Original Article

Comparative accuracy assessment of the Gustilo and Tscherne classification systems as predictors of infection in open fractures[☆]

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ABSTRACT

Objective: The aim of this study is to analyze the accuracy of the two classification systems for open fractures most commonly used in current medical practice, Gustilo and Tscherne, as predictors of infection.
Methods: A retrospective observational study was performed, including 121 patients suffering from open fracture of the appendicular skeleton treated at an emergency hospital. The fractures were classified according to Gustilo and Tscherne systems during the initial treatment, and ratings were subsequently confirmed or rectified during hospitalization. Sensitivity, specificity, positive and negative predictive values, and accuracy were calculated according to each classification adopted.
Results: The results of this study demonstrated that both classifications of Gustilo and Tscherne are associated with the clinical outcome of infection in open fractures. The Gustilo classification achieved sensitivity of 76.7%, specificity of 53.8%, and accuracy of 59.5%. Tscherne's classification had a sensitivity of 56.7%, specificity 82.4%, and accuracy of 76.1%.
Conclusion: The Tscherne system showed better accuracy, including specificity as a predictor of infection in open fractures, when compared with the Gustilo system.

Análise comparativa da acurácia das classificações de Gustilo e Tscherne como preditoras de infecção em fraturas expostas

RESUMO

Objetivo: Analisar comparativamente a acurácia dos dois sistemas para classificação de fraturas expostas mais usados na prática médica atual, Gustilo e Tscherne, como preditores de infecção nas fraturas expostas.
Métodos: Foi feito um estudo observacional retrospectivo com 121 indivíduos acometidos por fratura exposta do esqueleto apendicular atendidos em uma unidade de emergência

hospitalar. As fraturas expostas foram classificadas segundo os dois sistemas durante o atendimento inicial; as classificações eram posteriormente confirmadas ou retificadas durante o internamento. Foram calculados sensibilidade, especificidade, valores preditivos positivos e negativos e acurácia, segundo cada classificação adotada.

Resultados: Os resultados demonstraram que ambas as classificações, de Gustilo e de Tscherne, apresentam associação com o desfecho clínico infecção em fraturas expostas. A classificação de Gustilo obteve sensibilidade de 76,7%, especificidade de 53,8% e acurácia de 59,5%. A classificação de Tscherne obteve sensibilidade de 56,7%, especificidade de 82,4% e acurácia de 76,1%.

Conclusão: O sistema de classificação de Tscherne demonstrou maior acurácia, apresentou melhor especificidade como preditor de infecção em fraturas expostas quando comparado com o sistema de Gustilo.

Introduction

Open fractures of long bones occur with an incidence of 11.5 to 30.7 per 100,000 people per year.[1,2] In the United States, it is estimated that such fractures represent an annual cost of USD 230 million, which indicates the high socioeconomic impact of these injuries.[3] Open fractures occur most frequently in the tibia, its prevalence ranging from 20% to 40% of the cases,[1,4–7] followed by those occurring in the femur (12%), metacarpals, and ulna.[1,4]

The initial management of open fractures has been based on the same principles for 60 years,[7] and include surgical cleaning and debridement, wound closure, antibiotic therapy, and fracture fixation. The main goals of treatment include avoiding infection and re-establishing function.[1–7] In clinical practice, the orthopedist needs to establish different protocols, being more aggressive in cases of fractures with a higher chance of infection.[5,7–10] Therefore, stratification of the various fractures according to their degree of risk is paramount.[7,10]

The open fracture classification system most used in clinical practice is that proposed by Gustilo,[11] with its subsequent modification by Gustilo et al.[12] This system is based on the size of the skin lesion, the degree of contamination, the capacity of bone coverage, and the vascular lesion of the limb. The classification of Tscherne and Gotzen[13] was proposed for closed and open fractures, and takes into account the lesion of adjacent soft tissue, regardless of the size of the skin lesion. More detailed classification systems have also been proposed, such as that of the Arbeitsgemeinschaft für Osteosynthesefragen (AO) group[14] and the Orthopedic Trauma Association (OTA)[15]; however, these are still not widely used in orthopedic practice.

The prognosis of open fractures in general and specifically in relation to the infection outcome has dramatically improved since the Gustilo and Tscherne classification systems were elaborated. However, these two most commonly used systems date back over 30 years. Recently, Gustilo's classification has been criticized regarding its validity and reproducibility,[16–19] whereas the accuracy of the Tscherne's system has not yet been adequately validated.[8,9]

To be scientifically sound and justify their widespread use, systems for classifying open fractures must be reliable, reproducible, clinically relevant, and validated. Nonetheless, the data in the literature demonstrate the need to confront the prognostic accuracy of the two main classification systems in force, especially regarding the infection outcome.[8,9] Therefore, the present study is aimed at comparing the accuracy of the Gustilo and Tscherne classifications as predictors of infection in open fractures, and to discuss the use of both systems.

Material and methods

A retrospective observational study was conducted based on data from the hospital's orthopedic department. The target population was represented by patients admitted to the hospital who presented open fractures of the appendicular skeleton. The study assessed all patients admitted to the ward in 2009 and 2010. The research protocol was submitted to and approved by the Institution's Research Ethics Committee (opinion No. 121/2009).

The study included all patients who were admitted in the adult emergency department of the hospital with a diagnosis of open fracture and were treated according to the standardized protocol established at the Medical Service. The following were excluded: open fractures treated initially in other hospitals; open fractures of the axial skeleton (face, skull, thorax, spine); patients who did not remain in the hospital for at least eight days after the initial surgical procedure, due to death, discharge, or transfer, which implied in loss to follow-up, and patients with incomplete records. Patients with polytrauma or more than one fracture per anatomical segment were also excluded.

The calculated sample size was 94 patients. This number was based on the infection prevalence of 28% in open tibial fractures, using an alpha value of 0.05 and a sample error of 0.1.[8] The sample size obtained was 78 individuals; this number was increased by 20% to compensate for eventual losses, for a total of 94 patients. In the present study, the sample was larger than that estimated, since it had 121 individuals, increasing the statistical power.

All patients were treated in accordance to the previously established surgical protocol of the orthopedic department

of the hospital. This protocol includes initial evaluation of the patient; and surgical treatment is performed as soon as possible for thorough debridement and cleansing with a minimum of 10 liters of saline solution. During debridement, all tissues that are devitalized, including skin, muscle, and bone, are carefully removed. The fracture is stabilized at the discretion of the orthopedic surgeon; preference is given to internal fixation for Gustilo type I and II fractures, while external fixation is the method of choice for other fractures or for cases with a delay of more than 12 hours in the initial treatment. Gustilo type III B or C lesions were managed with secondary cutaneous coverage: later after a second look or evaluation for plastic surgery. After this immediate management, the patient is referred for treatment in the ward, and intravenous antibiotic therapy is maintained for a minimum of eight days, counting from the initial care.

All patients referred from the surgical operating rooms to the orthopedic department are evaluated clinically and through a standardized chart with clinical and sociodemographic data. This evaluation is complemented and reviewed during the patient's ward stay, until discharge from hospital. For the purpose of the study, the medical records and their respective standardized charts were analyzed. The main variables considered were: time between injury and surgical procedure; trauma type, location, and characteristics; severity of the open fracture, classified by Gustilo criteria[11,12]; severity of soft tissue involvement, classified by Tscherne criteria[13]; type of fracture stabilization (external or internal); and closure of the wound (primary or maintained open).

The outcome variable was the presence or absence of early superficial or deep infection during the patient's hospitalization or up to 15 days after the initial surgery, through an outpatient evaluation. At this Medical Service, open fractures are not routinely cultured for diagnosis of infection, because these types of trauma have some degree of contamination that does not necessarily evolve to acute infection[4,8,9]; therefore, this measure avoids a possible overestimation of the outcome. Cultures are only done in cases of a clinical suspicion of infection; in these situations, samples are always collected during surgical debridement, using fragments collected from the deep tissue of the wound.[9,20,21]

Early infection was determined according to the criteria by Willeneger et al.[20] and Matos et al.,[8,9] who classified early post-traumatic infections as those that manifest up to two weeks after the initial trauma and late infections, those that are observed after this period. According to these criteria, lesions that presented inflammatory characteristics with presence of necrotic tissue with purulent secretion (whether superficial or deep), associated or unassociated with fever, leukocytosis, and increased erythrocyte sedimentation rate, were considered to be infected.[8,9,21]

As a routine of the HGRS Orthopedics Department, all patients treated for open fractures who evolve without infection are discharged after one week of hospitalization; in cases with signs of infection, patients remain hospitalized for an undetermined period. For this reason, the last assessment of patients who were discharged before 16 days was made at the outpatient clinic one week after discharge, in accordance with the routine protocol of the Department.

The analytical part of the study consisted of classifying the patients using the Gustilo and Tscherne classification. Both classifications were performed by the on-call orthopedists responsible for the initial care and the patient's first surgical procedure. The information was obtained from the medical record and from the standardized form attached to the medical record. After a visit to the ward accompanied by the head of the Department, the classifications were confirmed or rectified by agreement of at least two orthopedists from the ward. After classification, patients were grouped according to the outcome variable, namely, presence or absence of infection. Group 1 included those who evolved without infection and group 2, those who presented infection.

The global data were presented as frequency distribution tables for discrete variables or as means and standard deviations for continuous variables. Crossing the Gustilo and Tscherne classifications for each patient with the infection outcome allowed the authors to infer the ability for each classification of predicting the outcome. Sensitivity, specificity, positive and negative predictive values, accuracy, and kappa value were calculated according to the classification adopted. The statistical difference between the groups was assessed using the chi-squared test or Fisher's test for discrete data, or the *t*-test for continuous data, always adopting 5% as a level of significance.

Results

A total of 213 medical records were evaluated; 92 (17.9%) were rejected in accordance with the exclusion criteria. The study sample was comprised of 121 patients with open fractures: 78 (64.5%) presented fractures in the lower limb; 37 in the leg (30.6%), 27 in the foot, six in the femur, four in the ankle, and four in the patella. Upper limb fractures were observed in 43 cases (35.5%), 25 in the forearm (20.7%), 16 in the humerus, and two in the clavicle.

The results of the infection outcome in the present sample indicate that fractures classified as Tscherne type IV and V had a high infection rate (50% and 67%, respectively), as did those classified as Gustilo type IIIA, IIIB, and IIIC (26%, 41%, and 50%, respectively). These data are shown in Table 1.

Both classifications have a good ability to predict the outcome of infection in the most severe lesions. In the Tscherne

Table 1 – Outcome (infection) percentage according to the Gustilo and Tscherne classifications.

Classification	Total number	Outcome (%)	p
Gustilo	121	–	0.021
I	11	1 (9.1%)	
II	45	6 (13.3%)	
IIIA	27	7 (25.9%)	
IIIB	32	13 (40.6%)	
IIIC	6	3 (50%)	
Tscherne	121	–	<0.001
I	37	5 (13.5%)	
II	51	8 (15.7%)	
III	30	15 (50%)	
IV	3	2 (66.7%)	

Table 2 – Gustilo and Tscherne classification according to the ability to predict infection.

Classification	Total	With infection (%)	Without infection (%)	p
Gustilo I and II	56	7 (12.50)	49 (87.50)	0.004
Gustilo III	65	23 (35.38)	42 (64.62)	
Tscherne I and II	88	13 (14.77)	75 (85.23)	<0.001
Tscherne III and IV	33	17 (51.51)	16 (48.49)	

Table 3 – Accuracy parameters of the Gustilo and Tscherne classifications.

Parameter	Gustilo Value (95% CI)	Tscherne Value (95% CI)	p
Sensitivity	76.7% (57.7–90.1)	56.7% (37.4–74.6)	0.003
Specificity	53.8% (43.1–64.4)	82.4% (73.1–89.6)	<0.001
PPV	35.4% (23.9–48.2)	51.5% (33.5–69.2)	
NPV	87.5% (75.9–94.8)	85.2% (76.1–91.9)	0.015
Accuracy	59.5% (47.7–70.7)	76.1% (64.8–91.9)	0.033
Kappa	24.1%(12.4–35.7)	37.8% (18.1–57.5)	

NPV, negative predictive value; PPV, positive predictive value.

classification, a 52% rate of infection was observed in the most severe lesions; in the Gustilo classification, this rate was 35%. Table 2 presents the values referring to the ability of each classification to predict infection.

The accuracy parameters observed in each classification are shown in Table 3. The Gustilo classification presented a sensitivity of 76.7%, specificity of 53.8%, and accuracy of 59.5%. The Tscherne classification presented sensitivity of 56.7%, specificity of 82.4%, and accuracy of 76.1%.

Discussion

The results of the present study demonstrated that both the classifications of Gustilo and Tscherne are associated with the clinical outcome of infection in open fractures. However, the comparative findings of sensitivity, specificity, and accuracy indicated that, for infection prediction, the classification proposed by Tscherne was more accurate, and was superior to the Gustilo classification for assessing infection outcome in open fractures.

The findings indicate that, when using the Tscherne system, the orthopedist will overestimate probable infections and will treat more aggressively some patients who would not progress to infection; however, practically only patients who would evolve without infection will be treated less aggressively. In Gustilo's classification, there is little overestimation, but almost half of those who would evolve with infection will be treated less aggressively and, therefore, inadequately.

Although the Tscherne system was more accurate than that of Gustilo, the latter was more linear in terms of the prevalence of the infection outcome when each subtype was considered in isolation. Tscherne's classification showed a very similar prevalence of infection when comparing types I and II (13.5% and 15.7% respectively) and types III and IV (50% and 66.7%, respectively), while the Gustilo classification presented the infection outcome with increasing percentages at more regular intervals, as shown in Table 1. This may have

been due to the low number of individuals classified as types IIIC of Gustilo and IV of Tscherne. In turn, when the Tscherne classification was subdivided into only two groups (types I/II and III/IV), infection was observed in 14.77% of the cases in the first group and in 51.51% of the cases in the second group (p < 0.001). When the Gustilo classification was subdivided into two groups (types I/II and IIIA/B/C), infection was observed in 12.5% of the cases in the first group and in 35.38% of the cases in the second group (p = 0.004). Thus, the Tscherne classification also appeared to be more efficient when milder cases are compared with more severe cases.

The Gustilo classification has good validity for the prognoses of infection, nonunion, and other complications.[22] Its good association with infection has been used for decades to help improve treatment, antibiotic therapy, fracture fixation type, and cutaneous coverage protocols.[23,24] Nonetheless, two characteristics are fundamental for adopting a classification as gold standard to determine the appropriate type of fracture and foretell infection: reliability and accuracy.

An important factor to be considered is that the reliability of the Gustilo classification is not considered to be excellent. Brumback and Jones,[16] studying images of open fractures presented to 245 orthopedists, reported an interobserver agreement of only 60%, that is, moderate to poor. In another important study, the agreement was 53%; experienced orthopedists and residents presented the same ability to discriminate using the system.[19] The fact that the Gustilo classification presents only moderate agreement raises serious doubts on this being the best model to predict infection in open fractures.

In turn, the reliability of the Tscherne classification for open fractures has not yet been assessed in the orthopedic literature, and its validity has rarely been addressed. Gaston et al.[25] evaluated various classifications for tibial fractures in search of good predictors of prognosis; in that study, the Tscherne classification was not associated with deep infection, but was associated with functional prognosis. Matos et al.[8] presented a study in which the Gustilo classification was associated with the infection prognosis, with odds ratio of 4.3. The Tscherne classification, in turn, was shown to have the strongest factor associated with the infection outcome, with odds ratio of 8.1. In that study, Tscherne type I fractures presented a 0% infection rate; Tscherne II, 20.7%; Tscherne III, 63.6%; and, finally, Tscherne type IV fractures had an infection prevalence of 100%. These data, while requiring confirmation by other studies, indicate that the Tscherne classification may be a promising and perhaps more efficient alternative to the Gustilo classification.[8,9]

A possible limitation of the present study was the fact that the sample included open fractures from different regions of the skeleton. The behavior of each lesion depends on multiple characteristics, including the anatomical region affected. Another limitation is the fact that this was a retrospective study, its data being collected from medical charts. Studies with this characteristic tend to overlook important information; many variables that could interfere with the result could not be included in the analyses. For the same reason, the classifications could not be reviewed by the authors. Additional studies will be needed to assess the behavior of anatomically

similar fractures, including a new set of clinical variables to confirm the present findings.

Conclusion

The Tscherne classification system showed greater accuracy, presenting better specificity as a predictor of infection in open fractures when compared with the Gustilo classification.

Conflicts of interest

The authors declare no conflicts of interest.

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