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Original article

Association between open tibia fractures and acute compartment syndrome: a retrospective cohort study

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Abstract

Background: studies on the association of open tibia fractures and acute compartment syndrome (ACS) show confusing results, with some papers highlighting a positive association, and others failing to do so. The aim of this study was to determine if an open tibia fracture is at increased risk of ACS occurrence, when compared to a closed fracture.

Hypothesis: skin injury in the setting of an open tibia fracture does not prevent from ACS occurrence, because the energy transmitted to the limb during trauma may lead to soft tissue lesions, including skin lacerations and ACS.

Patients and Methods: 711 consecutive adult patients (mean age 44.6 years; 65.8% males) sustaining 725 tibia fractures between 01.01.2005 and 31.12.2009 were included in this retrospective study. The outcome measure was ACS. The following variables were assessed:

soft tissue condition, age, sex, low- vs. high-energy injury, type of fracture, associated contiguous skeletal injury. A logistic regression model was used and adjustment was performed for age and sex.

Results: ACS occurred in 10.4% of proximal intra-articular fractures, 10.4% of extra-articular fractures and 3.3% of distal intra-articular fractures, and in 8.7% of closed fractures, 7.8% of open Gustilo 1 fractures and 13.3% of open Gustilo 2 and 3 fractures. Open lesions were not associated with ACS when tibia fractures were considered as a whole. When stratifying by types of fractures, open Gustilo 2 and 3 lesions were associated with ACS in proximal intra-articular fractures (p=0.048). There was no association with closed or any type of open lesions for extra-articular fractures. There were not enough ACS cases among distal intra-articular fractures to draw conclusions.

Discussion: as ACS may occur with any type of open tibia fractures, clinicians should not be wrongly reassured by an open fracture, assuming that the wound would relieve the pressure inside the muscle compartments. There is a weak association between open Gustilo 2 and 3 lesions and ACS in proximal intra-articular fractures only. These findings are important for surgeons treating these injuries, especially by intubated, sedated or obtunded patients.

Level of Evidence: III; retrospective diagnostic study.

Keywords: proximal tibia fracture; tibial shaft fracture; distal tibia fracture; acute compartment syndrome; open fracture

Abbreviations:

ACS: acute compartment syndrome

ICP: intra-compartmental pressure

1.Introduction

Tibia fractures are common. Proximal tibia fractures represent 1% of all fractures, tibial shaft fractures 2%, and distal tibia fractures 0.5%[1]. Tibia fracture spectrum ranges from low-energy undisplaced to high-energy multifragmentary or displaced fractures[2-4]. The energy transmitted to the limb during trauma may also lead to soft tissue lesions, including skin lacerations (open fractures) and acute compartment syndrome (ACS)[2,3,5-7]. Risks of ACS reach 12% for overall tibial plateau fractures (even 53% for high-energy subtypes)[8-16] and 11.5% for tibial shaft fractures[8,12,13,17-19]. The risk seems lower for pilon tibial fractures, with two papers reporting an occurrence rate of 2% and another of 12.5%[8,13,20].
Studies on the association of open tibia fractures and ACS show confusing results. For proximal intra-articular fractures, a linear association between ACS occurrence and severity of skin lesions was reported in the univariate analysis of a recent study[11], while another publication did not find any association[16]. Similarly, two old publications on diaphyseal fractures reported an association between open fractures and occurrence of ACS, with open fracture severity directly proportional to ACS incidence[5,21], while other investigations did not find any association[13,17-19]. Finally, a non-evidence-based statement from a case report evoked soft-tissue damage as a potential risk factor for ACS occurrence after pilon tibial fractures[7]. This weak evidence may not be sufficient to definitively oppose a widespread theory from the past, which assumed that the skin wound of an open fracture relieves intra-compartmental pressure (ICP) and decreases ACS risk.

The aim of this study was to determine if open tibia fractures are at increased risk of ACS occurrence when compared to closed lesions. The working hypothesis was that skin injury in the setting of an open tibia fracture does not prevent from ACS occurrence, because the energy transmitted to the limb during trauma may lead to soft tissue lesions, including skin lacerations and ACS.

2. Materials and Methods

Before initiation of the study, approval was obtained from the institutional research ethics board.

2.1 Patients

This retrospective cohort study was performed in an academic medical center serving 500,000 inhabitants. All consecutive patients admitted with a tibia fracture were identified using the institutional hospitalization diagnoses database. Inclusion criteria were: 1) an intra- or extra-articular proximal tibia fracture (AO/OTA classification codes 41A2, 41A3, 41B, 41C), a tibial shaft fracture (AO/OTA 42), or an intra- or extra-articular distal tibia fracture (AO/OTA 43)[22]; 2) traumatic event causing the fracture; 3) hospital admission between 01.01.2005 and 31.12.2009; 4) definitive treatment at the authors' institution; and 5) age >16 years old at the time of injury. At this point, 770 fractures were eligible. Exclusion criteria were: 1) presentation to the authors' institution >24 hours after trauma (n=28); 2) pathological or spontaneous fracture (n=1); 3) peri-implant fracture (n=10); 4) open growth plates (n=4); 5) transfer to another institution for definitive treatment (n=1); 6) above or below the knee amputation within 24 hours after trauma (n=0); and 7) death within 24 hours after trauma (n=1). Finally, 725 fractures in 711 patients were included in the analysis.

2.2 Methods

The outcome was development of ACS leading to fasciotomy. Every patient was clinically examined focusing on ACS signs and symptoms at admission and during every preoperative and postoperative visit, as well as during surgery. Using a previously published method[11,19], monitoring of ICP was not routinely used, but only in selected patients with equivocal clinical signs and those intubated, sedated or obtunded[23-25]. Open dual-incision four compartments fasciotomy was performed when patients had clinical signs of ACS and/or pathological ICP values (ICP >30 mmHg or a difference <30 mmHg between diastolic blood pressure and ICP)[18,24,26-28]. Muscle bulging or suffering was evaluated at the time of fasciotomy. Definition of ACS was pathological ICP values before fasciotomy and/or

presence of muscle bulging or suffering at the time of fasciotomy.

2.3 Methods of assessment

The main variable of interest (closed or open fracture with Gustilo classification[29,30]) was extracted from patients' charts. For statistical analysis, fractures were considered in three categories: closed, Gustilo type 1, and Gustilo type 2 and 3.

Other variables (age, sex, mechanism of injury, type of fracture) were extracted from patients' charts. Mechanism of injury was further classified as either "fall from own height" or "other" in order to differentiate low- and high-energy trauma. Fractures were classified following AO/OTA[22] and stratified into three groups: proximal intra-articular fractures (AO/OTA 41B and C), extra-articular fractures (AO/OTA 41A2 and A3, 42 and 43A) and distal intra-articular fractures (AO/OTA 43B and C). The presence of an associated contiguous skeletal injury was sought, as this variable was highlighted as a risk factor for ACS occurrence in two recent publications[11,19]. A contiguous skeletal injury was defined as followed: 1) for proximal intra-articular fractures: either a tibial shaft or pilon fracture (AO/OTA 42 or 43)[22] or a dislocation of both medial and lateral femoro-tibial joint lines[11]; 2) for extra-articular fractures: either a proximal or distal tibia fracture (AO/OTA 41 or 43)[22]; for distal intra-articular fractures: either a tibial plateau or shaft fracture (AO/OTA 41 or 42)[22].

2.4 Statistical analysis

Patient and fracture characteristics with and without ACS were compared using frequency distributions for discrete variables and mean and standard deviation for continuous variable. To evaluate the association of the covariates with ACS, a logistic regression analysis was used to obtain univariate odds ratios and 95% confidence intervals. Age was dichotomized at approximate midpoint (age < vs. ≥45 years).

Because the risk of ACS may be related to the energy dissipated during the impact, and because men and younger patients may be more likely to sustain high-energy impacts, each covariate was then separately adjusted for age and sex using the logistic regression analysis.

Statistical significance was defined as $p<0.05$.

IBM® SPSS® Statistics version 19.0.0 software (IBM SPSS, Chicago, IL) was used for statistical analysis.

3. Results

Tibia fractures occurred at a mean age of 44.6±17.4 years and among 477 (65.8%) men. Overall, ACS occurred in 67 (9.2%) cases; 28 out of 269 (10.4%) proximal intra-articular fractures, 35 out of 336 (10.4%) extra-articular fractures and 4 out of 120 (3.3%) distal intra-articular fractures. Diagnosis was made 49 times using ICP, and 18 times using only clinical examination. Diagnosis occurred 30 times preoperatively (all surgeries performed within 24 hours after admission), 19 times peroperatively (all surgeries performed within 28 hours after admission), and 18 times postoperatively (between day 0 and day 9 after surgery).

Table 1 describes patients' characteristics. There were 49 ACS out of 563 closed fractures (8.7%), 5 ACS out of 64 open Gustilo 1 fractures (7.8%) and 13 ACS out of 98 open Gustilo 2 and 3 fractures (13.3%).

Univariate analysis and analysis after adjustment for age and sex did not recognize any soft tissue condition as associated with ACS occurrence when tibia fractures were considered as a whole (Table 2).

When stratifying by fracture types (Table 3), open Gustilo 2 and 3 injuries were associated with ACS occurrence in proximal intra-articular fractures. No association with closed or any type of open injuries was highlighted for extra-articular fractures. There were not enough ACS cases (four) among distal intra-articular fractures to draw conclusions.

4. Discussion

This study demonstrated that skin opening in the setting of an open tibia fracture did not prevent from ACS occurrence. This finding could be anticipated, as one publication showed that a too short skin incision could lead to insufficient compartment decompression despite

complete fasciotomy[31]. Furthermore, a cadaveric study concluded that incomplete fasciotomy (one quarter to one half of the entire muscle compartment length) was insufficient to significantly decrease ICP in an induced acute anterior compartment syndrome model[32]. Both publications investigated situations comparable to an open fracture, where the skin opening does not correspond to a complete dermotomy along the entire muscle compartment and does not imply that all the four muscle compartments are completely released by the traumatic wound. The present study confirms that clinicians should not be wrongfully reassured by an open fracture, assuming that the skin lesion relieves ICP, as ACS may still develop. Skin wounds close to a fracture should not be underestimated but recognized as a sign of major trauma to the underlying fascia and muscles[11,19].

Because ACS occurrence rates and highlighted risk factors (young age, male sex, high-energy trauma, contiguous skeletal injury) match previous reports[8-20,33], the study cohort is assumed to closely represent the habitual tibia fracture spectrum, and results might be generalized to most tibia fractures. The ACS rate in distal intra-articular fractures was statistically lower than in other tibia fractures. The explanation for this finding is not clear but might be related to a lower muscle mass around distal tibia, less prone to absorb trauma energy[19], and to possible energy dissipation along the tendons into the foot. This point would need a dedicated study for definitive clarification.

In the analysis without stratification by fracture type, there was no association between ACS occurrence and soft tissue condition. In the analysis by fracture types, ACS occurrence was associated with open Gustilo 2 and 3 injuries in proximal intra-articular tibia fractures only, with a weak significance level (p=0.048). One recent paper reported a significant linear association between occurrence of ACS and severity of open fracture in the univariate analysis, which failed to be confirmed after adjustment for age and sex[11]. Another paper did not show any association between open fracture and ACS even in the univariate analysis[16]. Due to this weak evidence, one cannot definitively conclude that an open skin lesion is associated with a higher risk of ACS in proximal intra-articular tibia fractures.

However, the physician in charge should be aware of these findings and should actively look for signs and symptoms of ACS when treating this type of fractures. No association with closed or any type of open injuries was highlighted for extra-articular tibia fractures. This finding is in line with previously published research[13,17-19] despite two older publications recognizing open tibial shaft fractures as associated with the occurrence of ACS, with open fracture severity directly proportional to ACS incidence[5,21]. In this fracture type also, the physician in charge should be aware of these findings and should actively look for signs and symptoms of ACS. There were not enough ACS cases among distal intra-articular tibia fractures to draw any conclusions. The association of ACS with open fractures of the pilon tibial has not been investigated in a well-conducted study yet. To the best of the authors' knowledge, there is only one case-report citing increased soft tissue damage as a potential risk factor for ACS occurrence after pilon tibial fracture; however in this paper, this statement was not evidence-based and it was not specified if increased soft tissue damage included open fractures[7].

Despite being the largest series to date analyzing the association between soft tissue injury and ACS in tibia fractures, this paper suffers several limitations. First, this study was prone to biases inherent to its retrospective design and to possible inexactitudes in patients' charts. For example, injury mechanisms different from fall from own height were arbitrarily classified as high-energy trauma, even though some road traffic accidents or sports injuries might not necessarily represent a high-energy trauma. Accurate information on vehicle speed or type of sports injury might be difficult to retrospectively extract from patients' charts to precisely determine energy release. Secondly, ICP measurements were performed only on a subset of patients, introducing the possibility of false positive or negative diagnosis. However, there were no clinical records suspect of late ACS sequelae in the hospitalization or follow-up charts of patients that were not diagnosed with ACS, and every patient who underwent fasciotomy had pathological ICP values, and/or muscle bulging or suffering. Moreover, we did not receive any report on potential missed ACS for patients that had their follow-up

performed elsewhere. Thus, we can reasonably assume that the number of missed ACS is close to zero. Thirdly, the influence of the fixation method was not taken into account in our analysis[17]. Finally, the tibia fracture stratification does not strictly follow the AO/OTA classification. However, we felt that an AO/OTA 41A2 or A3 fracture was closer to an AO/OTA 42 fracture than to an AO/OTA 41B or C fracture in terms of fracture line anatomy and absence of articular involvement.

5. Conclusions

Clinicians should not be wrongfully reassured by an open fracture, assuming that the skin laceration would relieve the pressure inside the muscle compartments, as ACS may still develop. Skin wounds close to a fracture should not be underestimated but recognized as a sign of major trauma to the underlying fascia and muscles. This is especially true for open Gustilo type 2 and 3 lesions in proximal intra-articular tibia fractures. These findings must raise the level of suspicion of any surgeon treating these injuries, particularly by intubated, sedated or obtunded patients.

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Contribution of authors: AG: study conception and design, data acquisition and interpretation, manuscript draft and critical revision; LW, PB, GC: data acquisition and interpretation, manuscript critical revision; MZ: data interpretation, manuscript critical revision; AIG: study conception and design, statistical analysis, data interpretation, manuscript draft and critical revision.

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TABLE 1 Demographics, injury characteristics and clinical and radiographic factors of the 711 study patients with 725 fractures

	ACS absent, n=658 (90.8%)	**ACS present, n=67 (9.2%)**
Age (years)	45.2±17.6	37.1±12.8
Age <45 years, n (%)	347 (52.7%)	54 (80.6%)
Male sex, n (%)	419 (63.7%)	58 (86.6%)
High-energy trauma, n (%)	484 (73.6%)	67 (92.5%)
Closed fracture, n (%)	514 (78.1%)	49 (73.1%)
Open fracture Gustilo 1, n (%)	59 (9.0%)	5 (7.5%)
Open fracture Gustilo 2 & 3, n (%)	85 (12.9%)	13 (19.4%)
Proximal intra-articular fractures, n (%)	241 (36.6%)	28 (41.8%)
Extra-articular fractures, n (%)	301 (45.7%)	35 (52.2%)
Distal intra-articular fractures, n (%)	116 (17.6%)	4 (6.0%)
Associated contiguous skeletal injury, n (%)	11 (1.7%)	12 (17.9%)
No associated contiguous skeletal injury, n (%)	647 (98.3%)	55 (82.1%)

ACS: acute compartment syndrome. *Proximal intra-articular fractures:* AO/OTA 41B and C. *Extra-articular fractures:* AO/OTA 41A2 and A3, 42 and 43A. *Distal intra-articular fractures:* AO/OTA 43B and C.

TABLE 2 Association between variables of interest and occurrence of acute compartment syndrome

	Univariate analysis		**Each variable adjusted for age and sex***	
	OR (95% CI)	**P value**	**OR (95% CI)**	**P value**
Age <45 years	3.72 (1.99-6.95)	**<0.001**	-	-
Male sex	3.68 (1.79-7.55)	**<0.001**	-	-
High-energy trauma	4.46 (1.76-11.27)	**0.002**	2.81 (1.09-7.26)	**0.033**
Soft tissue condition				
Closed fracture	Reference		Reference	
Open fracture Gustilo 1	0.89 (0.34-2.32)	0.810	0.74 (0.28-1.97)	0.551
Open fracture Gustilo 2 & 3	1.60 (0.84-3.08)	0.156	1.30 (0.67-2.56)	0.440
Fracture type				
Proximal intra-articular fracture	Reference		Reference	
Extra-articular fracture	1.00 (0.59-1.69)	0.998	0.80 (0.46-1.37)	0.411
Distal intra-articular fracture	0.30 (0.10-0.87)	**0.026**	0.23 (0.08-0.68)	**0.008**
Associated contiguous skeletal injury	12.83 (5.41-30.42)	**<0.001**	9.33 (3.80-22.92)	**<0.001**

*Each variable was adjusted for age (<45 years vs. ≥45 years) and sex (male vs. female)

OR: odds ratio. *95% CI*: 95% confidence interval. *Proximal intra-articular fractures:* AO/OTA 41B and C. *Extra-articular fractures:* AO/OTA 41A2 and A3, 42 and 43A. *Distal intra-articular fractures:* AO/OTA 43B and C. *Reference*: OR and 95% CI for soft tissue conditions and fracture types were obtained by comparison with an arbitrary reference, which was a closed fracture and a proximal intra-articular fracture respectively.

TABLE 3 Association between soft tissue condition and occurrence of acute compartment syndrome, by fracture types

Soft tissue condition	**Proximal intra-articular fracture** **OR (95% CI); P value**	**Extra-articular fracture** **OR (95% CI); P value**	**Distal intra-articular fracture** **OR (95% CI); P value**
Closed fracture	Reference	Reference	*
Open fracture Gustilo 1	4.07 (0.75-22.23); 0.105	0.47 (0.13-1.62); 0.233	*
Open fracture Gustilo 2 & 3	3.39 (1.01-11.42); **0.048**	0.79 (0.31-1.62); 0.628	*

*There were only four cases of acute compartment syndrome among distal intra-articular fractures, making statistical analysis unreliable.

Proximal intra-articular fractures: AO/OTA 41B and C. *Extra-articular fractures:* AO/OTA 41A2 and A3, 42 and 43A. *Distal intra-articular fractures:* AO/OTA 43B and C. *OR*: odds ratio. *95% CI*: 95% confidence interval. *Reference*: OR and 95% CI for soft tissue conditions were obtained by comparison with an arbitrary reference, which was a closed fracture.