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Surgical site infection in upper extremity fracture

Incidence and prognostic risk factors

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Abstract

Upper extremity fractures (UEF) occurred in about 0.67% of males and females at some point in their lifetime. Surgical treatment has the advantage of good functional recovery, however, the occurrence of surgical site infection (SSI) affects the clinical outcome of operation. Currently, there are few studies focused on SSI of UEF. Consecutive patients with UEF and underwent surgeries from January 2010 to February 2021 were recruited. Demographic data, surgical related variables and laboratory test index of these patients were extracted and collected from the electronic medical records and picture archiving and communication system by well-trained investigators. Receiver operating characteristic (ROC) analysis was performed to detect the optimum cut-off value for continuous variables. Multivariate logistic regression analysis was performed to identify independent risk factors of SSI. In total, 286 patients with a mean age of 44.4 ± 16.6 years were identified for inclusion, 59.8% patients diagnosed with fracture of radius and ulna and 40.2% fractures located in the humerus, closed and open fractures were occurred in 252 and 34 adult patients respectively. 7.3% UEF patients were encountered with SSI, incidence of superficial and deep infection was 6.3% and 1.0%. Open fracture (OR, 8.33; *P*, .000), operation time longer than 122 minutes (OR, 3.12; *P*, .036), intraoperative blood loss more than 135 mL (OR, 3.98; *P*, .009) and albumin (ALB) lower than 40.8 g/L (OR, 3.60; *P*, .015) were demonstrated as independent risk factors of SSI. Adequate preoperative evaluation, careful intraoperative manipulation, and timely and appropriate postoperative interventions should be formulated to reduce the incidence of SSI in patients with the above perioperative high-risk factors.

Abbreviations: ALB = albumin, ROC = receiver operating characteristic, SSI = surgical site infection, UEF = upper extremity fracture, WBC = white blood cell.

Keywords: malnutrition, open fracture, risk factors, surgical site infection, upper extremity

1. Introduction

In the United States 2009, there were 590,000 upper extremity fractures (UEF) occurred, and demonstrating an incidence of 67/10,000.[1] Distal radius fractures occur in about 6% of males and 33% of females at some point in their lifetime[2,3] and distal radius fractures and proximal humerus fractures are the second and third most common fractures in elderly population respectively.[4] Pediatric fractures are common and account for 10% to 25% of injuries in children which accompanied by considerable effects on activity restriction and subsequent high socioeconomically impact. Eighty percent of all fractures in children occur at the upper extremity.[5] Epidemiology of adult UEF was far less studied, however, some authors suggested that proximal humerus fracture may be associated with increased mortality during the first year after injury,[6,7] and increased mortality was found in patients older than 65 years with distal radius fractures.[8]

Wound infection is one of the most common devastating postoperative complications for all the surgical disciplines, it is reported that surgical site infection (SSI) accounting for 22% of all the social-health related infections.[9] Patients that develop SSI often require multiple surgical procedures, a long course of antimicrobial therapy, have a prolonged time until bony union and a possible poor functional outcome, and even encountered with amputation.

However, to date, there are few studies evaluate the incidence and risk factors of SSI after operative-treatment of UEF when compared to the spine and lower extremity. Based on the above considerations, we designed this retrospective cohort study with the aim to: revealing the incidence of SSI following UEF through the analysis of a large sample size; and demonstrating independent risk factors of SSI. Finally, reducing rate of wound infection and promoting a rapid postoperative functional recovery by intervening in some manipulative variables based on the results of the present study.

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

This study was approved by the Institutional Review Board of Beijing Rehabilitation Hospital, Capital Medical University and received written consent from all the study participants.

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2. Patients and method

2.1. Study design

After approved by the Ethics Committee of our hospitals this retrospective study was conducted, consecutive patients with from January 2010 to February 2021 were recruited. Data of these patients were extracted and collected from the electronic medical records and picture archiving and communication system by well-trained investigators.

The inclusion criteria were: UEF involving shoulder to wrist; Patients with underwent open reduction and internal fixation which confirmed by surgery record and postoperative imaging data; Patients were admitted to our trauma center due to fracture and had not received surgical treatment in other institutes; Patients aged 18 years or older; Patients with good willing of cooperation and can complete the collection of follow-up data.

All the surgical procedures were performed by 2 senior surgeons, some classical and modified surgical approach were used during operations: volar approach for the treatment of distal radius fractures and lateral deltoid muscle approach was adopted in the fixation of proximal humeral fractures, lateral approach and posterior or combined anterior-posterior surgical approach for humeral shaft fracture and elbow fractures.

2.2. Definition of SSI

Definition of SSI was based on the criteria of the United States Center for Disease Control and Prevention.[10] Superficial infection: infection occurred no more than 30 days postoperatively; redness, swelling, pain of the incision, purulent discharge, spontaneous wound dehiscence or positive results of bacterial culture around the surgical site skin or subcutaneous were observed or extracted. Deep infection: infection occurred within 90 days postoperatively which involves the fascial and musclar layer and requiring surgical debridement and implant exchange or removal.

Regular observation of the wound was carried out by ward staff while patients were resident in the hospital. Patients were discharged from hospital were followed up for any evidence of SSI occurrence via telephone assessment or promptly clinical interview.

2.3. Data collection

Data were collected from patients' electronic medical records. The demographic data: age, gender, height; weight; body mass index, site of primary fracture, tobacco and alcohol consumption and so on; surgical related variables: operation time, intraoperative blood loss, surgical incision length, interoperative body temperature, drainage usage, American Society of Anesthesiologists (I–IV) classification, preoperative albumin (ALB), protein, lymphocyte, and c creative protein level, and other laboratory indexes such as white blood cell, red blood cell, hemoglobin, blood platelet, globulin, blood glucose were collected.

2.4. Statistical analysis

Statistical procedures were performed by SPSS 20.0 software package (SPSS Inc., Chicago, IL). Continuous variables were expressed as the mean ± SD, Whitney *U* test was used for non-normally distributed continuous variables, *t* test for normally distributed variables and the Chi square test for categorical data. Receiver operating characteristic (ROC) analysis was performed to detect the optimum cut-off value for continuous variables (such as age, surgical duration, anesthesia time, intraoperative blood loss and body temperature). Multivariate logistic regression analysis was performed to analyze the factors which would associate with the occurrence of SSI, and the OR value and 95% confidence interval (CI) were calculated respectively. The Hosmer–Lemeshow test was used to evaluate goodness-of-fit of the final model, and an acceptable fitness was enacted as $P > .05$. Values of $P < .05$ were considered to indicate a significant difference.

3. Result

3.1. Demographic data

In total, 286 patients with a mean age of 44.4 ± 16.6 years were identified for inclusion, there were 160 male and 126 females in this study. Table 1 shows the primary demographic data of included patients. Among the 286 cases, 59.8% patients diagnosed with fracture of radius and ulna and 40.2% fractures located in the humerus. Closed and open fractures were occurred in 252 and 34 adult patients respectively, as far as the mechanism of injury, 43.4% fractures were caused by high-energy damage which including road traffic trauma, falling injury and so on, meanwhile 56.6% patients were hurt by low-energy damage. All the enrolled patients have a mean hospitalization stay of 17.1 ± 11.9 days, and mean intraoperative blood loss was 235.9 ± 109.7 mL.

3.2. Characteristics of SSI

Twenty-one UEF patients were encountered with wound infection in this study, which indicating an infection rate of 7.3%. There were 18 cases of superficial infection and 3 cases of deep infection in the infected sample with an incidence of 6.3% and 1.0% for superficial and deep SSI, respectively. All patients were received intravenous antibiotics treatment and wound disinfection, debridement and continuous negative pressure suction was applied in 11 patients to promote wound healing and exchange of fixation from internal to external were conducted in 2 patients. Mean length of hospital stay for infected patients was 32.4 ± 16.6 days, and ranges from 17 to 73 days. In contrast, length of hospital stay for Non-infected ones was 15.9 ± 10.6 days, which was shorter than the infections cases for 16.5 days. Bacterial culture of pathogenic microorganism showed staphylococcus aureus and Staphylococcus epidermis being the most common one (20.2%, 12.6%).

Table 1

Demographic data of patients included in this study.

Age (yr)	44.4 ± 16.6
Gender	
Male	160
Female	126
Fracture type	
Closed	252
Open	34
Location of fracture	
Radius and ulna	171 (59.8%)
Humerus	115 (40.2%)
Injury mechanism	
Low energy	162 (56.6%)
High energy	124 (43.4%)
Body mass index (kg/m^2)	25.0 ± 3.9
Intraoperative blood loss (mL)	235.9 ± 109.7
Operation time (min)	125.5 ± 61.0
Length of hospital stay (d)	17.1 ± 11.9

3.3. Risk factors of SSI

ROC analysis was performed in surgery related variables and other laboratory test indexes to detect the optimum cut off value of these continuous data which could affect the occurrence of infection (Fig. 1), cut-off value along with the area under the cure and 95% confidence interval for those variables were summarized in Table 2. The comparison of demographic data, surgery related variables and laboratory indexes between SSI and non-SSI group were showed in Table 3, from which we can see that open fracture, preoperative leukocytometer and serum ALB level between the 2 groups were significantly different ($P < .05$). In the multivariate logistic regression model, open fracture (OR, 8.33; *P*, .000), operation time longer than 122 minutes (OR, 3.12; *P*, .036), intraoperative blood loss more than 135 mL (OR, 3.98; *P*, .009) and ALB lower than 40.8 g/L (OR, 3.60; *P*, .015) were demonstrated as independent risk factors of postoperative wound infection (Table 4), and a preferable fitness of the statistical model was showed by the Hosmer-Lemeshow test (χ^2, 7.235; *P*, .511).

4. Discussion

Epidemiology of UEF have been well investigated, a previous study which identified 266,324 first incident UEF from 2013 to 2017, showed that the highest incidence of specific fracture was distal radius fractures followed by metacarpal, phalangeal, distal phalangeal, proximal humerus, clavicle, radial head and scaphoid fractures.[11] At present, data on surgical approaches,

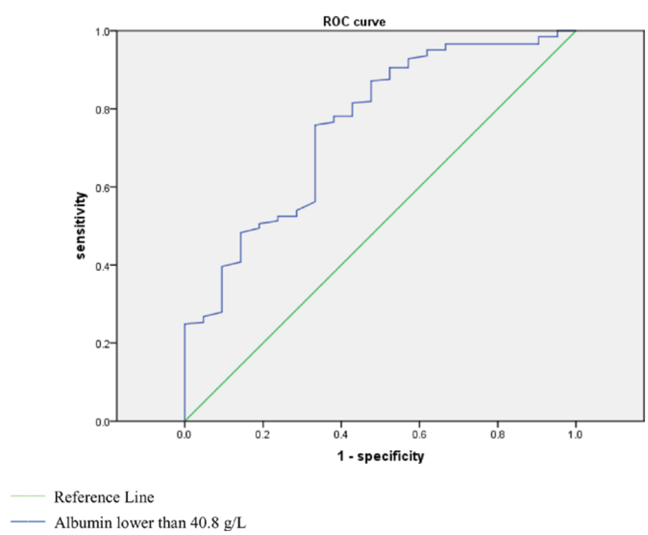

Figure 1. Receiver operating characteristic (ROC) analysis of albumin.

Table 2

Cut-off value of variables detected by the ROC curve.

Variables	Cut-off value	Area under the cure (AUC)	95% CI
Age (yr)	54.5	0.540	0.417–0.662
Operation time (min)	122	0.335	0.194–0.476
Intraoperative body temperature (°C)	36.5	0.543	0.429–0.658
White blood cell (WBC, 10^9/L)	5.66	0.413	0.282–0.544
Body mass index (BMI, kg/m^2)	26.9	0.587	0.472–0.703
Intraoperative blood loss (mL)	135	0.335	0.194–0.476
Hemoglobin (HGB, g/L)	116.3	0.580	0.439–0.721
Serum albumin (ALB, g/L)	40.8	0.754	0.645–0.864

CI = confidence interval, ROC = receiver operating characteristic.

Table 3

Comparison of related variables of wound infection between infected and un-infected patients.

Variables	Wound infection (n = 21, 7.3%)	No wound infection (n = 265, 92.7%)	*P* value
Age (>54 yr)	4 (19.0)	89 (33.6)	.305
Gender (male)	15 (71.4)	145 (54.7)	.450
Open fracture	11 (52.4)	23 (8.7)	.000*
Operation time (>122 min)	15 (71.4)	101 (38.1)	.075
Intraoperative blood loss (>135 mL)	16 (76.2)	118 (44.5)	.121
Hypertension	2 (9.5)	32 (12.1)	.755
Anemia	0 (0.0)	1 (0.4)	N/A
Diabetes mellitus	1 (4.8)	10 (3.8)	.828
Surgical duration (>122 min)	15 (71.4)	101 (38.1)	.075
WBC (<5.66 × 10^9/L)	4 (19.0)	12 (4.5)	.013*
‡ASA score (III–IV)	5 (23.8)	23 (8.7)	.054
Hemoglobin (<116.3 g/L)	9 (42.9)	52 (19.6)	.061
Drainage usage	5 (23.8)	89 (33.6)	.500
Erythrocyte (<3.82 × 10^{12}/L)	6 (28.6)	49 (18.5)	.370
Serum albumin (<40.8 g/L)	14 (66.7)	78 (29.4)	.023*
Blood glucose (>6.10 mmol/L)	7 (33.3)	60 (22.6)	.397

WBC = white blood cell.
*Significant variables.
‡American Society of Anesthesiologists.

Table 4

Risk factors of SSI following operative treatment of upper extremity fractures which demonstrated by multivariate logistic regression analysis.

Variable	Odds ratio	95% CI	*P* value
Open fracture	8.33	2.97–23.40	.000
Operation time > 122 min	3.12	1.07–9.05	.036
Serum albumin < 40.8 g/L	3.60	1.27–10.14	.015
Intraoperative blood loss (>135 mL)	3.98	1.41–11.20	.009

SSI = surgical site infection.

types of internal fixation and postoperative rehabilitation of UEF have been relatively scientific and substantial reported. Even methods of prevention and treatment of infection after upper extremity allotransplantation has been studied.[12] However, few studies have focused on wound complications after open reduction and internal fixation of UEF, while there are more articles demonstrated characteristics and prognostic risk factors of SSI following spine and lower extremity.[13–17] In this study, we retrospectively enrolled 286 UEF patients, demographic data, fracture and surgery related variables and laboratory examination indexes were extracted and analyzed, statistical results confirmed that incidence of SSI after surgical treatment of upper limb fracture was 7.3%, and open fracture, operation duration longer than 122 minutes, preoperative serum ALB lower than 40.8 g/L and intraoperative blood loss more than 135 mL would increases the risk of wound infection by 3.12 to 8.33 times.

Open fractures, which has certain relationship with wound complication, was well demonstrated by authors form orthopedic discipline. Momaya et al[18] retrospective analyzed patients with tibial plateau fractures and underwent open reduction and internal fixation over 10-year period (2003–2012), they found 11.1% patients developed a deep infection and open fractures was demonstrated to be independent risk factor of SSI. An age and sex-matched case-control study which aimed to analyze patients-related risk factors for deep SSI following operative treatment of ankle fractures was conducted by Ovaska et al,[19] they enrolled 1923 cases of ankle fracture operation which performed from 2006 to 2009. Final results showed 6.8% patients suffered from deep infection and soft tissue injury would increase the risk of SSI by 2.6 times. Ryan et al[20] have recruited 22,578 UEF patients in their study, the overall wound infection rate was 0.79%; patients inherit the characteristic of open fractures, obesity, smoking and American Society of Anesthesiologists class >2 were at prominent risk of SSI; meanwhile, patients with open fracture were found have a higher incidence of infection when compared to those with closed injuries (1.7% vs 0.7%). There were 34 cases of open fractures were extracted in the present study, which indicating a constituent ratio of 11.8%. The proportion of open injury in our study was consistent with the previous reports. In the study which conducted by MacDermid et al,[11] only 4.7% of the 266,324 patients were identified as open fractures, mean age of their cohort was 51.5 years and was much older than that in our investigation (44.4 years), moreover, a large group of fractures caused by fall from level ground and classified as fragility fractures in the previous study. However, in our research, 43.4% patients encountered with high-energy trauma and this characteristic may explain the high rate of open injury in the studied sample. Particularly, majority of patients with open fractures were referred by other medical institutions to our hospital, fracture type was complicated and soft tissue defect was serious for these patients, which often requires multiple surgeries to reconstruct the continuity of upper limb and ensure the effective coverage and survival of tissue, this situation may also attribute to a higher ratio of SSI in our study.

Longer operation time was also reported as an independent risk factor of SSI by studies involving in different disciplines. In colorectal surgery patients, incidence of SSI would increase to 1.7-fold when operation time >240 minutes,[21] patients who underwent primary joint arthroplasty and with an operative time of >90 minutes had a significantly higher incidence of SSI and periprosthetic joint infection (2.1% and 1.4%, respectively) compared to cases lasting between 60 and 90 minutes (1.1% and 0.7%), and those lasting ≤60 minutes (0.9% and 0.7%).[22] A systematic review which included 81 prospective and retrospective studies, the pooled analyses demonstrated that association between extended operative time and SSI typically remained statistically significant, with close to twice the likelihood of SSI observed across various time thresholds and risk of SSI increased with increasing time increments; for example, 13%, 17%, and 37% increased likelihood for every 15, 30, and 60 minutes of surgery, respectively.[23] Operation duration >122 minutes was identified as an important risk factor of SSI, at same time, intraoperative blood loss >135 mL would also increase the incidence of wound infection. Tourniquets are often not available for UEF, especially humerus fractures, and a longer operation time inevitably leads to increased bleeding loss. The longer operation time makes surgical incision exposed to the external environment, moreover, the increased amount of blood loss comprised immune capacity of the surgical site tissue, what's more, blood is a good culture medium for bacteria, which will elevate the incidence of SSI. These results suggest that intraoperative difficulties in fracture reduction and fixation should be fully evaluated preoperatively and the operation time should be shortened as much as possible. In addition, a good understanding of the anatomical structure of the surgical site also helps to reduce the amount of bleeding and surgical trauma.

Serum ALB level is an important index and simple method for evaluation of preoperative nutrition statue and malnutrition is reported as one of the prognostic risk factors of surgical infection. In Ushirozako[24] and his colleagues' research, data of 1115 patients who received spine surgery were analyzed, after at least 1 year follow-up 3.9% patients experienced wound infection, and ALB level of infected patients were lower than the non-SSI group (48.5 vs 51.7), what is more, patients with a normal and better nutrition condition were 0.94 times more likely to develop infection after spine surgery than those with malnutrition. For patients who underwent surgery due to SSI, nutrition statue was also plays an important role in the management of infection, in Maurer's[25] investigation 32.8% of orthopedic trauma patients suffered from SSI were at risk of malnutrition. Patients with SSI is associated with an increased number of comorbidities and need for medication intake, a decrease in mobility and a higher dependency for food acquisition, moreover, patients with poor nutrition statues exhibited a 6.2-times higher mortality rate than well-nourished ones.[25] In our study, mean ALB level for SSI and non-SSI groups were 36.9 ± 1.5 and 42.9 ± 0.3 g/L (*P*, .000), and preoperative ALB <40.8 g/L would increase the risk of wound infection by 3.6 times. It should be pointed out that, ROC analysis was introduced to determine the precise cut-off value of ALB in the present study rather than "malnutrition" to evaluating the association between nutrition status and SSI when compared with previous studies. This value was instructive in identifying patients with high risk of infection and formulating comprehensive evaluation and nutritional support as soon as possible.

Our study is not without limitations. First of all, the retrospective experimental design inevitably had selection bias and single-center design may limit the generalizability of the study results. Meanwhile, the sample size of this study was still relatively small, and the possible correlation between some demographic data, such as age, diabetes, hypertension and SSI has not been fully revealed. Variables that are widely concerned by clinicians, such as type of closed fracture and Gustilo-Anderson classification of open fracture, were not extracted and analyzed, relationship between such clinical indicators and the occurrence of wound infection was also not documented. Despite these limitations, our study still identifies some modifiable factors that would have positive role in the prevention of SSI after UEF.

5. Conclusions

In summary, 7.3% of patients with UEF were at risk of SSI, open fracture, longer operation duration, larger amount of intraoperative bleeding and a poor nutrition statue will increase the risk of wound infection by several times. Adequate preoperative evaluation, careful intraoperative manipulation, and timely and appropriate postoperative interventions should be formulated to reduce the incidence of SSI.

Author contributions

Data curation: Xin Dong.
Formal analysis: Xin Dong.
Investigation: Xin Dong.
Methodology: Xin Dong.
Software: Xin Dong.
Supervision: Xin Dong.
Writing – original draft: Xin Dong.
Writing – review & editing: Xin Dong.

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