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ORIGINAL ARTICLE

Wound infection in elbow fractures: Incidence and new management protocol

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Key Messages

- The purpose of the study was to demonstrate the role of wound management protocol in prevention of SSI following elbow fractures.
- Perioperative blood loss control and pain management were associated with a lower incidence of wound infection.
- Open fracture, diabetes mellitus, high level of glucose and leukocyte and ASA classification may increase the risk of SSI.
- Patients who are under the guidance of a wound management programme have a better NRS score and wound healing rate

1 | INTRODUCTION

Anatomical structure along with the trauma mechanism of elbow joint both are complex, therefore treatment of fracture around elbow remains a major challenge for orthopaedic surgeons. Clinical epidemiology studies demonstrated that, together with the forearm, elbow injuries constitute up to 15% of emergency visits for upper extremity injuries,[1-4] and the fracture incidence in men peaked at 37 years with high-energy traumas.[5] Acute elbow trauma is often combined with bone, ligament and muscle injury.[6] There is less soft tissue coverage around the joint; once the intraoperative dissection scope is too large, postoperative ectopic ossification and wound infection may occur, which will inevitably compromise the clinical outcome and quality of life of patients.

Surgical site infection (SSI) is one of the adverse events in trauma patients; it is reported that the overall incidence of infection after orthopaedic surgery and open fracture was 0.4 to 16.1% and 1 to 55%, respectively.[7-10] SSI is estimated to have an annual financial impact of more than $3 billion dollars nationally and is the largest contributor to the overall cost of health care-associated infections.[11] Infection follows open reduction and internal fixation (ORIF) of elbow fractures, especially the deep infection will cause catastrophic consequence, immobilisation time of elbow joint will be prolonged, which is accompanied by an obvious decrease of range of motion and function of the joint. Some patients have to undergo multiple operations to control persistent infection; in severe cases, amputation has to be performed.

At present, most of the current studies are focused on improvement of surgical techniques, and few authors have reported incidence and related factors of wound infection in patients who underwent ORIF of elbow fractures. What is more, an active and effective wound management pathway will undoubtedly contribute to satisfying wound healing and improvement of clinical effects. Given that, we conduct this study with the aim to: (I) formulate a perioperative wound management protocol to reduce the occurrence of postoperative wound infection; (II) report the incidence of SSI in elbow fractures; (III) identify the risk- and protect-factors associated with wound infection after ORIF in elbow trauma.

2 | MATERIAL AND METHODS

2.1 | Inclusion and exclusion criteria

After being approved by the Ethics Committee of the hospital, this retrospective study was conducted. Patients were recruited who were diagnosed with elbow fractures and underwent ORIF from January 2015 to August 2020 in our trauma centre.

The inclusion criteria were as follows: (I) elbow fractures: proximal humeral fracture, supracondylar fracture of the humerus, proximal ulnar radius fracture, radial head fracture, terrible triad of the elbow; (II) patients with elbow fractures and underwent ORIF; (III) patients were admitted to our trauma centre because of fracture and had not received surgical treatment in other institutes; (IV) patients with good willing of cooperation and can complete the collection of follow-up data.

The exclusion criteria were as follows: (I) patients with only soft tissue injuries and undergo debridement and suture; (II) patients with open fractures and treated with external fixator; (III) patients were diagnosed as postoperative wound infection of elbow fracture at the initial hospital admission; (IV) manipulative reduction, closed reduction and Kirschner wire fixation; (V) patients with incomplete clinical or follow-up data.

Patients who accepted the new wound protocol were defined as "WP" group; the others who underwent ORIF and received the conventional pathway of wound management programme were divided into the "traditional" group. The flow of participants through each stage of the study is presented in Figure 1.

2.2 | Wound management protocol

The new wound management pathway includes two aspects: perioperative blood loss control and surgical site pain relief. Tranexamic acid (TXA) and brachial plexus nerve block were introduced to ensure the application of this protocol.

TXA: Half an hour before the operation, patients received a continuous intravenous infusion of 15 mg/kg tranexamic acid, which was diluted in 100 mL 0.9% normal saline; 1 g of tranexamic acid was intraarticularly injected into the soft tissue when the incision was closed.

Pain management and rehabilitation programme: 5 days of patient-controlled analgesia (PCA) of brachial plexus after operation was applied to patients, 0.2%

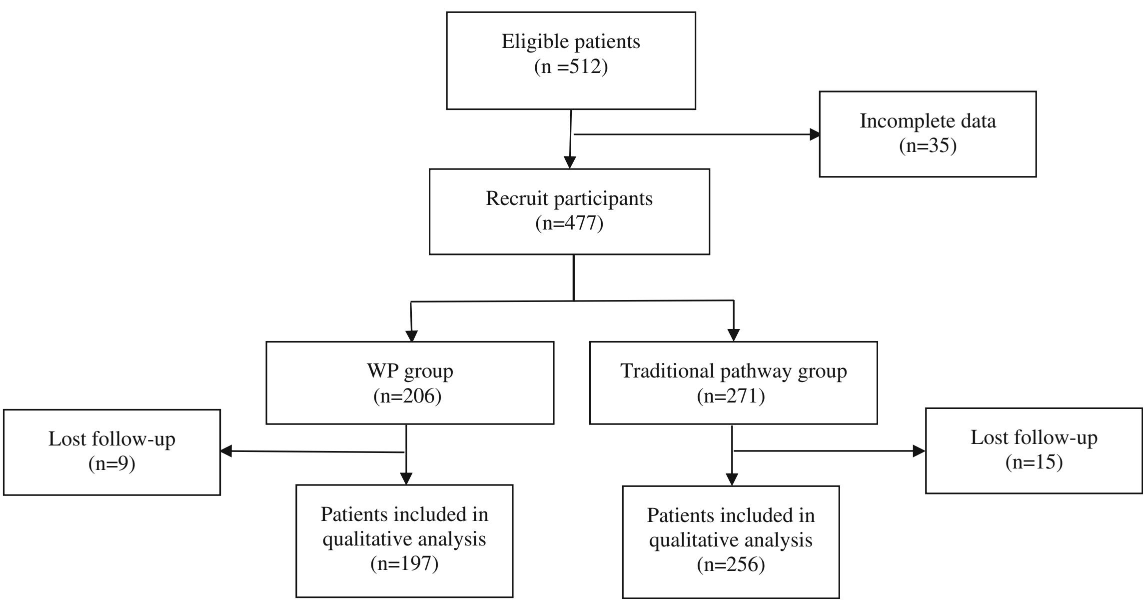

FIGURE 1 Flow diagram of recruited patients who underwent ORIF of elbow fractures and received new protocol and traditional pathway of wound management

TABLE 1 Comparison of the basic variables between patients in WP and traditional groups

Variables	WP group (n = 197)	Traditional group (n = 256)	*P* value
Age (year)	36.5 ± 17.7	39.5 ± 17.4	0.073
Gender (male/female)	130/67	155/101	0.234
Tobacco consumption	35	42	0.748
Additional comorbidities			
diabetes mellitus	8	17	0.259
cardiovascular disease	5	15	0.102
hypertension	19	21	0.624
ASA classification			
I	82	107	0.981
II	106	127	0.616
III	9	22	0.115
Intraoperative blood loss (ml)	160.5 ± 42.4	172.6 ± 55.6	0.029
Operation time (minutes)	115.1 ± 71.4	118.9 ± 58.6	0.539
Laboratory test indexes			
WBC (10^9/L)	8.3 ± 2.5	8.25 ± 2.6	0.832
RBC (10^{12}/L)	4.4 ± 0.5	4.3 ± 0.5	0.502
HG (g/L)	132.7 ± 17.2	131.9 ± 16.6	0.590
ALB (g/L)	42.9 ± 4.6	42.7 ± 5.0	0.634
GLU (mg/dL)	5.3 ± 1.1	5.4 ± 1.2	0.631
PLT (10^9/L)	239.4 ± 57.8	238.9 ± 60.9	0.920
Injury type (open/closed)	17/180	30/226	0.285
BMI (kg/m^2)	23.8 ± 4.1	23.6 ± 3.9	0.770

Abbreviations: ALB, serum albumin; ASA, American Society of Anesthesiologists; BMI, body mass index; GLU, blood glucose; HG, haemoglobin; PLT, blood platelet; RBC, red blood cell; WBC, white blood cell.

TABLE 2 Statistical results of multivariable logistic regression model for factors associated with the occurrence of wound infection

Variables	Odds ratio	95%CI	*P* value
Injury type (open fractures)	7.19	1.92–26.94	0.003
ASA classification	3.36	1.27–8.87	0.014
Residential location (rural/urban)	7.86	0.95–14.62	0.055[†]
Diabetes mellitus	7.06	1.76–28.27	0.006
GLU (mg/dL)	1.64	1.19–2.25	0.002
Anaesthesia type	0.33	0.10–1.00	0.051[†]
WBC count (10^9/L)	9.39	1.24–31.14	0.030
RBC count (10^{12}/L)	0.57	0.26–0.94	0.012
HG (g/L)	1.05	0.99–1.10	0.073[†]
CRP (mmol/L)	0.99	0.99–1.00	0.095[†]
New wound protocol	0.19	0.04–0.80	0.024

Abbreviation: CRP, C-reactive protein.
[†]$P > 0.05$, variables do not increase or reduce incidence of infection.

ropivacaine 250 mL was used to control postoperative pain and parameter setting of this analgesia model were background infusion rate of 2 mL/h (2 mL, locking time 60 min). Isometric contraction of biceps brachii and triceps brachii of the surgical limb was encouraged 2–6 days postoperatively; Passive training of flexion and extension for elbow and pronation/supination of forearm within the allowable range were conducted to accelerate blood circulation, reduce swelling and promote healing of wounds, as well as prevent adhesion of elbow joint.

2.3 | Data collection

The basic characteristics of participants were extracted from electronic patient record (EMR), including gender, age, body mass index (BMI), fracture type (open, closed) and operation side, residence and occupation, medications and additional comorbidities (diabetes mellitus, anaemia, chronic obstructive pulmonary disease, hypertension, immune system disease, cardiovascular disease), tobacco and alcohol intake.

Indicators related to operation were also analysed, including emergency or elective surgery, anaesthetic type and time, operation time, intraoperative blood loss and transfusion, type and dose of antibiotics, American Society of Anesthesiologists (ASA) classification. Preoperative laboratory test indexes, such as serum albumin (ALB), globulin (GLOB), total protein (TP), red blood cell (RBC), haemoglobin (HG), blood platelet (PLT); blood glucose (GLU), white blood cell (WBC), neutrophile granulocyte (NEUT), were recorded to assess the general situation of patients. Wound healing time and rate and length of hospital stay were recorded to evaluate the surgical wound condition of patients in different groups. What is more, numerical rating scale (NRS) was adopted to quantify the degree of wound pain for each patient.

2.4 | Statistical analysis

All the statistical analyses were conducted by using SPSS 19.0 software package (SPSS Inc., Chicago, Illinois). The continuous variables were summarised using mean ± standard, and categorical variables were expressed as frequencies. Mann-Whitney *U* test was carried out for abnormally distributed continuous variables and *t*-test for normally distributed variables. A *P* value <0.05 will be considered to be significant. Multivariable logistic regression analysis model was performed to verify the association

TABLE 3 Comparison of factors associated with wound infection in patients with and without SSI

Variables	Wound infection (n = 19)	Non-infection (n = 434)	*P* value
Injury type (open/closed)	5/14	42/392	0.020[‡]
ASA classification			
II	9	224	0.835
III	4	27	0.027[‡]
Injury mechanism (high/low energy)	9/10	176/258	0.554
Diabetes mellitus	4	21	0.007[‡]
GLU (mmol/L)			
3.90-6.10, References	11	348	0.396
>6.10	8	93	0.116
Anaesthesia type (General)	5	44	0.061
WBC count (10^9/L)			
4-10, References	13	335	0.743
>10	6	93	0.419
RBC count (10^{12}/L)			
3.80-5.10, References	12	344	0.545
<3.80	5	46	0.075
HG (g/L)			
115-150, References	12	313	0.724
<115	5	57	0.175
CRP (mg/L)			
0.00-10.00, References	4	130	0.526
>10	7	66	0.048[‡]
New wound protocol			0.001[‡]
Yes	3	240	
NO	16	194	

[‡]$P < 0.05$, there are significant differences between postoperatively infected or not patients for these variables.

TABLE 4 Statistical results of postoperative wound healing in patients under or not under the guidance of new wound management programme

Variables	WP group (n = 197)	Traditional group (n = 256)	*P* value
Wound healing time (day)	11.9 ± 0.9	13.9 ± 3.2	0.005[‡]
Length of hospital stay (day)	13.2 ± 8.0	15.3 ± 10.9	0.021[‡]
NRS score	1.35 ± 1.06	2.49 ± 1.86	0.002[‡]
Primary wound heal rate (%)	95.4	89.4	0.020[‡]

Abbreviation: NRS, numerical rating scale.
[‡] $P < 0.05$.

between included indexes and wound infection, Hosmer-Lemeshow test was used to evaluate goodness-of-fit of this model, and an acceptable fitness was enacted as $P > 0.05$.

3 | RESULTS

3.1 | Demographic data

Finally, a total of 453 patients who underwent initial ORIF of elbow fracture with complete data were recruited in our investigation, and the minimum follow-up time was 1 year. There were 197 patients with a mean age of 36.5 ± 17.7 years old who received the wound management protocol; and 256 patients with a mean age of 39.5 ± 17.4 years old in the traditional groups. Comparison of basic variables, such as age, gender, BMI, additional comorbidities, ASA classification, operation time, intraoperative blood loss, ALB, RBC, HG, PLT, WBC, between the two groups was summarised in Table 1, and there were no significant differences ($P > 0.05$) for all of the parameters mentioned above expect for intraoperative blood loss ($P = 0.029$).

3.2 | Wound infection: incidence and related factors

Nineteen patients were suffered from postoperative SSI, which demonstrated that the infection rate for patients who underwent ORIF following elbow fractures was 4.1%. All perioperative variables entered into the multivariable logistic regression model and the statistical results showed that diabetes mellitus (OR = 7.06, $P = 0.006$), GLU (OR = 1.64, $P = 0.002$), WBC count (OR = 9.39, $P = 0.030$), open fracture (OR = 7.19, $P = 0.003$), ASA classification (OR = 3.36, $P = 0.014$) were independent risk factors of wound infection. Moreover, the new wound management protocol (OR = 0.19, $P = 0.024$), RBC (OR = 0.57, $P = 0.012$) were contributed to a decreased infection rate (Table 2). The results of Hosmer-Lemeshow test at the first and last step were $P = 0.484$ and 0.691 ($P > 0.05$), respectively; these data demonstrated the goodness-of-fit of this logistic regression model. In terms of wound condition, the mean time of wound healing for uninfected patients was 12.3 ± 5.0 days and 30.4 ± 13.9 days for infected ones ($P = 0.015$); two cases of deep infection were observed in patients who have not received the new wound protocol, one case had delayed healing after debridement and change of internal fixation; internal fixation was replaced by external fixator for one case because of repeated infection.

3.3 | Role of wound management protocol

Three patients were diagnosed with wound infection in the WP group, which indicated a 1.5% (0.6% for overall rate) incidence of SSI. By contrast, 16 patients developed SSI postoperatively, and the calculated infection rate was 6.2% (3.5% for overall rate). Variables that demonstrated association with infection identified by multivariable logistic analysis are shown in Table 3, from which we can see that the percentage of open fracture, ASA classified III, diabetes was higher in infected patients than the normal ones, and the difference was significant ($P < 0.05$). Table 4 presented the parameter of wound healing for patients who suffered from SSI or not. Length of hospital stay for WP group patients was 13.2 ± 8.0 days, which was 2.1 days shorter than the traditional group; the NRS score of each patient in the two groups at discharge was 1.35 ± 1.06 and 2.49 ± 1.86, respectively; as for wound healing time and primary wound healing rate, WP patients have obtained better results than traditional group patients in both two aspects (11.9 ± 0.9 versus 13.9 ± 3.2; 95.4% versus 89.4%) mentioned above.

4 | DISCUSSION

Elbow joint is a stable and flexible joint in the human body, which contains intricate bone and soft tissue structure; a stable and painless movable elbow joint is essential for most of the activities of daily living.[12] Currently, modern angular stable and anatomically preshaped implants facilitate a biomechanically adequate osteosynthesis and avoid or decrease functional impairment. However, complications following surgical intervene of elbow fracture will inevitably and significantly compromise the therapeutic effect. Among which, wound infection is one of the most feared and challenging adverse events; infection can generate delayed healing, permanent functional loss and even amputation of the affected limb. A substantial number of patients with wounds require hospital treatment at some stage, which can escalate the costs of care significantly, and a study from the United States estimated the costs of SSI to be approximately $20 800 for each patient.[11]

Because of the significant soft tissue dissection and damage, elbow joint is at great risk for severe wound complications in patients who have received surgical treatment. In addition, relatively thin soft tissue envelope along with postoperative swelling and shear force all contributed to the occurrence of infections. In this study, a total of 4.1% of patients developed SSI, infection rates after open and closed fracture were 10.6% and 3.4%, respectively, and these data were consistent with previous studies.[7] Meanwhile, 3.7% of patients were diagnosed with superficial infection and 0.4% of patients suffered from deep infection. Distal humeral fractures in adults have an estimated annual incidence of 5.7 per 100 000 persons[13] and occur in a bimodal distribution. There are two high-risk ages for fractures of distal humerus: the first peak refers to males aged 12 to 19 years and injury is usually caused by high-energy trauma, whereas the other peak occurs in elderly population, especially in ageing women.[14] Palvanen et al[15] reported a significant increase in the incidence of these fractures in elderly women, they found a 5-fold increase in the annual number of distal humeral fractures in women older than 60 years. Patel et al[16] reported a deep infection incidence of 9% in 43 distal humeral fracture patients in 2020. A series of 32 type C distal humerus fractures fixed with parallel plates were analysed by Athwal,[17] of which 6% developed a superficial wound infection. Lwernce et al[18] conducted a study on 89 recruited distal humeral fracture patients of whom 29 fractures were open, and there were 7, 11 and 11 cases for Gustilo-Anderson grade I, II and III, respectively. During the follow-up period, 14 cases of wound complications were observed, which indicated an incidence ratio of 15.7%; 10 patients (11.2%) developed infection and organisms were grown from culture specimens taken at the time of debridement. In this study, the average time to complete clinical healing of wound was 30.4 days (ranges, 19-112 days); this time was shorter than that of 79 days reported by Lwernce, considering the mean age and proportion of open fracture in their study (58 versus 38.2 years; 33% versus 10.3%) were older and higher than ours, this difference could be explained. However, excellent results were also demonstrated by other authors, Moursy et al[19] retrospectively reviewed 30 consecutive distal humerus fracture patients (over 70 years) who underwent ORIF, after a mean follow-up period of 3.8 years (range, 1-9 years) they found no infections occurred in the presented cohort. In summary, wound infection is one of the most common complications after ORIF of elbow fractures and is often observed even after optimal stable fixation and proper rehabilitation. Therefore, some scholars even advocated that infection should be suspected in any patient with persistent drainage and delayed union or non-union of the fracture around elbow.

The most important finding of this study is that patients with diabetes mellitus, open elbow fractures, worse ASA score and a high preoperative level of blood glucose and leukocyte would have an increased risk of infection compared with similar injury patients. Epidemiologic studies have demonstrated that in United States, diabetes mellitus affects an estimated 18 million people and costs $132 billion of the federal annual expenditures.[20] Similarly, a nationally representative cross-sectional survey, which consisted of 170 287 participants in 2013 in Mainland China, found that the estimated standardised prevalence of total diagnosed and undiagnosed diabetes was 10.9% among the Chinese adult population.[21] In the present study, the risk of wound infection for patients with diabetes mellitus was 7-fold than that of non-diabetic ones; meanwhile, a high preoperative level of blood glucose would also increase the probability of SSI (OR = 1.64). In spinal instrumentation surgery, diabetes has been demonstrated by many researchers to be an important risk factor for wound infection. Fifteen (3.5%) cases of superficial and deep infection were observed in 431 patients who received spine surgery in Shoji and his colleagues' study;[22] they found diabetes have a significant relationship with SSI and the odds ratio was 4.7 (95% CI:1.5-14.4). Association between diabetes and SSI was also presented by other surgical disciplines; in a 7-year single-centre study performed by Lemaignen et al[23] in 2015, among the 7170 patients who have undergone cardiac surgeries, 4.1% developed SSI and diabetes mellitus was identified as an independent risk factor. Hyperglycaemia will significantly increase the risk of infection were also reported in general surgery,[24] breast surgery,[25] neurosurgical procedures and so on. In the clinical practices, it was considered that high level of glucose at the surgical site is conducive to bacterial colonisation; however, the main mechanism between diabetes and infection was that the immune function of diabetic patients was compromised and physiological "barrier" was weakened, thereby leading to delayed healing and increasing the risk of infection.

Open fractures constitute a major source of morbidity and mortality associated with adult trauma,[26] and a serious complication after open fractures is infection. SSI prevention has been assisted by identification of open fractures as independent predictors of infection, which was first published by Gustilo et al.[27] Ryan et al[28] retrospectively analysed the American College of Surgeons National Surgical Quality Improvement Program database from 2008 to 2015, a total of 1298 open upper extremity fractures were identified, the incidence of wound infection was 1.7%, and this rate was higher when compared with those with closed injuries (0.7%). By contrast, the incidence of infection for open and closed elbow fracture was 10.6% and 3.4% in our study, and this difference was statistically significant ($P = 0.000$); moreover, open injury and high preoperative WBC count would increase the risk of infection by 7- and 9-fold, respectively (OR: 7.19, 9.39). In terms of open fracture of the lower limb, a 7.6% deep infection incidence at 30 days was observed in Costa and his colleagues' study.[29] Open fractures are always represented as a major challenge for the orthopaedist and frequently demand a complex of soft tissue and bone procedures to achieve a satisfying wound healing along with adequate limb function. Administration of systemic antibiotics is still an essential part of the surgical management pathway for prevention of infection;[30] early antibiotic administration is a key principle of open fracture management, because most patients with open fractures have wounds contaminated with microorganisms.[31] No deep wound infections were seen 90 days after type III open tibial fractures if antibiotics were given within 66 min of initial injury occurred, and this rate was unaffected by patients' basic condition of age, tobacco consumption, diabetes mellitus and injury score.[32] Optimal duration of antibiotics therapy remains controversial; some authors have demonstrated that 1 to 5 days of application of antibiotics have similar infection rates; however, an additional 3 days administration of antibiotics is still recommended for subsequent surgical procedures.[33]

ASA classification was performed in the surgical disciplines to evaluate the patients' comorbidities and physical status; consistent with other studies, we identified ASA score as an independent predictor of SSI.[34,35] RBC was identified as a protective factor in this study with an odds ratio and 95% confidence interval of 0.57 and 0.26 to 0.94, respectively. Erythrocytes are the most abundant cell type in the human body, numbering between 20 and 30 trillion and accounting for nearly 70% of the total cell count in the average adult,[36] these cells play an important role in preventing postoperative incision infection through a variety of mechanisms. First of all, RBC retains the ability to bind and interact with a variety of inflammatory molecules, including pathogens, nucleic acids and chemokines, thereby regulating and modulating immune responses. What is more, haemoglobin, heme and other internal components of erythrocytes are also formidable facets of innate immunity, capable of generating antimicrobial reactive oxygen species to defend against invading hemolytic microbes as well as promoting pathologic inflammatory and autoimmune responses.

Collaborators from a study group of academic surgeons initially invented the term of enhanced recovery after surgery (ERAS) in 2001, London.[37] As important content of ERAS program, wound management plays an indispensable role in reducing surgical-related complications and improving the clinical effect. As an antifibrinolytic hemostatic agent, TXA can competitively block lysine binding sites on plasminogen molecules, and has been proved to be a cost-effective "tool" to control perioperative blood loss. In the present study, we have introduced the combination of intravenous and local administration of TXA in elbow fractures patients to decrease the intro- and postoperative blood loss and transfusion. TXA was confirmed to be associated with reduced periprosthetic joint infection (PJI) after primary total joint arthroplasty (TJA); in a prospective study that used an institutional database and identified 6340 patients who undergone initial TJA, univariable analysis demonstrated administration of TXA contributed to a lower infection rate (OR, 0.47).[38] In addition, TXA can also reduce the risk of subsequent acute PJI in aseptic revision arthroplasty.[39] Pain management as a part of wound treatment has predominantly targeted acute pain resulting from surgery or trauma; wound pain is a complex pathophysiologic process occurring locally and systemically, and has adverse impact on mobility and has regarded as a risk factor of decline in quality of life. Notably, wound pain has been linked with delayed wound healing.[40,41] In the clinical practice, we adopt PCA of brachial plexus nerve block to relieve patients' pain around surgical site and guarantee the remission of anxiety and distress caused by surgical trauma. Patients who have received the wound management protocol in our study obtained a better NRS score when compared with the rest of the ones. Meanwhile, a good pain management programme ensures the effectiveness of early active and passive rehabilitation exercise, which is particularly important for the elbow joint, which is prone to postoperative stiffness. However, some authors found that denervation could lead to significantly impaired bone healing with decreased callus density and mechanical strength,[42] and the role of neuropeptides and neurotrophins play in the regulation of bone healing has aroused the interest of many scholars.

There are some limitations for the present study; first, this investigation was designed as a single-centre one, and the sample of patients who developed postoperative wound infection was relatively small, and some information and selection bias may be inherited; in addition, confounding factors, including experience of surgeons and time between initial injury and surgery, have an influence on the statistical results probably. Thirdly, all data were extracted from patients who underwent ORIF; therefore, we cannot apply the results to all elbow fractures patients. Despite these disadvantages, our study had several strengths, we have evaluated the relationship between demographic and clinical variables and the occurrence of wound infection in patients with elbow fractures following ORIF; moreover, we have formulated a wound management protocol and verified the positive role of blood loss control and pain relive in reducing the incidence of SSI.

5 | CONCLUSION

In summary, the incidence of wound infection in fracture around elbow after ORIF was 4.2%; open injury, diabetes mellitus, high level of preoperative blood glucose and WBC count and ASA classification score were associated with high risk of SSI. Erythrocyte immunity plays a positive role in promoting wound healing. Wound management pathway, including blood loss control and pain relief, was helpful to prevent infection and reduce the risk of SSI to 0.2-fold compared with traditional management programme.

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ETHICAL BOARD REVIEW STATEMENT

This material has not been published and is not under consideration elsewhere.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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