures. The mean (SD) age for those who developed CST was 27.35 (8.42). For every unit increase in age, the probability of developing CST decreased. Furthermore, male gender had 18.52 times greater probability of developing CST (P <0.001). AO/OTA 32-C3 and subtrochanteric femoral fracture patterns demonstrated 15.42 (P = 0.011) and 3.15 (P <0.001) greater probability of developing CST, respectively. Patients who presented to the hospital following a motor vehicle accident (MVA) or gunshot wound (GSW) had 5.90 (P= 0.006) and 14.87 (P < 0.001) greater probability of developing CST, respectively.

Conclusion: Patients who were male, younger in age, and had a 32-C3 and subtrochanteric femoral fractures were at increased probability of developing CST. High energy trauma also increased the risk of developing CST. A high index of suspicion should be expressed in patients with these risk factors.

Level of evidence: III

Keywords: Diaphyseal femoral fracture Subtrochanteric femoral fracture, Thigh compartment fasciotomy, Thigh compartment syndrome

Introduction

Acute thigh compartment syndrome (CST) is an ongoing challenge for orthopaedic surgeons as the diagnosis is often difficult to establish. Acute compartment syndrome is an orthopaedic emergency requiring urgent fasciotomy and decompression to avoid significant morbidity, with cited mortality rates of 11-47% in the literature.[1,2] Absence of proper and timely treatment results in ischemia and myonecrosis to the affected limb. CST is a clinical diagnosis and serial examinations by experienced providers is the best tool for accurate

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diagnosis. However, when a complete physical examination cannot be obtained due to patient factors, intra-compartmental pressures (ICP) >30mmHg may be utilized to help facilitate diagnosis.[3,4]

Several studies have attempted to identify a relationship between the mechanism of injury and thigh compartment syndrome. In a systematic review by Ojike *et al*., about 90% of patients with thigh compartment syndrome had a blunt injury to the thigh.[5] In contrast, Knab *et al*. reported a case series of ten patients with six out of ten suffering from penetrating injuries requiring thigh fasciotomies.[6]

Currently, there is a shortage of studies investigating risk factors for the development of thigh compartment syndrome following subtrochanteric and diaphyseal femoral fractures. The purpose of this study was to identify risk factors that increase the probability of developing thigh compartment syndrome among patients with femoral fractures. The primary aim of this study was to study the relationship between Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaeedic Trauma Association (AO/OTA) classification and the development of compartment syndrome. We hypothesized that high energy mechanism fracture patterns such as 32-C2 or 32-C3 will have a higher rate of developing compartment syndrome. The secondary aim of this study was to identify relationships between patient characteristics and the development of CST.

Materials and Methods

Approval from our institutional review board was obtained to perform a retrospective analysis from January 1, 2011 to December 31, 2020 (IRB # 21-020). Data was collected from a single level one trauma center. Patients were extracted from our institution's database by querying for CPT codes 27506 and 27507. A total of 403 patients met our inclusion criteria, which included patients age > 18 treated for acute traumatic subtrochanteric or diaphyseal femoral fractures. Patients excluded were those that sustained pathological fractures (ie. infection or malignancy), and those patients that did not undergo operative fixation.

For all 403 patients, data was solely collected through the evaluation of medical records on the electronic database at our institution from date of admission to date of discharge. Demographic information collected on all patients included gender, age, injury severity score (ISS) scores, mechanism of injury, AO/OTA classification of femoral fracture, open versus closed injuries (gunshot wounds (GSW) were classified as closed fractures), development of compartment syndrome, time to compartment syndrome diagnosis, number of subsequent surgeries, and primary wound closure versus split-thickness skin graft. AO/OTA femoral fracture classification was performed blindly under the oversight of the senior author of this paper.

Statistical analysis was performed using IBM SPSS software. The statistics used for the analysis of this study include descriptive analysis, simple logistic regression, paired T-test, and Wilcoxon Signed Rank. *P-value* of 0.05 was utilized as the threshold to establish statistical significance and confidence intervals were obtained for those values with $p < 0.05$.

Results

There were a total of 403 patients included in this study, with a mean age 43.2 years (range: 18-98). A majority of the patients were male, making up 64.52% (n= 260) of the patients. Of the 403 patients included, 31 (7.69%) developed CST. The mean age of these patients who developed CST was 27.35 years (SD 8.42).

Type of femoral fracture

AO/OTA 32-C3 fractures were the most common fracture pattern among patients who developed compartment syndrome [Table 1]. Those patients with this fracture pattern had 15.42 times greater probability of developing CST than those with AO/OTA 32-A1 fractures (P= 0.011). AO/OTA 32-A1 was the least common fracture pattern in patients who develop CST (3.2%). In addition, those patients that suffered a subtrochanteric femoral fracture had 3.15 greater probability of developing CST than those with diaphyseal femoral fractures (P<0.001) [Table 2]. Almost all patients who developed compartment syndrome had closed fractures (90.3%). However, no statistically significant difference was identified when comparing open versus closed fractures with the development of compartment syndrome (P = 0.958) [Table 3].

Table 1. Risk of developing compartment syndrome following femur fractures based on AO/OTA classification

AO/OTA classification	No. with CS (%)	No. without CS (%)	P-value	Probability (95% CI) *
32-A1	1 (3.2)	60 (16.1)	-	-
32-A2	5 (16.1)	75 (20.2)	0.211	4.00 (0.46-35.16)
32-A3	4 (12.9)	57 (15.3)	0.205	4.21 (0.46-38.81)
32-B2	7 (22.6)	79 (21.2)	0.123	5.32 (0.64-44.38)
32-B3	2 (6.5)	37 (9.9)	0.344	3.24 (0.28-37.03)
32-C2	3 (9.7)	29 (7.8)	0.121	6.21 (0.62-62.29)
32-C3	9 (29.0)	35 (9.4)	0.011	15.43 (1.88-126.96)
Total	31	372	-	-

No: Number; CS: Compartment syndrome; CI: Confidence interval
*Significance analysis performed in comparison to AO/OTA classification 32-A1

Table 2. Risk of developing compartment syndrome following femur fractures based on anatomic location

Type of Femur fracture	No. with CS (%)	No. without CS (%)	*P-value*	Probability (95% CI)
Subtrochanteric	8 (25.8)	37 (74.2)	0.010	3.15 (1.32 – 7.54)
Diaphyseal	23 (9.9)	335 (90.1)	-	-

No: Number; CS: Compartment syndrome; CI: Confidence interval

Table 3. Risk of developing compartment syndrome comparing open versus closed fractures

Type of Fracture *	No. with CS (%)	No. without CS (%)	*P-value*	Probability (95% CI)
Open	3 (9.7)	37 (9.9)	0.958	0.97 (0.28-3.34)
Closed	28 (90.3)	334 (89.8)	-	-

No: Number; CS: Compartment syndrome; CI: Confidence interval
*Gunshot wounds were classified as closed fractures

Mechanism of Injury

Motor vehicle accident (51.6%) was the most common mechanism of injury in patients with compartment syndrome diagnosis followed by gunshot wounds (35.5%). Patients who presented following a motor vehicle accident or gunshot wound had 5.90 and 14.87 greater probabilityof developing CS, respectively, when compared to those with "Other" as the mechanism of injury (fall from standing height, assault, crush) [Table 4].

Table 4. Risk of developing compartment syndrome based on mechanism of injury

Mechanism of Injury	No. with CS (%)	No. without CS (%)	P-value	Probability (95% CI) *
Gunshot wound	11 (35.5)	36 (9.7)	<0.001	14.87 (3.94- 56.10)
Motor vehicle accident	16 (51.6)	133 (35.8)	0.006	5.86 (1.67 – 20.54)
Motorcycle accident	1 (3.2)	57 (15.3)	0.892	0.85 (0.09-8.38)
Other	3 (9.7)	146 (39.2)	-	-

No: Number; CS: compartment syndrome; CI: confidence interval
* Significance analysis performed in comparison to "Other" (fall from standing height, assault, crush, seizure)

Gender and Age

Male gender was a significant risk factor for the development of compartment syndrome. Thirty (96.8%) of patients who developed CST were male and only one patient (3.2%) was female [Table 5]. As a result, male gender had 18.52 times greater probability of developing compartment syndrome than their female counterpart (P <0.001). The mean (SD) age for those who developed CS was 27.35 (8.42). For every unit increase in age, the probability of developing compartment syndrome decreased (OR: 0.94; 95% CI: 0.91-0.97). Thus, younger patients had greater probability of developing compartment syndrome following femoral fracture [Table 6].

Table 5. Risk of developing compartment syndrome based on gender

Gender	No. with CS (%)	No. without CS (%)	P-value	Probability (95% CI)
Female	1 (3.2)	142 (38)	-	-
Male	30 (96.8)	230 (61.8)	0.004	18.52 (2.50-137.31)

No: Number; CS: Compartment syndrome; CI: Confidence interval

Table 6. Risk of developing compartment syndrome based on age

Compartment Syndrome Diagnosis	Mean Age (Range; SD)	P-value	Probability (95% CI)
Yes	27.35 (18-63; 8.424)	<0.001	0.94 (0.905-0.971)
No	44.53 (18-98; 22.197)	-	-

SD: Standard Deviation; CI: Confidence Interval

*For every unit increase in age, the odds of developing compartment syndrome decreases

Injury severity score (ISS)

In our study sample, the median ISS for patients that developed CST was 10 (25th and 75th percentile: 9.0-20.0). However, the median ISS for patients who did not develop compartment syndrome was 13 (25th and 75th percentile: 9.0-16.0). No statistically significant difference was identified when comparing the median ISS of the two groups (P = 0.088) [Table 7].

Table 7. Risk of developing compartment syndrome based on Injury Severity Score (ISS)

Compartment Syndrome Diagnosis	Median ISS (25th-75th percentile)	P-value	Probability (95% CI)
Yes	10 (9.0 – 20.0)	0.880	1.0 (0.96-1.03)
No	13 (9.0 – 16.0)	-	-

ISS: Injury Severity Score; CI: Confidence Interval

Thigh Compartment Syndrome Diagnosis

Thigh compartment syndrome was observed in 31 patients who sustained a subtrochanteric or diaphyseal femoral fracture. The median time from injury to diagnosis was 21 hours. After diagnosis was established, median time to fasciotomy was one hour. After fasciotomies were performed, patients underwent a median of two additional surgeries until final wound closure. Eleven patients required split-thickness skin grafting (STSG) and the median time to STSG was six days. The remaining patients underwent primary skin closure and the median time to primary skin closure was 3.5 days [Table 8].

Table 8. Thigh compartment syndrome additional data

	Median (25th -75th Percentile)
Time to Development of CS (hours)	21.0 (11.0-40.0)
Time from CS Dx to Surgery (hours)	1.0 (0-1.0)
Number of Additional Surgeries	2.0 (0.75-2.0)
Time to STSG (days)	6.0 (4.8-9.5)
Time to Primary Skin Closure (days)	3.5 (0-6.3)

CS: Compartment Syndrome; Dx: Diagnosis; STSG: Split Thickness Skin Graft

Discussion

Acute compartment syndrome of the thigh is a rare entity and does not occur as frequently as compartment syndrome of the lower leg. The diagnosis is challenging due to the larger potential space within the thigh compartments, relatively more elastic fascia, and direct proximal contact to the hip musculature which allows extravasation of fluid out of the compartment and accommodates acute changes in intra-compartmental pressure.[7,8] The primary aim of this retrospective study was to identify a relationship between OA/OTA femoral fracture classification and the development of compartment syndrome. The secondary aim of this study was to identify relationships between patient characteristics and the development of CST.

In our study, patients with 32-C3 fractures had 15.43 greater probability of developing thigh compartment syndrome than those with 32-A1 fractures. In addition, those with subtrochanteric femoral fracture had 3.15 greater probability of developing CST when compared with diaphyseal femoral fractures. To our knowledge, this is the

first study identifying a relationship between femoral fracture patterns and the development of acute compartment syndrome of the thigh. There is limited evidence in the literature regarding thigh compartment syndrome. The currently published literature on CST only reflects a small portion of patients who develop CST in the setting of diaphyseal femoral fractures specifically. Remeder et al. performed a retrospective study in which 69 patients developed thigh compartment syndrome. However, only 9/69 had an ipsilateral femoral fracture and those patients had a statistically significant increase in the number of surgeries they underwent. In addition, the rate of major complications significantly increased if patients underwent greater than three surgeries.[9] Zuchelli et al. reported nine patients that developed compartment syndrome after blunt trauma, out of which only six suffered ipsilateral femoral fracture.[10] Furthermore, Mithofer et al. published a multicenter retrospective study in 2004 reporting 29 thigh compartment syndromes in which only 15 had associated ipsilateral femoral fracture.[1] Although there is limited evidence available about the development of thigh compartment syndrome following femoral fractures, this data suggests that these patients have higher morbidity than those that develop isolated compartment syndrome without associated femoral fracture.[1,9] Orthopaedic surgeons need to maintain a high index of suspicion in patients that present with femoral fractures, especially those with 32-C3 and subtrochanteric fracture patterns, in order to minimize the morbidity associated with the development of compartment syndrome through accurate diagnosis and timely surgical treatment.

The most common mechanism of injury in our cohort was motor vehicle accidents (51.6%) followed by gunshot wounds (35.5%). Patients who presented following a motor vehicle accident or gunshot wound had 5.90 and 14.87 greater probability of developing thigh CS, respectively. Many case reports have been published on rare incidences of thigh compartment syndrome including: atraumatic, vascular injuries, muscle contusion following a direct blow to the thigh, blunt trauma without associated femoral fracture, following extracorporeal life support (ECLS), and athletes following repetitive trauma.[8,11–16] This study found that high impact mechanisms such as motor vehicle accidents and gunshot wounds have a greater incidence of thigh compartment syndrome when compared with low impact blunt trauma, regardless of the presence of a femoral fracture. These results reflect what is present in the current literature, as supported by the data published by Ojike, Rameder, Zuchelli which is consistent with our findings.[5,9,10] Knab et al. published a case series of 10 patients with CST and found 60% of cases occurred in the setting of penetrating trauma 40% of cases developed in the setting of blunt trauma.[6] Among these patients, those who suffered from penetrating trauma had a statistically significant increased ICU admission rate and hospital length of stay (18.7 vs. 7 days).[6]

In our cohort, 30/31 patients who developed thigh compartment syndrome were male, with younger male patients having an increased probability of developing CST. This trend parallels the findings published by Verwiebe, et al. In their retrospective study, they found an association between CST and younger patients (mean age 34.8 years old).[17] this statistically significant difference could be attributed to the following two hypotheses. (1) Young men tend to develop a more robust thigh musculature. Thus, decreasing the potential space available to accommodate intra-compartmental pressure changes. (2) Men tend to participate in more risky and higher velocity/impact activities leading to a higher rate of injuries as a result of motor vehicle accidents and gunshot wounds.

Timely and accurate diagnosis is critical in order to minimize the morbidity associated with delayed treatment. In our 10 years long retrospective study, the median time for the development of thigh compartment syndrome was 21 hours from the time of admission. Following diagnosis, patients underwent fasciotomy within a median time of one hour. Thus, indicating that prompt treatment had been accomplished. Due to the soft tissue swelling associated with compartment syndrome, it is very difficult to accomplish primary closure of the wound at the index procedure. A median of two additional surgeries were performed following fasciotomy to accomplish primary skin closure (median: 3.5 days) or STSG application (median: 6.0 days). In our cohort, 11/31 (35.5%) patients required STSG application due to the inability to obtain primary skin closure. In a systematic review including 89 patients, Ojike et al. reported 26% patients requiring STSG following thigh compartment syndrome, similar to our findings.[5]

This study found no statistically significant difference in ISS between patients who developed CST compared to those who did not. Although there is a 3 point difference between the two groups, this finding is likely not clinically significant either based on existing literature. A severe ISS is considered between 8 and 15, which is the range where the median ISS of both cohorts fall.[18] additionally, there is no established Minimal Clinically Important Differences (MCID) for the ISS. In light of this gap in literature, the clinical impact of the ISS difference in the absence of statistical significance cannot be determinied. Future studies should focus on establishing an MCID for the ISS, including in the context of compartment syndrome.

Our study did not investigate the functional outcomes following diagnosis and treatment of thigh compartment syndrome. There is very limited data on patients' recovery following this devastating injury. Mithoefer et al. published a study on the functional outcomes following thigh compartment syndrome. This cohort reported outcomes at 62 months follow-up following surgical treatment. Full recovery of thigh-muscles strength was only observed in 5/18 patients. Long-term functional deficits were reported in 8/18 patients. In those patients that had persistent dysfunction, overall functional outcome scores were worst. Increased long-term functional deficits, persistent thigh-muscle weakness, and worse functional outcomes were associated with high ISS, ipsilateral femoral fracture, delayed time to decompression, age >30, and presence of

myonecrosis at time of fasciotomy.[19] Future studies should aim to identify the functional outcomes following thigh compartment syndrome and how the rehabilitation process could be optimized to minimize persistent dysfunction.

Our study has several limitations that need to be considered. Retrospective studies are limited in several ways. Our data was solely collected through the evaluation of medical records, making the study susceptible to incomplete and erroneous medical record information. Unfortunately, due to the retrospective nature of the study, no intra-compartmental measurements were available to confirm the diagnosis of compartment syndrome. However, thigh compartment syndrome was diagnosed based on clinical examination and surgical findings consistent with compartment syndrome such as outpouching of the muscle at the time of fascial release. Another limitation was that fracture classification systems are prone to some degree of subjectivity. In an attempt to combat this phenomenon, the femoral fracture classifications were performed blindly under the oversight of the senior author of this study. An additional limitation of this study is that no data was collected concerning recovery and functional outcomes following this injury. Also, preoperative comorbidities including BMI were not collected, and as such the role that preoperative medical history plays in the development of CST is not reflected in this paper. Future research should focus on this area to identify means to improve patients' quality of life and maximize functional outcomes.

To our knowledge, this is one of the more highly-powered retrospective studies evaluating thigh compartment syndrome following femoral fractures. The findings of this study contribute to the existing literature by helping to identify a relationship between fracture patterns and the development of thigh compartment syndrome, providing data for the orthopaedic surgeon to consider when evaluating fracture patterns on radiographs. Our study provides new and significant information regarding patient characteristics placing patients at higher risk for developing thigh compartment syndrome. As aforementioned, timely diagnosis is critical to preventing the devastating consequences following delayed treatment of thigh compartment syndrome.

Conclusion

Thigh compartment syndrome is a rare and difficult diagnosis to establish. Delayed treatment could lead to severe consequences and disability. Our study aimed to identify risk factors associated with the development of compartment syndrome in patients with femoral fractures. In our study, AO/OTA 32-C3 and subtrochanteric femoral fractures demonstrated greater probability for the development of thigh compartment syndrome. Patients who suffered from motor vehicle accidents and gunshot wounds were more likely to develop CST.

Finally, male and younger patients were significantly at higher risk for developing compartment syndrome following subtrochanteric and diaphyseal femoral fractures. These risk factors are important to keep in mind when evaluating patients with femoral fractures in an attempt to minimize delays in diagnosis and treatment of potential CST.

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Authors Contribution:

Dr. Rivera-Pintado, Dr. Patel, Dr. Hernandez, Dr. Hunter, Dr. Gloekler, Mrs. Tornberg, and Dr. Graf have met all COPE and ICJME requirements for authorship and have all made substantial contributions to the conception and design of the work, acquisition, analysis, and interpretation of the data, and the production of this work as well as reviewing the work for critically important intellectual content and data integrity.

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References

1. Mithöfer 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 :(425):223-9. doi: 10.1097/00003086-200408000-00032.
2. Schwartz 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(3):392-400.
3. Torlincasi AM, Lopez RA, Waseem M. Acute Compartment

Syndrome. In: StatPearls. tudy Guide from StatPearls Publishing, Treasure Island (FL), 2017.
4. Tillinghast CM, Gary JL. Compartment Syndrome of the Lower Extremity. In: Mauffrey C, Hak DJ, Martin III MP, eds.
136. doi:10.1016/j.injury.2009.03.016.
6. Knab LM, Abuzeid A, Rodriguez H, Issa N. Thigh compartment syndrome in urban trauma: bullets to blame, not collisions. J Surg Res. 2013; 185(2):748-752. doi:10.1016/j.jss.2013.07.003.
7. Riede U, Schmid MR, Romero J. Conservative treatment of an acute compartment syndrome of the thigh. Arch Orthop Trauma Surg. 2007; 127(4):269-275. doi:10.1007/s00402-006-0199-1.
8. Javedani PP, Ratnabalasuriar R, Grall KJH. Spontaneous Compartment Syndrome of the Thigh in the Absence of Trauma. J Emerg Med. 2016; 51(1):70-72. doi:10.1016/j.jemermed.2016.04.001.
9. Rameder P, Schmidt R, Machold W, et al. Epidemiology, treatment and outcome after compartment syndrome of the thigh in 69 cases – Experiences from a level I trauma centre. Injury. 2019; 50(6):1242-1246. doi:10.1016/j.injury.2019.04.001.
10. Zuchelli D, Divaris N, McCormack JE, et al. Extremity compartment syndrome following blunt trauma: a level I trauma center's 5-year experience. J Surg Res. 2017; 217:131-136. doi:10.1016/j.jss.2017.05.012.
11. Slade HJT, De Ridder K. A rare cause of acute compartment syndrome in the thigh: a case report. J Surg Case Rep. 2020; 2020(12):rjaa546. doi:10.1093/jscr/rjaa546.
12. Nooh A, Wang CK, AlAseem A, Harvey EJ, Bernstein M. Acute Thigh Compartment Syndrome due to an Occult Arterial Injury Following a Blunt Trauma: A Case Report. JBJS Case Compartment Syndrome. Springer International Publishing; 2019.
5. Ojike NI, Roberts CS, Giannoudis PV. Compartment syndrome of the thigh: A systematic review. Injury. 2010; 41(2):133-Connect. 2020; 10(1):e0506-e0506. doi:10.2106/JBJS.CC.18.00506.
13. Kreibich M, Czerny M, Benk C, Beyersdorf F, Rylski B, Trummer G. Thigh compartment syndrome during extracorporeal life support. J Vasc Surg Venous Lymphat Disord. 2017; 5(6):859-863. doi:10.1016/j.jvsv.2017.07.005.
14. Schimelpfenig S, Liddell T, Page E. A Case of Acute Compartment Syndrome of the Thigh Associated with Repetitive Athletic Trauma. S D Med. 2016; 69(12):553-555.
15. Uzel AP, Bulla A, Henri S. Compartment syndrome of the thigh after blunt trauma: a complication not to be ignored. Musculoskelet Surg. 2013; 97(1):81-83. doi:10.1007/s12306-011-0176-x.
16. Colosimo AJ, Ireland ML. Thigh compartment syndrome in a football athlete: a case report and review of the literature. Med Sci Sports Exerc. 1992; 24(9):958-963.
17. Verwiebe EG, Kanlic EM, Saller J, Abdelgawad A. Thigh Compartment Syndrome, Presentation and Complications. Bosn J Basic Med Sci. 2009; 9(1):S28-S33. doi:10.17305/bjbms.2009.2751.
18. Palmer C. Major trauma and the injury severity score--where should we set the bar? Annu Proc Assoc Adv Automot Med. 2007; 51:13-29.
19. Mithoefer K, Lhowe DW, Vrahas MS, Altman DT, Erens V, Altman GT. Functional outcome after acute compartment syndrome of the thigh. J Bone Joint Surg Am. 2006; 88(4):729-737. doi:10.2106/JBJS.E.00336.