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Risk Factors for Open Malleolar Fractures: An Analysis of the National Trauma Data Bank (2007 to 2011)

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ABSTRACT

A limited number of studies have described the epidemiology of open fractures, and the epidemiology of open ankle fractures is not an exception. Therefore, the risk factors associated with open ankle fractures have not been extensively evaluated. The frequencies and proportions of open ankle fractures among all the recorded malleolar fractures in the US National Trauma Data Bank data set from January 2007 to December 2011 were analyzed. Clinically relevant variables captured in the data set were also used to evaluate the risk factors associated with open ankle fractures, adjusting for other covariates. The entire cohort was further subdivided into "lower" and "higher" energy trauma groups and the same analysis performed for each group separately. We found that a body mass index of >40 kg/m^2 and farm location were risk factors for open ankle fractures and impaired sensorium was protective against open ankle fractures. In the "lower energy" group, male gender, alcohol use, peripheral vascular disease, other injuries, and injury occurring at a farm location were risk factors for open fractures. In the "higher energy" group, female gender, work-related injury, and injury at a farm or industry location demonstrated statistically significantly associations with open fractures.

A limited number of studies have described the epidemiology of open fractures (1). Even less information is available for site-specific open fractures, such as fractures of the ankle joint (2). Therefore, the risk factors associated with open ankle fractures have not been extensively evaluated. Furthermore, anecdotal references to risk factors could be subject to selection bias from how the open ankle fractures were triaged and managed. In addition, the presentation patterns of open fractures can depend greatly on hospital location, patient educational status, and payer structure. Although understanding the epidemiology of open ankle fractures might not directly affect operative planning, the information is useful in preventive medicine and health services research and in developing health care policies and guiding standards of practice. Educational curricula can also be developed for those interested in pursuing careers with an emphasis on trauma.

The American College of Surgeons publishes the National Trauma Data Bank (NTDB) data set each year from >900 participating trauma centers in the United States. Using the data set from January 2007 to December 2011, we evaluated the risk factors associated with open ankle fractures among all ankle fractures.

Patients and Methods

The NTDB data set covering admission years January 2007 to December 2011 was used for analysis. From the data set, malleolar fractures were identified using the International Classification of Diseases codes listed in Table 1. Pilon and stress fractures were excluded. Each patient admission was considered as 1 incident. When both open and closed ankle fractures were coded on the same admission, the admission was captured as an open fracture for the purpose of the present study. Therefore, a single patient could have >1 ankle fractures/types during the same admission but would be considered as 1 incident in the final analysis. Patients with multi-trauma and multiple fractures were not excluded; therefore, patients could have had fractures or injuries elsewhere in the body.

The malleolar fractures were dichotomized into open and closed fracture groups. The independent variables listed in Table 2 were then evaluated for an association with

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Table 1
ICD-9 codes used to identify patients with ankle fracture

ICD-9 Code	Fracture Description
824.0	Medial malleolus, closed
824.1	Medial malleolus, open
824.2	Lateral malleolus, closed
824.3	Lateral malleolus, open
824.4	Bimalleolar, closed
824.5	Bimalleolar, open
824.6	Trimalleolar, closed
824.7	Trimalleolar, open
824.8	Unspecified ankle, closed
824.9	Unspecified ankle, open

Abbreviation: ICD-9, International Classification of Diseases, 9th revision.

open fractures. The analysis was performed for the entire cohort and for patients with "higher energy" and "lower energy" trauma separately. The "higher energy" trauma group was defined as incidents involving all types of motor vehicle trauma and trauma associated with machinery. All remaining mechanisms of injury were considered "lower energy" trauma for the purposes of the present study.

Although many traumatologists would consider most of the mechanisms in the data set to be a high-energy trauma, with the exception of mechanisms such as "exertion" and "bites and stings," this type of classification would result in a disproportionally small sample size in the low-energy group (<1% of the entire cohort). Therefore, we grouped the heavy machine-related injuries, such as the motor vehicle trauma and injuries due to machinery into the "higher energy" group to have a reasonably meaningful statistical analysis.

The working definitions of each comorbidity evaluated in the present study were based on the NTDB data dictionary (available at http://www.ntdsdictionary.org/dataElements/datasetDictionary.html). Obesity was defined as a body mass index (BMI) of >40 kg/m^2 in the data set. A smoker was defined as having smoked cigarettes in the year before admission. Alcohol use was defined as having 2 drinks a day for the previous 14 days. Although patient age is available by year, we coded age by decades. The Injury Severity Score (ISS) scale used to assess the severity of a traumatic injury has been shown to correlate with mortality, morbidity, and hospitalization time after trauma (3). The ISS is an anatomic scoring system with values ranging from 1 to 75. Each injury is assigned a number known as the Abbreviated Injury Scale score, for each of 6 body regions (i.e., head, face, chest, abdomen, extremity, and external). The ISS is then calculated using the highest 3 Abbreviated Injury Scale values, squaring each, and summing them. In our study, the ISS was treated as a continuous variable.

Statistical Analysis

The prevalence and proportion of open ankle fracture were calculated. The number of patients with multiple ankle fractures was also determined. The proportions of open fractures by hospital type (i.e., community, nonteaching, university) and mechanism of trauma were also evaluated.

Bivariate analyses with the chi-square test or Fisher's exact test, as appropriate, for categorical variables and the Student's *t* test for continuous variables were used to

Table 2
Independent variables examined for association with open ankle fractures

Variable	Stratification
Age	By decade
Gender	Male/female
Obesity	Obese/not obese*
Steroid use	Yes/no
Trauma other than foot and ankle	Yes/no
Alcoholism	Yes/no
Diabetes	Yes/no
Injury Severity Score	Continuous
Type of facility	Community/university/ nonteaching
Current history of smoking	Yes/no
Myocardial infarction within 6 mo	Yes/no
Dialysis	Yes/no
History of revascularization or amputation	Yes/no
Impaired sensorium	Yes/no
Chemotherapy for cancer in previous 30 days	Yes/no

* Obese defined as a body mass index >40 kg/m^2 and not obese as a body mass index ≤40 kg/m^2.

obtain a first impression of the covariates that affected the occurrence of open ankle fractures and to determine the inclusion of each variable in a multiple logistic regression model. As a general rule, those covariates with a bivariate analysis *p* value of < .02 were included in the multivariate model. Age, gender, ISS, and obesity were included in the model, regardless of the bivariate analysis results.

Odds ratios (ORs) with 95% confidence intervals were then determined for each variable, adjusted for covariates using the logistic regression analysis. ORs computed for the location of injury used "street" as the reference value, because this is the location at which the plurality of injuries occurred. *p* Values < .05 were considered statistically significant for these logistic regression analyses. These analyses were performed in the entire ankle fracture cohort, and they were performed in the "lower energy" and "higher energy" groups separately.

All statistical analyses were performed using the R statistical package (R, Developmental, Core, Team. R: A Language and Environment for Statistical Computing 2013; http://www.R-project.org).

Results

A total of 149,653 ankle fractures were identified using our inclusion criteria. Of these, 72,807 (49.06%) were in females and 75,600 (50.94%) were in males. Also, 67% of the patients had experienced trauma other than an ankle fracture. Open fractures were found in 17.57% (n = 26,288) of all ankle fractures. The mean ISS was 9.13 ± 8.45, and 56,553 ankle fractures (38.56%) were grouped into the "higher energy" group. The frequencies of open fractures by mechanism of trauma are presented in Table 3. The proportions of open ankle fractures in each malleolar type are presented in Table 4. The proportions of open ankle fractures were relatively similar among the different malleolar types, except for the trimalleolar fracture type, which yielded the lowest proportion of open fractures.

Of the ankle fractures, 5% were work related, and the most frequent location of injury was on the street (44.26%). The remainder of the injuries occurred at home (32.23%), at unspecified locations (7.95%), at recreational locations (6.61%), at other locations (5.14%), at industrial locations (3.06%), on farms (0.67%), and in mines (0.08%).

The mean age was 42 ± 20.5 years. In this cohort, 7494 (5.55%) were obese, 456 (0.34%) were taking steroids, 9016 (6.67%) were alcohol users, 16,333 (12.09%) had diabetes, 11,809 (8.74%) were smokers, 1636 (1.21%) had experienced a previous myocardial infarction (MI), 644 (0.48%) required dialysis, 115 (0.09%) had history of peripheral vascular disease (PVD), 7049 (5.22%) had impaired sensorium, and 153 (0.11%) were receiving chemotherapy for cancer.

Table 3
Frequencies and proportions of open ankle fractures stratified by mechanism

	Open (n)	Closed (n)	Total (n)	% Open
Firearm	872	163	1035	84.3
Cut/pierce	120	112	232	51.7
Machinery	396	678	1074	36.9
MVT, motorcyclist	3261	8559	11,820	27.6
MVT, other	103	276	379	27.2
Pedestrian, other	182	480	662	27.5
Natural/environmental, bites, stings, other	72	236	308	23.4
MVT, pedestrian	1927	5806	7733	24.9
Transport, other	1708	5519	7227	23.6
MVT, occupant	7568	25,925	33,493	22.6
MVT, unspecified	129	467	596	21.6
MVT, pedal cyclist	297	1161	1458	20.4
Pedal cyclist, other	186	1021	1207	15.4
Struck by, against	819	5517	6336	12.9
Fall	8001	71,176	79,177	10.1
Overexertion	130	1944	2074	6.3

Abbreviation: MVT, motor vehicle trauma.
Mechanisms with a frequency of <100 and unspecified/null/other types were excluded.