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Δ What Factors are Associated with Infection in Open Fractures?
A Predictive Model Based on a Prospective Evaluation of 2338 Patients

Paul Tornetta III, MD[1]; Gregory Della Rocca, MD, PhD, FACS[2]; Saam Morshed, MD[3];
Clifford Jones, MD, FACS[4]; Diane Heels-Ansdell, MSc[5]; Sheila Sprague, PhD[5];
Brad Petrisor, MD[6]; Kyle Jeray, MD[7]; Mohit Bhandari, MD, FRCSC, PhD[8]; FLOW Investigators
[1]Boston Medical Center, Boston, Massachusetts, USA;
[2]University of Missouri School of Medicine, Columbia, Missouri, USA;
[3]University of California San Francisco, San Francisco General Hospital, Orthopaedic Trauma Institute, San Francisco, California, USA
[4]Orthopaedic Associates of Michigan, Grand Rapids, Michigan, USA;
[5]McMaster University, Hamilton, Ontario, CANADA;
[6]Hamilton General Hospital, Ontario, CANADA;
[7]Greenville Health System University Medical Center, Greenville, South Carolina, USA;
[8]MacOrtho Research, Ontario, CANADA

Purpose: The primary risk of open fractures is infection. The majority of data regarding infection in open fractures exist in tibial shaft fractures, which have been reported to have the highest rate of infection. Additionally, upper extremity injuries are thought to be more resistant to infection than lower extremity injuries. The purpose of this study is to analyze a large series of open fractures of the lower and upper extremities to determine the risk factors that predict the development of infection.

Methods: This study was a prospective evaluation of soap and irrigation pressure on a combined event outcome. The trial showed no difference in irrigation pressure and a slight advantage using saline rather than soap on the primary outcome of revision surgery. In this study, a statistician used a Cox proportional hazards regression analysis to identify the factors associated with "any" and "deep" infection. Results are presented as hazard ratios (HRs) and 95% confidence intervals (CIs). Irrigation pressure and use of soap were included in both models as they were the basis of the initial study. A research team identified the most likely factors that would contribute to infection and limited the number of factors to the number of events/10 as is recommended for regression analysis.

Results: We analyzed 2338 patients with upper extremity (UE) and lower extremity (LE) open fractures to identify the risk factors for infection. The average age was 45 and 69% were male. Location was divided into tibia (883) (shaft, plateau and pilon), other LE (726), and UE (729). There were 289 infections of which 156 were deep. For all factors found to be predictive, the following text shows HRs and P values (also see data tables). The factors associated with any infection were: location (tibia vs UE: 5.13, other LE vs UE: 3.63; P <0.001), high-energy mechanism of injury (0.61; P = 0.019), degree of contamination (moderate vs mild: 1.08, severe versus mild: 2.12; P = 0.004) and need for flap coverage (1.82; P = 0.017). The factors associated with deep infection were: location (tibia vs UE: 2.72, other LE vs UE: 2.98; P <0.001), Gustilo type 3 (1.57; P = 0.016), delayed closure (1.89; P = 0.003), and need for flap (2.05; P = 0.017).

Conclusion: We performed a regression analysis of the trial data to determine the risk factors for any infections and for deep infections. Having a tibia fracture was the strongest predictor of any and deep infection. Degree of contamination and grade 3 open fracture predicted any and deep infection, respectively. Finally, the need for a flap for coverage predicted any and deep infection and a delayed closure predicted deep infection independent of the requirement for a flap. Soap and irrigation pressure were not predictive in this model.

PAPER ABSTRACTS

What Factors are Associated With Infection in Open Fractures? A Predictive Model Based on a Prospective Evaluation of 2338 Patients

Cox proportional hazards regression analysis with time to Any Infection as the dependent variable. N=2338 with 289 events (complete case). Our main analysis for Any Infection excludes 7 patients with delayed definitive fixation who experienced an infection prior to definitive fixation.

Independent Variable	Incidence of Predictors n (%)	Adjusted Hazard Ratio (95% CI)	p-value
Age (10-year increase)	45.1 (17.8) mean (SD)	1.04 (0.96, 1.12)	0.376
Male	1622 (69.4)	1.05 (0.79, 1.39)	0.733
Fracture location			<0.001
Tibia	883 (37.8)	5.13 (3.28, 8.02)	
Other lower extremity	726 (31.1)	3.63 (2.38, 5.55)	
Upper extremity	729 (31.2)	1.00	
High energy mechanism of injury	2058 (88.0)	0.61 (0.41, 0.92)	0.019
Current smoker	754 (32.2)	1.08 (0.84, 1.40)	0.537
Other major injury*	722 (30.9)	0.91 (0.69, 1.19)	0.496
Comminuted or segmental fracture	1579 (67.5)	1.21 (0.91, 1.60)	0.182
Bone loss	512 (21.9)	1.19 (0.90, 1.58)	0.223
Degree of contamination			0.004
Mild	1799 (76.9)	1.00	
Moderate	416 (17.8)	1.08 (0.78, 1.49)	
Severe	123 (5.3)	2.12 (1.35, 3.32)	
Method of definitive fixation			0.148
Nail	792 (33.9)	1.00	
Plate	1177 (50.3)	1.36 (0.997, 1.86)	
Other	369 (15.8)	1.30 (0.86, 1.98)	
Bone grafting at initial surgery	50 (2.1)	0.95 (0.35, 2.60)	0.918
Type III post-operative Gustilo Type	846 (36.2)	1.23 (0.92, 1.64)	0.161
Total operating time ≥120 minutes	997 (42.6)	1.11 (0.86, 1.44)	0.429
Time to first incision from injury			0.126
<6 hours	465 (19.9)	1.00	
6 to 12 hours	980 (41.9)	0.92 (0.68, 1.23)	
>12 to 24 hours	785 (33.6)	0.71 (0.50, 1.02)	
>24 hours	108 (4.6)	1.27 (0.66, 2.43)	
Wound *not* closed at initial I&D	373 (16.0)	0.95 (0.66, 1.38)	0.796
Randomized solution			0.922
Soap	1178 (50.4)	1.01 (0.80, 1.28)	
Saline	1160 (49.6)	1.00	
Randomized pressure			0.833
High	784 (33.5)	1.00	
Low	772 (33.0)	1.05 (0.79, 1.41)	
Very low	782 (33.4)	1.09 (0.82, 1.46)	
Time-dependent variables			
Wound flap (re-operation)	108 (4.6) ever	1.82 (1.11, 2.99)	0.017

* At least one of the following: femoral fracture, pelvic fracture, spinal fracture, liver injury, bowel injury, splenic injury, other abdominal injury, hemo/pneumothorax, closed head injury, urogenital injury, traumatic amputation, vascular injury, lung contusion, thoracic injury, hip fracture, spinal injury.

What Factors are Associated With Infection in Open Fractures? A Predictive Model Based on a Prospective Evaluation of 2338 Patients

Cox proportional hazards regression analysis with time to Deep Infection as the dependent variable. N=2346 with 156 events (complete case).

Independent Variable	Incidence of Predictors n (%)	Adjusted Hazard Ratio (95% CI)	p-value
Age (10-year increase)	45.1 (17.7) mean (SD)	1.07 (0.96, 1.18)	0.220
Male	1626 (69.3)	0.92 (0.64, 1.33)	0.663
Fracture location			<0.001
Tibia	885 (37.7)	2.72 (1.57, 4.71)	
Other lower extremity	729 (31.1)	2.98 (1.72, 5.18)	
Upper extremity	732 (31.2)	1.00	
Current smoker	758 (32.3)	1.03 (0.73, 1.47)	0.855
Other major injury*	724 (30.9)	1.03 (0.72, 1.45)	0.892
Type III post-operative Gustilo Type	852 (36.3)	1.57 (1.09, 2.27)	0.016
Total operating time ≥120 minutes	1000 (42.6)	0.98 (0.69, 1.39)	0.921
Time to first incision from injury			0.083
<6 hours	467 (19.9)	1.00	
6 to 12 hours	985 (42.0)	0.77 (0.52, 1.13)	
>12 to 24 hours	786 (33.5)	0.54 (0.34, 0.87)	
>24 hours	108 (4.6)	0.88 (0.36, 2.16)	
Wound *not* closed at initial I&D	380 (16.2)	1.89 (1.24, 2.90)	0.003
Randomized solution			0.955
Soap	1181 (50.3)	0.99 (0.72, 1.36)	
Saline	1165 (49.7)	1.00	
Randomized pressure			0.817
High	787 (33.5)	1.00	
Low	774 (33.0)	1.10 (0.75, 1.62)	
Very low	785 (33.5)	0.98 (0.66, 1.46)	
Time-dependent variables			
Wound flap (re-operation)	110 (4.7) ever	2.05 (1.14, 3.71)	0.017

* At least one of the following: femoral fracture, pelvic fracture, spinal fracture, liver injury, bowel injury, splenic injury, other abdominal injury, hemo/pneumothorax, closed head injury, urogenital injury, traumatic amputation, vascular injury, lung contusion, thoracic injury, hip fracture, spinal injury.

Sensitivity Analysis #1 – Outcome: Deep Infection
- Same as the main model except remove operative time and time to first incision from injury (these two variables account for much of the missing data).
- N=2401. No substantial changes for any predictor variables (ie. no changes in the conclusions).