Clin Orthop Relat Res (2016) 474:562–570
DOI 10.1007/s11999-015-4523-3

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

CLINICAL RESEARCH

What Factors are Associated With a Surgical Site Infection After Operative Treatment of an Elbow Fracture?

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Received: 21 May 2015 / Accepted: 12 August 2015 / Published online: 25 August 2015

Abstract

Background Surgical site infections are one of the more common major complications of elbow fracture surgery and can contribute to other adverse outcomes, prolonged hospital stays, and increased healthcare costs.

Questions/purposes We asked: (1) What are the factors associated with a surgical site infection after elbow fracture surgery? (2) When taking the subset of closed elbow fractures only, what are the factors associated with a surgical site infection? (3) What are the common organisms isolated from an elbow infection after open treatment?

Methods One thousand three hundred twenty adult patients underwent surgery for an elbow fracture between January 2002 and July 2014 and were included in our study. Forty-eight of 1320 patients (4%) had a surgical site infection develop. Thirty-four of 1113 patients with a closed fracture (3%) had a surgical site infection develop.

Results For all elbow fractures, use of plate and screw fixation (adjusted odds ratio [OR]= 2.2; 95% CI, 1.0–4.5; p = 0.041) and use of external fixation before surgery (adjusted OR = 4.7; 95% CI, 1.1–21; p = 0.035) were associated with higher infection rates. When subset analysis was performed for closed fractures, only smoking (adjusted OR = 2.2; 95% CI, 1.1–4.5; p = 0.023) was associated with higher infection rates. *Staphylococcus aureus* was the most common bacteria cultured (59%).

Conclusions The only modifiable risk factor for a surgical site infection after open reduction and internal fixation was cigarette smoking. Plate fixation and temporary external fixation are likely surrogates for more complex injuries, therefore no recommendations should be inferred from this association. Surgeons should counsel patients who smoke.

Level of Evidence Level IV, prognostic study.

One of the authors certifies that he (DR), or a member of his or her immediate family, has or may receive payments or benefits, during the study period, an amount of USD 10,000-USD 100,000 from Skeletal Dynamics (Miami, FL, USA); an amount of less than USD 10,000 from Biomet (Warsaw, IN, USA); and an amount of less than USD 10,000 from Acumed (Hillsboro, OR, USA) outside the submitted work.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research*® editors and board members are on file with the publication and can be viewed on request.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at Massachusetts General Hospital, Boston, MA, USA, Brigham and Women's Hospital, MA, USA, Faulkner Hospital, MA, USA and North Shore Medical Center, Salem, MA, USA.

Electronic supplementary material The online version of this article (doi:10.1007/s11999-015-4523-3) contains supplementary material, which is available to authorized users.

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Introduction

A surgical site infection (SSI) is the most common major complication of orthopaedic surgery [1, 31]. It can contribute to other adverse outcomes including nonunion, stiffness, arthritis, and heterotopic ossification [31]. Orthopaedic SSIs prolong hospital stays by 7 to 14 days per patient [10, 31] and increase healthcare costs by more than 300% [31]. The risk factors for an SSI after orthopaedic surgery include older age, other nosocomial infections, wound contamination class, rheumatoid arthritis, the use of a drain, and length of preoperative stay [9, 14, 24, 27]. A prior study identified the elbow and tibia as independently associated with SSI after trauma [4].

The incidence of a SSI after surgery for elbow stiffness varies from 1.3% to 6.5% [1]. For total elbow arthroplasty, the reported incidence varies from 3% to 9% [21, 22, 32]. The rate of infection after surgery for elbow fracture is less studied [4], and factors associated with infection after operative treatment of elbow fracture are incompletely understood. We separated closed fractures, as open fractures are a known factor associated with infection in other fractures.

We aimed to identify modifiable risk factors for SSI after surgery for elbow fractures that might help reduce the risk of infection. We asked: (1) What are the factors associated with a SSI after elbow fracture surgery? (2) When taking the subset of closed elbow fractures only, what are the factors associated with SSI? (3) What are the common organisms isolated from an elbow infection after open treatment?

Patients and Methods

With the approval of the institutional review board we retrospectively reviewed 1380 adult patients who underwent surgery for an elbow fracture between January 2002 and July 2014 at four area hospitals. Patients were identified using Current Procedural Terminology (CPT) codes for elbow fractures (Appendix 1. Supplemental materials are available with the online version of CORR®.). The first two hospitals are Level I trauma centers, the third is a community hospital tied to a Level I trauma center, and the other hospital is a community hospital.

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A multiinstitutional research patient data registry was used to compile data necessary to perform this study. This registry is a centralized clinical data registry that comprises diagnostic codes (ICD-9), CPT codes, demographic information (eg, sex, date of birth, and race), microbiology reports, prescription medication, and operative reports. For patients who had more than one elbow surgery, we tracked the first internal fixation for the elbow fracture as the index procedure.

A total of 60 patients were excluded from the study: 34 of the 60 patients had prior surgery for an elbow fracture elsewhere, 16 had a fracture through a malignant tumor, five had a nonunion, three had more than one skin incision, and two died owing to respiratory failure after the surgery. This resulted in a final cohort of 1320 patients. All patients had a followup of at least 4 months.

A SSI was defined according to the CDC criteria for superficial or deep SSI [17]. A superficial SSI was defined as an infection that involved only skin or subcutaneous tissue of the incision and occurred within 30 days after surgery combined with at least one of the following criteria: (1) purulent drainage, with or without laboratory confirmation, from the superficial incision; (2) organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision; (3) at least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat, and a superficial incision is deliberately opened by the surgeon unless the incision is culture-negative; and (4) a diagnosis of superficial incisional SSI by the surgeon or attending physician. A deep SSI was defined as an infection that occurred within 30 days after surgery if no implant was left in place or within one year if the implant is left in place, the infection appears to be related to the operation, and the infection involved deep soft tissues of the incision combined with at least one of the following criteria: (1) purulent drainage from the deep incision but not from the organ or space component of the surgical site; (2) a deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (> 38°C), localized pain, or tenderness, unless the site is culture-negative; (3) an abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination; and (4) diagnosis of a deep incisional SSI by a surgeon or attending physician.

The following patient-related factors were studied: obesity, smoking, alcohol abuse, diabetes mellitus, open fracture, Gustilo classification, the presence of other fracture of the same limb, the presence of other fractures in general, injury-affected side, and rheumatoid arthritis.

Additionally, the following surgery-related factors were studied: duration of surgery, experience of the surgeon in

years after board certification, hospital, use of a tourniquet, days between fracture and surgery, plate and screw fixation, screws alone, tension band wire, radial head arthroplasty, other fixation type, use of polyglactin 910 subcutaneous sutures (Vicryl®; Ethicon Somerville, NJ, USA) (because we had a sense that suture abscesses from this material were leading to infections around the plate for posterior plate wounds), location of the incision (posterior, lateral, medial, other), use of a postoperative wound drain, use of vacuum dressing, fracture type, plate and screw fixation, screw fixation, tension band wire, radial head arthroplasty, other fixation, and use of external fixation before surgery. Obesity, smoking recorded in medical records, alcohol abuse recorded in medical records, diabetes mellitus, and rheumatoid arthritis were retrieved based on ICD-9 codes (Appendix 2. Supplemental materials are available with the online version of CORR®.). The other variables were chart-reviewed.

Forty-eight of 1320 patients who underwent surgery for elbow fractures (4%) had an SSI according to the CDC criteria. The mean duration from surgery until diagnosis of infection was 34 days (SD = 29 days). Of the 1320 elbow fractures, 1113 (84%) were closed fractures. Thirty-four patients (3%) with closed fractures had had an infection.

Statistical Analysis

The normality of continuous data was tested using the Shapiro-Wilk test. Differences in explanatory variables between patients with and without infection after operative treatment for elbow fracture were assessed using Fisher's exact test for dichotomous and categorical variables and an unpaired t-test for continuous variables. Variables were presented with frequencies and percentages for categorical variables and as mean with SD for continuous variables. Mean imputation was used for missing data. There were no missing data in the variables age and duration of surgery. The years of experience of the surgeon during the surgery was unknown for one patient.

Factors with a probability less than 0.05 in bivariate analysis were entered in multivariable logistic regression analyses to assess if possible risk factors were independently associated with infection after surgery. Our α value was set at 0.05.

Results

For all elbow fractures, in multivariable analysis, use of plate and screw fixation (adjusted odds ratio [OR] = 2.2; 95% CI, 1.0–4.5; p = 0.041) and use of external fixation before surgery (adjusted OR = 4.7; 95% CI, 1.1–21; p = 0.035) were associated with higher infection rates (Table 1). In exploratory bivariate analysis, the factors associated with infection after surgery for elbow fracture included male sex, open fracture, plate and screw fixation, and use of external fixation before surgery (Table 2).

Table 1. Factors associated with infection after operative treatment of elbow fractures (n = 1320 patients) in multivariate analysis

Parameter	Adjusted odds ratio	Adjusted 95% CI	Adjusted p value
Sex	1.8	0.96–3.2	0.067
Open fracture	1.6	0.78–3.3	0.20
Plate and screw fixation	2.2	1.0–4.5	0.041
Use of external fixation before surgery	4.7	1.1–21	0.035

Thirty-seven (77%) patients had a deep infection and 11 (23%) had a superficial infection. In the closed fracture group, 23 (68%) had a deep infection and 11 (32%) had a superficial infection. All infections were deep in the open fracture group.

When subset analysis was performed for closed fractures using multivariate analysis, only smoking (adjusted OR = 2.2; 95% CI, 1.1–4.5; p = 0.023) was associated with higher infection rates (Table 3). In bivariate analysis, smoking and plate and screw fixation were associated with infection after surgery (Table 4), but only smoking was retained as an associated factor. *Staphylococcus aureus* was the most common bacteria cultured (59%) followed by *Serratia marcescens* (9.8%) (Table 5).

Discussion

A SSI is one of the more common major complications of elbow fracture surgery and can contribute to other adverse outcomes, prolonged hospital stays, and increased healthcare costs [1, 31]. The rate of infection after surgery for elbow fractures is less studied [4], and factors associated with infection after operative treatment of elbow fracture are incompletely understood.

We sought to determine factors associated with SSI after elbow fracture surgery. We hypothesized that there were no factors associated with a SSI after surgery for an elbow fracture. We found that infection is a common complication of operative treatment for elbow fractures, with an incidence of 4%. Plate and screw fixation and use of external fixation before surgery were associated with higher infection rates for all fractures, presumably because they indicate the most complex injuries. Smoking was the only modifiable risk factor.

Limitations include the use of ICD-9 and CPT codes to identify the initial diagnoses. There is likely a small

Table 2. Factors associated with infection after operative treatment for elbow fractures (n = 1320) in bivariate analysis

Parameter	Yes (n = 48, [4%]) Mean (SD)	No (n = 1272, [96%]) Mean (SD)	p value
Age (years)	54 (20)	54 (21)	0.74
Duration of surgery (hours)	2.3 (3)	1.9 (1)	0.051
Experience of surgeon (years)	9.5 (8)	10 (8)	0.67
Time between fracture and surgery (days)	3.0 (4)	2.7 (4)	0.68
	Number (%)	Number (%)	p value
Sex			0.015
Men	29 (60)	543 (43)	
Women	19 (40)	729 (57)	
Obesity			1.0
Yes	6 (13)	160 (13)	
No	42 (88)	1109 (87)	
Smoking*			0.24
Yes	16 (33)	327 (26)	
No	32 (67)	945 (74)	
Alcohol abuse*			1.0
Yes	2 (4)	67 (5)	
No	46 (96)	1205 (95)	
Diabetes mellitus			0.23
Yes	8 (17)	135 (11)	
No	40 (83)	1136 (89)	
Rheumatoid arthritis			0.67
Yes	2 (4)	41 (3)	
No	46 (96)	1230 (97)	
Open fracture			0.011
Yes	14 (30)	193 (15)	
No	32 (70)	1080 (85)	
Fracture type			0.14
Distal humerus	20 (42)	463 (36)	
Olecranon	13 (27)	443 (35)	
Complex combined	8 (17)	105 (8)	
Elbow dislocation with intraarticular fractures	7 (15)	261 (21)	
Other fracture of the same limb			0.82
Yes	6 (13)	145 (11)	
No	42 (88)	1127 (89)	
Other fractures of other limbs, spine, or pelvis			0.54
Yes	9 (19)	196 (15)	
No	39 (81)	1076 (85)	
Injury side			0.23
Right	25 (52)	540 (42)	
Left	23 (48)	731 (58)	
Polyglactin 910 subcutaneous sutures			0.88
Yes	32 (67)	825 (65)	
No	16 (33)	447 (35)	
Location of incision			0.39
Posterior	36 (75)	970 (76)	
Lateral	3 (6)	134 (11)	
Medial	2 (4)	65 (5)	

Table 2. continued

Parameter	Yes (n = 48, [4%]) Mean (SD)	No (n = 1272, [96%]) Mean (SD)	p value
Other	7 (15)	103 (8)	
Use of wound drain			0.16
Yes	8 (17)	132 (10)	
No	40 (83)	1140 (90)	
Use of vacuum dressing			0.68
Yes	2 (4)	43 (3)	
No	46 (96)	1228 (97)	
Plate and screws			0.020
Yes	39 (81)	823 (65)	
No	9 (19)	449 (35)	
Screws alone			0.69
Yes	6 (13)	195 (15)	
No	42 (88)	1077 (85)	
Tension band wire			0.22
Yes	7 (15)	298 (23)	
No	41 (85)	974 (77)	
Radial head arthroplasty			1.0
Yes	3 (6)	88 (7)	
No	45 (94)	1184 (93)	
Other fixation type			1.0
Yes	3 (6)	100 (8)	
No	45 (94)	1172 (92)	
Use of tourniquet			0.37
Yes	40 (83)	1119 (88)	
No	8 (17)	153 (12)	
Use of external fixation before surgery			0.010
Yes	3 (6)	10 (1)	
No	45 (94)	1262 (99)	
Hospital			0.97
Massachusetts General Hospital	31 (65)	825 (65)	
Brigham and Women's Hospital	16 (33)	399 (31)	
Faulkner Hospital	1 (2)	34 (3)	
North Shore Medical Center	0 (0)	14 (1)	

* Recorded in medical records.

Table 3. Factors associated with infection after operative treatment of closed elbow fractures (n = 1113) in multivariate analysis

Parameter	Adjusted odds ratio	Adjusted 95% CI	Adjusted p value
Plate and screw fixation	2.1	0.92–5.0	0.078
Smoking	2.2	1.1–4.5	0.023

amount of miscoding as is typical of studies based on databases. It might be possible that some of the variables were underpowered, as only a few patients in our cohort had these characteristics. Because of the high number of explanatory variables, we cannot confirm which variables will be important. However, we think that this approach—with its limitations—is a good start in using large databases to ask these questions. Finally, this study design is retrospective, which makes it inherently more susceptible to data loss, bias, and confounding than a prospective

Table 4. Factors associated with infection after operative treatment for closed elbow fractures (n = 1113) in bivariate analysis

Parameter	Yes (n = 34, [3%]) Mean (SD)	No (n = 1079, [97%]) Mean (SD)	p value
Age (years)	56 (21)	55 (19)	0.75
Duration of surgery (hours)	2.0 (1)	1.9 (1)	0.54
Experience of surgeon (years)	11 (9)	10 (8)	0.67
Time between fracture and surgery (days)	2.9 (3)	3.0 (4)	0.95
	Number (%)	Number (%)	p value
Sex			0.073
Men	19 (56)	423 (39)	
Women	15 (44)	656 (61)	
Obesity			0.43
Yes	6 (18)	134 (12)	
No	28 (82)	943 (88)	
Smoking*			0.027
Yes	15 (44)	275 (25)	
No	19 (56)	804 (75)	
Alcohol abuse*			1.00
Yes	2 (6)	61 (6)	
No	32 (94)	1018 (94)	
Diabetes mellitus			0.053
Yes	8 (24)	125 (12)	
No	26 (76)	953 (88)	
Rheumatoid arthritis			1.0
Yes	1 (3)	37 (3)	
No	31 (97)	1041 (97)	
Fracture type			0.26
Distal humerus	13 (38)	387 (36)	
Olecranon	10 (29)	379 (35)	
Complex combined	6 (18)	89 (8)	
Elbow dislocation with intraarticular fractures	5 (15)	224 (21)	
Other fracture of the same limb			0.77
Yes	4 (12)	112 (10)	
No	30 (88)	967 (90)	
Other fractures of other limbs, spine, or pelvis			0.80
Yes	5 (15)	150 (14)	
No	29 (85)	929 (86)	
Injury side			0.60
Right	16 (47)	459 (43)	
Left	18 (53)	619 (57)	
Polyglactin 910 subcutaneous sutures			0.86
Yes	23 (68)	697 (65)	
No	11 (32)	382 (35)	
Location incision			0.10
Posterior	29 (85)	841 (78)	
Lateral	1 (3)	121 (11)	
Medial	0 (0)	57 (5)	
Other	4 (12)	60 (6)	

Table 4. continued

Parameter	Yes (n = 34, [3%]) Mean (SD)	No (n = 1079, [97%]) Mean (SD)	p value
Use of wound drain			0.51
Yes	1 (3)	112 (10)	
No	33 (97)	967 (90)	
Use of vacuum dressing			0.49
Yes	1 (3)	22 (2)	
No	31 (97)	1056 (98)	
Plate and screws			0.039
Yes	27 (79)	685 (63)	
No	7 (21)	394 (37)	
Screws alone			0.22
Yes	3 (9)	166 (15)	
No	31 (91)	913 (85)	
Tension band wire			0.28
Yes	6 (18)	256 (24)	
No	28 (82)	823 (76)	
Radial head arthroplasty			0.4
Yes	3 (9)	76 (7)	
No	31 (91)	1003 (93)	
Other fixation type			1.0
Yes	2 (6)	87 (8)	
No	32 (94)	992 (92)	
Use of tourniquet			0.57
Yes	32 (94)	965 (89)	
No	2 (6)	114 (11)	
Hospital			0.96
Massachusetts General Hospital	23 (68)	694 (64)	
Brigham and Women's Hospital	10 (29)	337 (31)	
Faulkner Hospital	1 (3)	34 (3)	
North Shore Medical Center	0 (0)	14 (1)	

* Recorded in medical records.

evaluation. We used mean imputation in one patient in which the years of experience of the surgeon during the surgery was unknown. The strength of this study is the large consecutive cohort of patients with surgically treated elbow fractures.

The rate of SSI after elbow fracture surgery (4%) was lower than the 7% infection rate reported by Bachoura et al. [4]. The higher infection rate in their study could be the result of a 10-fold smaller number of patients with elbow fracture surgery compared with our study with a greater potential for spurious results.

Plate and screw fixation and use of external fixation before surgery were associated with higher infection rates after any elbow fracture. In prior research, olecranon osteotomy stabilized with a plate and screws was a risk factor for SSI [14], and plate and screw fixation also was found to be a risk factor for SSI in long bone fractures [29]. The data regarding SSI after plate and screw fixation of tibial plateau fractures, distal tibia fractures, proximal humerus fractures, and humeral shaft fractures are less consistent [5, 8, 12, 15, 16, 23, 26, 30, 33]. In the elbow, a higher rate of SSI in patients treated with plate and screw fixation might occur owing to the presence of implants directly underneath the wound, particularly if there is a suture abscess, wound separation, or wound edge necrosis. Open fractures were a risk factor for infection in bivariate but not multivariate analysis. We interpret this to mean that a subset of open fractures is at risk. It may be that use of an external fixator before surgery, which was retained in the final model, is a surrogate marker of extensive soft tissue injury or contamination.

Table 5. Bacteria type

Type of bacterium	Number (%)
Staphylococcus aureus	24 (59)
Staphylococcus aureus + other species	4 (10)
Bacillus species	2 (5)
Enterococcus species	3 (7)
Serratia marcescens	4 (10)
Other	4 (10)

For closed fractures, smoking was the only factor associated with an increased risk of SSI in multivariate analysis. This is consistent with prior studies of plastic surgery of the upper extremity and orthopaedic surgery [2, 6, 13, 20]. Smoking appears to suppress the immune system [18]. It was found that the percentage of impaired wound healing was greater in nonsmokers than individuals who had not smoked for more than 22 days (47% nonsmokers versus 67%, $p < 0.05$) after head and neck surgery [11]. A risk reduction of 19% is seen for each week of cessation before surgery [19]. However, former smokers were considered to have a lifetime greater risk of healing complications and SSI compared with nonsmokers [28]. This suggests that, when possible, patients who currently smoke should quit smoking before elbow fracture surgery to reduce the detrimental effects of smoking on perioperative and postoperative complications.

S aureus was the most common organism identified in the culture. This is consistent with prior studies of SSI after fracture fixation [3, 7, 13, 25, 29].

We did not identify any readily modifiable factors associated with SSI after elbow fracture surgery. The use of splinting techniques in lieu of external fixation may be preferred, but it is possible that external fixation is associated with more complex injuries at higher risk of infection. Patients who smoke should be counseled that smoking increases risk for infection after operative treatment of a closed elbow fracture 2.2 times.

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