Research Progress of Hidden Blood Loss after Tibial Fracture Surgery

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Abstract: Tibial fracture is a common traumatic injury in the field of orthopedics. The problem of hidden blood loss after tibial fracture is gradually attracting the attention of clinicians. Hidden blood loss not only has a negative impact on the rehabilitation process of patients, but also may cause a variety of complications. Therefore, it is particularly important to have a deep understanding of the mechanism of hidden blood loss and the related evaluation methods. Studies have shown that the mechanism of hidden blood loss after tibial fracture surgery is complex, involving the influence of many factors, including surgical methods, individual differences of patients, postoperative management and so on. Although a variety of methods have been proposed to assess hidden blood loss, they still face certain challenges and limitations in practical application. In addition, the impact of hidden blood loss on patient outcomes has not been fully studied and understood. This article reviews the research progress of hidden blood loss after tibial fracture surgery, discusses its mechanism, evaluation methods and influencing factors, and analyzes its potential impact on the rehabilitation of patients.

***Keywords*:** tibial fracture, hidden blood loss, postoperative management, evaluation methods, clinical research

1. Introduction

Tibial fracture is a common type of fracture, including tibial shaft fracture and tibial plateau fracture, among which tibial plateau fracture is more common. The incidence of this disease has been increasing in adolescents and the elderly. According to Swedish epidemiological studies, the annual incidence of tibial fractures is about 50 per 100,000 people, which is more significant in high-energy trauma (such as traffic accidents) and sports injuries[1]. Tibial fractures not only affect the quality of life of patients, but also lead to long-term dysfunction and complications, such as delayed union, nonunion, infection, and hidden blood loss after surgery. Therefore, understanding the epidemiological characteristics of tibial fractures and their clinical significance is essential to develop effective treatment options.

Hidden blood loss is defined as blood loss that is not immediately recognized during or after surgery and is usually assessed by postoperative blood tests or clinical findings. Studies have shown that the occurrence of hidden blood loss may lead to postoperative anemia, delayed recovery and increased risk of complications, and may even affect the overall treatment effect [2]. Patients with tibial fractures may face significant hidden blood loss after surgery, which is different in different types of tibial fractures, especially in the case of complex or multiple fractures. Therefore, the monitoring and management of postoperative hidden blood loss has become an important link in clinical practice.

The purpose of this article is to discuss the research progress of hidden blood loss after tibial fracture surgery, and analyze its mechanism, influencing factors and clinical management strategies. A systematic literature review was conducted to provide clinicians with a comprehensive framework of understanding to optimize postoperative management and treatment options for patients with tibial fractures.

2. Mechanisms of hidden blood loss

2.1 Vascular injury and hemorrhage.

Hidden blood loss is usually caused by vascular injury, especially during trauma or surgery. Studies have shown that the incidence of abdominal large vessel injury is 5% to 10% in patients suffering from blunt trauma, while it is as high as 20% to 25% and 10% in patients with gunshot and stab wounds, respectively [3].There are 5 types of vascular injury: intimal injury (flaps, disruptions, or subintimal/intramural hematomas), complete wall defects with pseudoaneurysms or hemorrhage, complete transections with hemorrhage or occlusion, arteriovenous fistulas, and spasm[4]. These injuries may cause massive internal bleeding and are often difficult to detect at the initial stage because of their concealment. Hidden blood loss caused by vascular injury can not only lead to acute anemia, but also cause serious complications such as shock, which requires timely diagnosis and intervention. It is essential for surgeons to be familiar with techniques for the identification and management of vascular injuries. Vascular injury in orthopedic trauma is challenging. The risk to life and limb can be high,

and clinical signs initially can be subtle. Recognition and management should be a critical skill for every orthopedic surgeon. In addition, Clinical presentation of vascular injury may not be straightforward. Physical examination can be misleading or initially unimpressive; a normal pulse examination may be present in 5% to 15% of patients with vascular injury[4].

2.2 Hemorrhage in the bone marrow cavity

Intramedullary hemorrhage is another important mechanism of hidden blood loss, which is common after traumatic injury or surgery. Bone marrow is not only the main site of hematopoiesis, but also closely related to a variety of pathological states. Hematoma formation in the bone marrow may lead to local ischemia, which in turn affects the production and function of blood cells. Some scholars have found that bone marrow (BM) biopsy is a common and generally safe procedure. Complications are rare and the incidence of significant bleeding is very low when bleeding does occur, it can be a catastrophic complication requiring emergent care. Quantifying bleeding risk is challenging given the low rate of events[5]. Therefore, intramedullary hemorrhage still needs more attention from clinicians. After trauma, bleeding in the bone marrow cavity may be mistaken for external bleeding by the clinician, thereby delaying treatment. Timely recognition and management of intramedullary hemorrhage is essential to prevent further complications. Therefore, it is also very important to consider and judge the possibility of intramedullary hemorrhage in surgery or trauma management.

2.3 Inflammatory response and coagulation mechanism

The mechanism of hidden blood loss is also closely related to inflammatory response and coagulation mechanism. Inflammatory response is not only the body's natural response to injury, but also triggers a series of coagulation responses, leading to local and systemic coagulation disorders. Following acute infections, activation of coagulation and inflammation, which are critical interconnected responses, lead to thromboinflammation and microthrombosis, thereby contributing to multiorgan dysfunction[6]. In a prior Anesthesiology editorial, Gropper suggested that “all of these conditions (in sepsis) likely share a common pathway for the development of multiple system organ failure: diffuse activation of endothelium by proinflammatory cytokines, leukocytes, and other proteins. Activated endothelium becomes prothrombotic in these conditions, leading to the formation of microvascular thrombosis. In addition, fibrinolysis is inhibited, resulting in the buildup of fibrin thrombus, which itself is proinflammatory[7]. It is the interplay between coagulopathy and inflammation that leads to a significant increase in mortality. The activation of various inflammatory cells such as monocytes and neutrophils will promote the aggregation of platelets and further aggravate the coagulation process, forming a vicious cycle [8]. Therefore, understanding the interaction between inflammation and coagulation is of great significance for the management and treatment of hidden blood loss.

3. Methods of evaluating hidden blood loss

3.1 Clinical manifestations and monitoring indicators

Hidden blood loss (HBL) is a bleeding state that is difficult to be detected clinically, and often manifests as no obvious symptoms or mild symptoms. Clinical manifestations may include fatigue, weakness, pale skin, and rapid heart rate, which are often overlooked or mistaken for signs of other conditions, such as anemia or IPT [9]. In order to effectively monitor hidden blood loss, clinicians will pass a number of laboratory testing techniques. For example, the decrease in hemoglobin and hematocrit is an important indicator of hidden blood loss, especially in patients with chronic diseases or after surgical procedures [10]. In clinical practice, occult blood loss can also be diagnosed by observing occult blood in urine and fecal occult blood test [11]. These monitoring indicators can not only help doctors judge the severity of bleeding, but also detect the potential risk of bleeding at an early stage, so as to take timely intervention measures.

3.2 Laboratory examination and imaging evaluation

Laboratory tests play a crucial role in the evaluation of hidden blood loss. Routine blood tests can provide information about hemoglobin levels, red cell counts, and other relevant parameters to help determine whether hidden blood loss is present [10]. Fecal occult blood tests and urinalysis are also important laboratory tests that can help detect occult gastrointestinal and urinary bleeding [11]. Imaging evaluation is equally important when visceral hemorrhage is suspected. Imaging techniques such as ultrasound, CT, and MRI can help identify the location and severity of the hemorrhage, and one study reported that imaging is important for the early diagnosis of retroperitoneal hematoma [12]. Ultrasound examination, which is commonly used in clinical practice, can quickly determine whether there is free fluid in the abdominal cavity, so that the doctor can make the next treatment for the patient's subsequent diagnosis and treatment according to the results. The reasonable application of laboratory examination and imaging evaluation can roughly judge the hidden blood loss and detect the occurrence of hidden blood loss in time.

3.3 Application of emerging techniques in the assessment of hidden blood loss

With the continuous progress of medical technology, the selection of hidden blood loss assessment methods is more diversified. For example, video capsule endoscopy (VCE) has been used in the diagnosis of difficult gastrointestinal bleeding, which can effectively identify hidden bleeding in the small intestine [13]. In addition, point-to-point ultrasound (POCUS) technology has gradually become an important tool in emergency and intensive care, which can quickly assess the hemodynamic status and fluid status of patients [14]. These emerging technologies not only improve the detection rate of hidden blood loss, but also provide clinicians with more intuitive and real-time information to help formulate more effective treatment plans.

4. Factors affecting hidden blood loss

The patient's age, gender and underlying diseases are important factors affecting the hidden blood loss. Moreover, with the increase of age, patients' physiological function gradually declines, especially cardiovascular and liver function, which may lead to an increased risk of postoperative bleeding. Some studies indicate that hidden blood loss constitutes a significant portion (40%) of total bleeding in congenital scoliosis surgery. Younger age is a risk factor for bleeding and the hidden blood loss should be taken into consideration in their perioperative management[15] .There is a greater risk of blood loss in diabetes, hypertension and preoperative MRI assessment of thickness of the psoas, thickness of the dorsal extensor group[16]. In terms of gender, male patients may face a higher risk of bleeding during surgery due to differences in physiological structure and hormone levels. Surgeons should be aware that patients who require blood transfusions and have longer surgical durations are at a higher risk of developing more hidden blood loss[17].Professor Kolz JM pointed out: For patients undergoing PSF for AIS there is more HBL after wound closure than intraoperative blood loss. This HBL is higher in older patients who undergo longer operations and have a BMI≥25kg/m^2[18]. This conclusion has implications for other types of occult blood loss. Moreover, the type and severity of the underlying disease can also directly affect the bleeding tendency of patients. The choice of surgical method and technique has a significant impact on the occurrence of hidden blood loss. Different surgical techniques, such as open versus minimally invasive surgery, may lead to different degrees of bleeding risk. Minimally invasive surgery usually reduces the likelihood of bleeding by reducing damage to surrounding tissues through smaller incisions and more delicate manipulation [19]. Besides, instruments and techniques used during surgery, such as electrotome and laser techniques, are able to effectively control bleeding and reduce the incidence of hidden blood loss. Some scholars study results showed that surgical time is an independent risk factor for HBL. Therefore, HBL should not be overlooked in patients with multilevel cervical spondylotic myelopathy (MCSM) undergoing unilateral open-door cervical laminoplasty (UOCL), particularly in the patients with expected long surgical time[20].

The effect of anesthesia method on hidden blood loss should not be ignored. There are significant differences between general and local anesthesia in terms of physiological response and bleeding control. General anesthesia may cause fluctuations in the patient's blood pressure during surgery, thereby increasing the risk of bleeding. In addition, the choice of anesthetic drug also affects the contraction and dilation of blood vessels, which in turn affects the amount of bleeding, Studies by Lee HA and other scholars show that Choosing propofol over volatile anesthetics during dilatation and evacuation might reduce bleeding and the incidence of excessive bleeding. However, the quality of the evidence was very low. This necessitates further trials with a low risk of bias[22].The risk factors of hidden blood loss are advanced age (> 60 years), unstable fracture, general anesthesia, and intramedullary fixation. Especially in elder patients with unstable fracture treated by intramedullary fixation under general anesthesia, hidden blood loss is more significant[21]. Local anesthesia usually provides better control of local blood flow and reduces intraoperative bleeding. Therefore, the choice of anesthesia method should be considered comprehensively according to the specific condition of the patient and the type of surgery to reduce the risk of hidden blood loss.

5. Effect of hidden blood loss on postoperative recovery

Hidden blood loss plays an important role in the recovery process after surgery, which not only affects the incidence of postoperative complications, but also involves the rehabilitation process, functional recovery and the evaluation of the quality of life of patients. Hidden blood loss may lead to postoperative anemia, aggravate the burden on the heart, prolong the length of hospital stay, and even increase the risk of death. Therefore, understanding the impact of hidden blood loss on postoperative recovery is essential to improve patient outcomes.

6. Incidence of postoperative complications and rehabilitation process

Hidden blood loss is closely related to the incidence of postoperative complications. Such as perioperative bleeding

remains a major complication during and after surgery, resulting in increased morbidity and mortality. The principal causes of non-vascular sources of haemostatic perioperative bleeding are a preexisting undetected bleeding disorder, the nature of the operation itself, or acquired coagulation abnormalities secondary to haemorrhage, haemodilution ,or haemostatic factor consumption[23]. Hidden blood loss may lead to low hemoglobin levels, which increase the risk of postoperative infection, cardiovascular complications, and other serious complications. Therefore, postoperative monitoring of hidden blood loss and timely correction of anemia are of great significance to reduce the occurrence of postoperative complications. Hidden blood loss not only affects the occurrence of postoperative complications, but also has an important impact on the rehabilitation process and functional recovery of patients [24]. Hidden blood loss may also lead to prolonged postoperative recovery and poor functional recovery, Professor Yang Y thinks that hidden blood loss is a major factor influencing functional recovery and quality of life in patients undergoing total knee arthroplasty[25].

7. Assessment of patients' quality of life

The impact of hidden blood loss on the quality of life of patients cannot be ignored. Studies have shown that postoperative anemia is significantly associated with patients' quality of life, in cardiac surgery, the reported incidence of postoperative anemia varied from 29% to 94% across the studies, likely because of variations in patient inclusion criteria and classification of postoperative anemia. Nonetheless, the weight of the evidence suggests that postoperative anemia is common and is an independent risk factor for adverse postoperative outcomes such as acute kidney injury, stroke, mortality, and functional outcomes[26]. Physical weakness and fatigue caused by hidden blood loss may make it difficult for patients to perform daily activities and reduce their quality of life. In addition, the increase of postoperative complications will also lead to the aggravation of the psychological burden of patients and further affect their quality of life. Therefore, evaluating the impact of hidden blood loss on the quality of life of patients and taking effective measures to improve their quality of life are important components of postoperative care.

8. Strategies to prevent hidden blood loss

In clinical practice, hidden blood loss is often ignored, resulting in slow recovery and various complications. Therefore, in surgery and trauma management, the prevention of hidden blood loss is very important. First of all, the preoperative blood status of the patient and the potential risk of bleeding should be evaluated, and various techniques should be used to evaluate the patient's coagulation function to develop an individualized surgical plan. Secondly, intraoperative use of hemostatic drugs and techniques can significantly reduce the occurrence of blood loss [27]. Of course, postoperative monitoring and management are also very important.

9. Individualized treatment options

The exploration of individualized treatment is an important direction in the development of modern medicine. Especially in the management of hidden blood loss, individualized treatment can significantly improve the treatment effect. Comprehensive assessment of a patient's genome, metabolic profile, and clinical presentation will allow physicians to develop more precise treatment strategies. For example, selecting appropriate hemostatic drugs and techniques according to the coagulation function and blood characteristics of different patients can effectively reduce the risk of hidden blood loss. Professor Oyake K pointed out that individualized treatment also includes assessing the patient's psychological state and helping the patient establish the correct coping mechanism to improve the compliance and effect of treatment [28].

10. The role of multidisciplinary collaboration in the management of hidden blood loss

Multidisciplinary collaboration plays an indispensable role in the management of blood loss. Studies have shown that: Patient blood management (PBM) is a multidisciplinary and patient-centered treatment approach, comprising the detection and treatment of anemia, the minimization of blood loss, and the rational use of allogeneic transfusions[29]. The complexity of hidden blood loss requires the participation of medical personnel with different specialties to provide a comprehensive treatment plan. The collaboration of a multidisciplinary team of surgeons, anesthesiologists, nursing staff and rehabilitation specialists can ensure that patients receive optimal care before, during and after surgery to reduce the risk of bleeding. At the same time, the nursing staff observed the patients carefully after the operation, and found and dealt with the potential bleeding problems in time. In addition, regular discussion and case analysis of the multidisciplinary team are helpful to summarize experience, optimize the management strategy of hidden blood loss, and improve the overall treatment effect of patients.

11. Discussion

After the above discussion, we can basically realize the importance of hidden blood loss in the postoperative management of tibial fractures, and the necessity of the evaluation and intervention measures of hidden blood loss. Hidden blood loss is often overlooked, but it has an important impact on patient recovery, postoperative complications, and overall treatment effect. Through the analysis of available studies, we found that despite differences in assessment methods and interventions for hidden blood loss across studies, there is overall agreement that early recognition and management of hidden blood loss are critical for improving clinical outcomes.

In the process of evaluating hidden blood loss, clinicians should not only consider the patient's physiological state, fracture type and surgical method, but also pay attention to the application of modern imaging technology and biomarkers to improve the diagnostic accuracy of hidden blood loss. In addition, appropriate interventions, reasonable fluid management and transfusion strategies, are also one of the effective ways to reduce postoperative complications caused by hidden blood loss.

Future research directions should focus on standardized and individualized assessment methods for hidden blood loss to improve the quality of patient care. At the same time, various prospective studies were carried out to explore the effects of different interventions on the recovery of patients with hidden blood loss. At the same time, education and training on hidden blood loss should be strengthened to improve the cognitive level of medical staff, so as to better ensure the safety of patients and postoperative recovery

In conclusion, hidden blood loss should not be overlooked in the postoperative management of tibial fractures and should be paid attention to in clinical practice. Through scientific evaluation and intervention, we can significantly improve the quality of postoperative recovery of patients and improve the overall medical effect. It is hoped that future research will further advance this field and provide more guidance for clinical practice.

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