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Comparison of plate and intramedullary nail fixation of extra-articular tibial fractures: A retrospective study exploring hidden blood loss

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ABSTRACT

Purpose: To explore the hidden blood loss (HBL) in treatment of extra-articular tibial fractures with plate and intramedullary nail fixation.
Methods: We conducted a retrospective study including 209 consecutive patients treated by plate (Group LCP) or intramedullary nail fixation (Group IMN) for extra-articular tibial fractures between January 2015 to December 2017. Demographics, intraoperative data, perioperative laboratory values, transfusion rate, and early complications were collected and analyzed.
Results: Of 209 patients, 96 patients fixed with IMN and 113 fixed with LCP. The average HBL was 272.71 ± 57.88 ml in Group LCP and 507.66 ± 109.81 ml in Group IMN, and there was statistical difference in the HBL between two groups ($p < 0.001$). The Hb and Hct loss, surgical duration, and postoperative number of anemic patients in Group IMN were significantly higher than in Group LCP ($p < 0.001$), and IMN fixation has a significantly higher rate of transfusion ($p = 0.027$), whereas patients in group IMN has significantly less VBL ($p < 0.001$), shorter postoperative hospital stay ($p < 0.001$), and less superficial infection ($p = 0.014$).
Conclusions: There was a significant amount of hidden blood loss after reamed intramedullary nail fixation for extra-articular tibial fractures, which was much higher than expected. In view of the morbidity of acute anaemia and transfusion, we suggest that for patients who suffer from extra-articular tibial fractures with multiple injuries, or those with low haemoglobin preoperatively, plates might be more suitable than nail fixation.

Introduction

The optimal implant for repair of extra-articular tibial fractures remains controversial; the main controversy is between plate and intramedullary nailing fixation [1–3]. As is well known, traditional open reduction and locking compression plate (LCP) fixation is the most common fixation method to achieve anatomical reduction; however, LCP can cause great trauma and has a high risk of soft-tissue complications, such as poor healing of incision, and wound infection [4,5]. With the development of internal fixation, intramedullary nails (IMNs) are widely used by surgeons because of their wide indications, minimal invasion, reliable fixation, strong torsional stress and low stress shielding [6–8]. It is worth noting that IMNs will temporarily damage the blood supply of the medulla [9], moreover, malunion is more likely to occur after IMN fixation, and there is a trend toward more patients with persistent knee pain [10]. Xue et al. performed a systematic review and meta-analysis comparing IMNs and plates for treatment of extra-articular tibial fractures and reported that IMN fixation may be better than plate fixation, with better functional recovery and lower risk of infection, but IMN has a higher malunion rate [11]. In addition, Vallier reported that plates and nails are both effective in treating tibial fractures, and most patients have good long-term function [9]. Furthermore, he considered that careful soft tissue handling during the operation minimises the risk of infection and poor wound healing resulting from plate fixation, and suprapatellar nailing is expected to reduce intraoperative malalignment.

Previous studies usually compared the clinical and radiological outcomes between plate and IMN fixation, and owing to the low amount of intraoperative blood loss, the amount of postoperative blood loss is rarely noticed [1,12]. Minhas et al. reported no difference in complications within one month after plate fixation

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and intramedullary nailing for extra-articular tibial fracture, but the demand for blood transfusion after plate fixation was reduced (5.96% transfusion rate after IMN fixation versus 2.56% after plate fixation, p = 0.047) [13]. Thus, we hypothesised that a significant amount of invisible blood loss (hidden blood loss) may occur after IMN fixation, which may increase the risk of blood transfusion and may influence the effect of treatment and functional recovery.

Since the concept of hidden blood loss (HBL) was put forward in 2000 [14], an increasing number of studies have provided evidence for HBL in a range of orthopaedic surgical procedures, such as hip fracture surgery [15–17], total knee [18–20] or hip arthroplasty [21] and spinal surgery [22–26]. To the best of our knowledge, there are very few reports in the literature comparing the HBL between plate and IMN fixation for extra-articular tibial fracture. The aim of our retrospective study was to explore the HBL in treatment of extra-articular tibial fractures with plate and IMN fixation.

Patients and methods

Patients

This study protocol was approved by the Ethics Committee of our hospital. The inclusion criteria were as follows: closed extra-articular tibial fracture with or without fibula fracture fixed with LCP or IMN, and no other traumatic fractures and pathological fracture; no history of haematological diseases (i.e. haemophilia or vitamin K deficiency); and no history of anticoagulant drugs. From January 2015 to December 2017, 258 consecutive extra-articular tibial fracture patients were fixed with LCP or IMN in our institution. Of these patients, 49 were excluded: 32 patients combined with other traumatic fractures, 11 were open fractures, 5 had a history of taking anticoagulant drugs and there was one haemophiliac patient. Finally, 209 patients (134 males and 75 females) met our inclusion criteria and were enrolled in our study: 96 patients were fixed with IMN and 113 patients with LCP. The data of age, sex, weight and height; BMI; fracture type (AO type 42-A, B, and C); comorbid diseases (i.e., hypertension, diabetes); laboratory data (including preoperative platelet (PLT), plasma fibrinogen (FIB), activated partial thromboplastin time (APTT), prothrombin time (PT), haemoglobin (Hb), and haematocrit (Hct) levels; postoperative Hct and Hb levels 72 h after surgery); the type of anaesthesia; American Society of Anesthesiologists (ASA) scores; the visible blood loss (VBL) during the operation; the operation delayed time (ODT); surgical duration; the length of postoperative hospital stay (LOPS); and early complications (superficial infection or thrombosis) were recorded and analysed. All patients underwent surgery in our institution; Group LCP were treated with open reduction and locking compression plate fixation (Synthes, Switzerland), and Group IMN were fixed with reamed intramedullary nails (Trigen Meta-Nail, Smith & Nephew, Andover, MA, U.S.A.) with compression, via suprapatellar or infrapatellar approach. Blood transfusion was performed when haemoglobin was below 80 g/L or appeared with ischaemic symptoms (i.e. shock, chest pain and shortness of breath, etc.) [27].

Calculation of hidden blood loss

The estimated blood volume (EBV) of each patient was calculated through Nadler's formula [28].

$$EBV(L) = k1 \times height(m)^3 + k2 \times weight(kg) + k3$$

where k1 = 0.3669, k2 = 0.03219, and k3 = 0.6041 for males, and k1 = 0.3561, k2 = 0.03308, and k3 = 0.1833 for females.

Then we assumed that the blood volume on admission and at 72 h after surgery was the same [23], and total blood loss (TBL) was calculated by Gross's formula [29], which could be reflected by a reducation of Hct level perioperatively.

$$TBL(ml) = EBV(L) \times (Hct_{pre} - Hct_{post}) / Hct_{ave} \times 1000$$

The VBL during the surgery was recorded by the anaesthetists, and included the blood in the sponges used during the operation and in suction bottles (without the lavage fluid used during the surgery). In addition, if a patient had received a blood transfusion, as denoted by the transfusion volume (TV), this part of blood would be included in the TBL calculation. The HBL was calculated by the formula:

$$HBL(ml) = TBL(ml) - VBL(ml) + TV(ml).$$

Additional measurements

Hb concentration was used to define anaemia, with separate threshold values for women and men, as established by the World Health Organization (<120 g/L for women and <130 g/L for men) [30] (<120 g/L for women and <130 g/L for men). The preoperative and postoperative number of anaemic patients are shown in Fig. 2.

Statistical analysis

The data analysed using SPSS for Windows software (ver. 19.0; SPSS Inc., Chicago, IL). For continuous variables, the Kolmogorov–Smirnov test was applied to determine whether they followed a normal distribution. For normally distributed variables, the means were calculated and compared using the independent samples *t*-test (Student's *t*-test); otherwise, the Mann–Whitney *U* test was used for group comparison. The chi-square test was used to analyse qualitative variables. In all analyses, $p < 0.05$ was taken to indicate statistical significance.

Results

In total, 209 patients were included in our study: 96 patients fixed with IMN and 113 with LCP. The demographic and preoperative laboratory data of the patients are shown in Table 1, and there was no statistically significant difference between the two groups in terms of sex, age, height, weight, BMI, fracture type,

Table 1
The demographic and preoperative laboratory data of the patiens.

Characteristic	Group LCP	Group IMN	p
Number of patients	113	96	
Gender (male/female)	73/40	61/35	0.873
Age(Year)	43.21 ± 14.57	46.22 ± 13.06	0.121
Height(m)	1.67 ± 0.12	1.66 ± 0.09	0.679
Weight(Kg)	64.55 ± 9.37	64.92 ± 10.21	0.786
BMI	22.96 ± 1.42	23.25 ± 2.30	0.265
Fracture type			0.346
AO type 42-A	44 (38.94%)	47 (48.96%)	
AO type 42-B	45 (39.82%)	32 (33.33%)	
AO type 42-C	24 (21.24%)	17 (17.71%)	
Hypertension	9/113	10/96	0.539
Diabetes	7/113	8/96	0.551
APTT(S)	33.50 ± 4.70	33.98 ± 4.02	0.436
PT(S)	13.50 ± 0.72	13.40 ± 0.69	0.303
FIB(g/L)	16.14 ± 0.84	16.06 ± 1.09	0.509
PLT(10^9/L)	212.06 ± 51.07	214.69 ± 56.95	0.726
Hb(g/L)	130.89 ± 16.45	128.84 ± 13.60	0.333
Hct	0.38 ± 0.05	0.39 ± 0.04	0.832

BMI: body mass index; APTT, activated partial thromboplastin time; PT, prothrombin time; FIB, plasma fibrinogen; PLT, platelet; Hb, Hemoglobin; Hct, Hematocrit.

comorbid diseases, APTT, PT, FIB, PLT, preoperative Hb, or preoperative Hct. The data of the ASA scores, the type of anaesthesia, the ODT, surgical duration and the LOPS are shown in Table 2. In addition, the perioperative blood loss data of the two groups are shown in Table 3 and Fig. 1. No difference was found between the two groups in the ASA scores, the type of anaesthesia, the ODT and the EBV, whereas the surgical duration, HBL, Hb loss and Hct loss in Group IMN were significantly higher than in Group LCP. In addition, Group IMN had less LOPS and VBL than did Group LCP. In Groups LCP and IMN, 12 and 2 cases, respectively, had a superficial infection ($p = 0.014$), which healed after debridement and wound dressing, and there was no case of thrombosis in either group. Meanwhile, in Groups LCP and IMN, 2 and 8 cases, respectively, received a transfusion ($p = 0.027$). In Groups LCP and IMN, there were 27 and 22 preoperative anaemic cases, respectively, and this number increased to 55 and 79, respectively, after the surgery ($p < 0.001$).

Table 2
Comparison of ASA scores, Anesthesia type, operation delayed time, surgical duration, the length of postoperative hospital stay between IMN and LCP fixation.

Characteristic	Group LCP	Group IMN	p
ASA scores			0.866
1	36 (31.86%)	29 (30.21%)	
2	67 (59.29%)	60 (62.50%)	
3	10 (8.85%)	7 (7.29%)	
Anesthesia type			0.684
General anesthesia	37 (32.74%)	34 (35.42%)	
CSEA	76 (67.26%)	62 (64.58%)	
ODT (d)	3.75 ± 1.98	3.61 ± 2.04	0.597
Surgical duration(min)	54.91 ± 7.71	88.12 ± 12.06	<***0.001***
LOPS(d)	5.37 ± 2.18	4.26 ± 1.02	<***0.001***

ODT, the operation delayed time; CSEA, combined spinal-epidural anesthesia; LOPS, the length of postoperative hospital stay.
Bold values indicate $p < 0.05$.

Table 3
The perioperative blood loss and early complications between two groups.

Characteristic	Group LCP	Group IMN	p
EBV(L)	4.26 ± 0.72	4.28 ± 0.70	0.873
TBL(ml)	272.71 ± 57.88	507.66 ± 109.81	<***0.001***
VBL(ml)	123.01 ± 34.41	54.17 ± 26.78	<***0.001***
HBL(ml)	153.24 ± 45.79	473.29 ± 102.75	<***0.001***
Hb loss	10.46 ± 3.71	16.71 ± 4.79	<***0.001***
Hb loss %	8.12 ± 3.19	13.15 ± 4.20	<***0.001***
Hct loss	0.02 ± 0.01	0.04 ± 0.01	<***0.001***
Blood transfusion	2	8	***0.027***
Superficial infection	12	2	***0.014***
Thrombosis	0	0	–

EBV, estimated blood volume; TBL, total blood loss; VBL, visual blood loss; HBL, hidden blood loss; Hb, hemoglobin; Hct, hematocrit.
Bold values indicate $p < 0.05$.

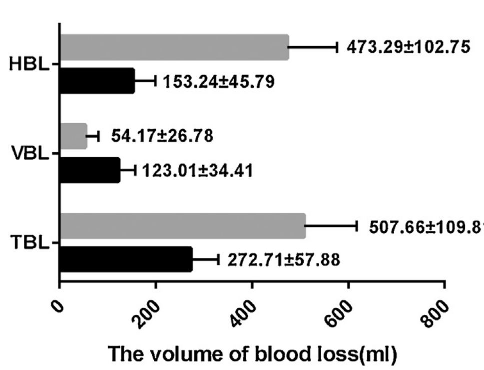

Fig. 1. Mean volume of blood loss between 2 groups.
TBL, total blood loss; VBL, visual blood loss; HBL, hidden blood loss.

Discussion

Many studies have suggested that there is a large proportion of HBL after orthopaedic surgery. After studying 101 cases of total hip arthroplasty (THA) and 101 of total knee arthroplasty (TKA), Sehat et al. showed that the mean TBL after THA was 1510 ml, of which the HBL was 471 ml (26%) and the mean TBL after TKA was 1498 ml, of which the HBL was 765 ml (49%) [31]. In addition, there is significant HBL in minimally invasive surgery. Wu et al. found a volume of 282 ± 162 ml HBL after percutaneous kyphoplasty surgery, which was much higher than expected [23]. Generally, a large amount of postoperative HBL may increase the incidence of adverse events. Liu et al. considered that postoperative hyperfibrinolysis causes the accumulation of HBL in the third space of anatomy, resulting in postoperative inflammation, lower limb swelling and pain [32]. Moreover, Tian et al. suggested that HBL often leads to postoperative anaemia and requires blood transfusion, which is usually associated with transfusion-related complications [33]. Although numerous studies have compared the plate and IMN fixation of extra-articular tibial fractures from clinical and radiological outcomes [7,13,34], few studies have evaluated the effect of these two different fixation methods on HBL, and the HBL of this patient group should not be ignored.

At present, studies usually concern intraoperative VBL, and the total amount of VBL is rarely during the surgery of extra-articular tibial fractures. The data from Zou et al. showed that the VBL during open reduction and internal fixation was a mean volume of about 87.5 ml (range 69–115 ml) [12]. Shen et al. reported a mean volume of 20 ml (range 10–30 ml) VBL during IMN fixation [1]. In fact, IMN fixation had a higher rate of blood transfusion than LCP fixation, and the TBL may be far greater than that reported in previous studies [13]. Thus, we indicated that a significant amount of invisible blood loss (HBL) may occur after IMN fixation.

Our preliminary data suggested that the amount of TBL and HBL were significantly higher in Group IMN, while Hb and Hct in Group IMN were significantly decreased, which indicates that patients fixed with IMN had a higher perioperative blood loss. This might be due to the reaming steps of the IMN fixation; as is well known, the larger the nail diameter, the better the stability that can be provided [35]. When the inner cortical bone is removed to increase

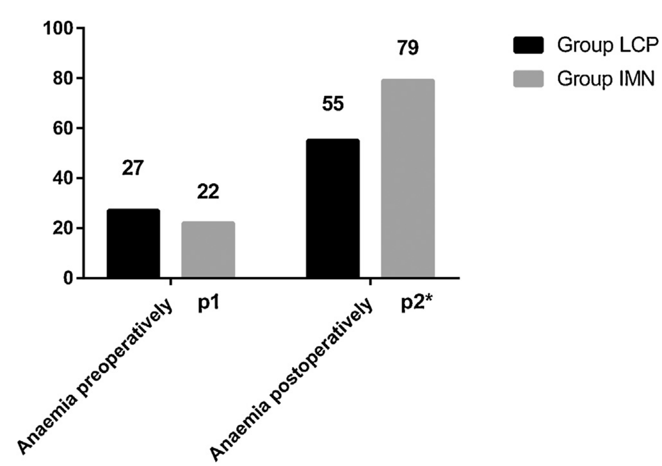

Fig. 2. The preoperative and postoperative number of anemic patients.
Hb concentration was used to define anemia, with separate threshold values for women and men, as established by the World Health Organization (<120 g/L for women and <130 g/L for men).$p1 = 0.868$ and $p2^{*} < 0.001$.

the diameter of the medullary canal, additional postoperative blood loss will be caused. In addition, we found that the surgical duration for IMN fixed patients was significantly higher than that for LCP fixation, and Saied et al. reported that the tourniquet used during extra-articular tibial fractures will increase the amount of postoperative haemo-vacuum drainage [36]. Similarly, Huang et al. reported that TKA without a tourniquet resulted in less HBL than with a tourniquet [37]. The extension of surgical duration usually means the prolongation of tourniquet time, which may cause more HBL than LCP fixation. In the present study, HBL was approximately 50% of TBL in Group LCP, and this number rises to more than 90% in the IMN group. The perioperative blood loss of IMN patients was almost all HBL, so we cannot ignore this part of blood loss. The anaemia patients in Group IMN were significantly more than in Group LCP, and severe HBL can cause an adverse effect on wound healing and affect patient's postoperative recovery, and usually need blood transfusion [38]. A large number of postoperative blood transfusion patients will increase the occurrence of haemolysis, thereby increasing the amount of HBL [24]. Shobhit et al. reported that plate fixation has a lower risk of postoperative blood transfusion compared to IMN (5.96% transfusion rate after IMN fixation versus 2.56% after plate fixation, $p = 0.047$) [13]. Furthermore, blood transfusion will also increase the incidence of infections or other complications, such as transfusion reaction [15,39,40]. Previous studies suggest that an increase in postoperative blood loss will lead to prolonged hospitalisation and an increased risk of wound infection [10]. Our data indicated that there was a significant amount of HBL after reamed intramedullary nail fixation; however, patients in the IMN group had significantly shorter postoperative hospital stays, and a lower rate of poor healing of the incision. We thought that although larger HBL occurred after IMN fixation compared to LCP fixation, this method does not require a large incision and extensive soft tissue dissection [3], which may reduce the risk of superficial infection and shorten postoperative hospital stay.

A significant amount of postoperative blood loss will increase the risk of deep-vein thrombosis, and kidney and heart decompensation [41], and such blood loss should be considered when managing extra-articular tibial fractures. Reducing blood loss is the first issue that should be solved; bone healing and functional recovery are further considerations [42]. In our opinion, although IMN fixation results in less VBL, shorter postoperative hospital stays and less superficial infection, IMN fixation leads to more HBL and TBL than does plate fixation. Similar to previous studies, we found a statistically higher transfution rate in the IMN group. Due to the significant amount of HBL, more rigorous postoperative haemoglobin monitoring should be performed after IMN fixation for extra-articular tibial fractures. Based on our results, plates might be more suitable than IMN fixation for patients with multiple injuries or those with low haemoglobin preoperatively, in view of the morbidity of acute anaemia and transfusion.

To our knowledge, this is the first investigation of HBL after LCP and IMN fixation for extra-articular tibial fractures; we found that there was a significant amount of HBL after IMN fixation. It is worth mentioning that the amount of HBL was much higher than expected, and should be considered when treating extra-articular tibial fractures.

There are several limitations of our study that should be clarified. First, the sample size of our retrospective study was relatively small, and other potential factors that affect HBL may not be included in this study. Thus, further prospective studies with larger samples are required to validate our findings. Second, our study compared the differences between the two internal fixation methods only from the perspective of HBL; however, we did not involve other factors such as fracture healing rate, functional scores etc. Finally, postoperative Hct was estimated on the third day after surgery; we assumed that fluid shifts would have been completed in the patient by this time. However, if this is not the case, the HBL obtained might be falsely low.

Conclusion

There was a significant amount of hidden blood loss after reamed intramedullary nail fixation for extra-articular tibial fractures, which was much higher than expected. In view of the morbidity of acute anaemia and transfusion, we suggest that for patients who suffer from extra-articular tibial fractures with multiple injuries, or those with low haemoglobin preoperatively, plates might be more suitable than nail fixation.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Statements

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethics Committee of Second Affiliated Hospital of Wenzhou Medical University and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards, for this type of study formal consent is not required.

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