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Conditions for Early Application of Interlocking Intramedullary Nails for Closed Tibial Shaft Fractures in Severe Polytrauma Patients

Yonggang Li[a]*, Weiguo Huang[b]

Abstract

Objective: To investigate the conditions for the early application of interlocking intramedullary nails in closed fractures of the tibial shaft in patients with severe polytrauma, by comparing with classic external fixators.

Methods: A retrospective analysis was done on 33 cases of closed fracture of the tibial shaft in severe polytrauma patients. The patients had the following characteristics: New Injury Severity Score (NISS) <50; no shock; and no condition of the lethal triad: acidosis, body temperature <35.0°C, or coagulopathy. All cases were divided into two groups and compared with each other (intramedullary nail group [18 cases] and external fixator group [15 cases]).

Results: The follow-up time was 6–24 months. The interlocking intramedullary nail group showed better results than the external fixator group in bony callus time (4.7 ± 0.8 vs. 5.5 ± 0.5 weeks, $P < 0.05$) and bony union time (13.2 ± 1.4 vs. 15.4 ± 2.0 weeks, $P < 0.05$); however, they showed a much longer operation time (52.8 ± 11.3 vs. 40.7 ± 11.0 min, $P < 0.05$) and higher blood loss (239.4 ± 69.1 vs.139.3 ± 82.2 mL, $P < 0.05$). The preoperative and postoperative pH, temperature, prothrombin time, and activated partial thromboplastin time were not significantly different between the two groups. There were also no statistically significant differences in complications, mortality, and Johner-Wruhs score between the two groups.

Conclusion: In severe polytrauma patients with NISS <50, no shock, and no condition of the lethal triad, better effects can be achieved with interlocking intramedullary nails than with external fixators in closed tibial shaft fractures.

Keywords: conditions; intramedullary nail; severe polytrauma; tibia fracture

Introduction

The main concern in orthopedic treatment in patients with polytrauma has been the same for almost 40 years: “where” and “when” to proceed (Dei et al., 2015). The optimal timing of definitive fracture stabilization in multiple-trauma patients has probably been one of the most controversial topics in recent years (Kucukdurmaz and Alijanipour, 2015). Advocates of early total care (ETC) insist on the advantages of early fixation, such as lower rates of pulmonary complications, shorter hospital and intensive care unit (ICU) stays, fewer ventilator days, and lower hospital charges (Harvin et al., 2012). However, some authors suggest that in cases of uncertainty, damage control orthopedics (DCO) is a safer strategy (Steinhausen et al., 2014). Although early definitive fixation and DCO both offer undeniable benefits in certain clinical situations, the appropriate patient criterion remains elusive (Weinberg et al., 2015). Increasing literature evidence

[a]*Orthopaedics Department & trauma center,Fuxing Hospital,Capital Medical University, No.20A Fuxingmen Wai Street, Xicheng District, Beijing 100038,China*
[b]*Department of Orthopaedics, Civil Aviation General Hospital,Civil Aviation Clinical College,Attached to Peking University,No.1A Gaojing ChaoYang Road, Chaoyang District, Beijing 100123,China*
**Corresponding author: Yonggang Li*
Email: stoneli1392@126.com

suggests that neither ETC nor temporary external fixation with secondary definitive internal osteosynthesis should be considered as standard therapy in all patients (Rixen et al., 2016). Instead, the decision-making should be dependent on the individual risk of patients according to the severity of the anatomic and physiologic injury (risk-adapted damage control concept) (Rixen et al., 2016). Moreover, no study has yet clearly stated the useful historical, clinical, instrumental, or laboratory data for a trauma team leader or orthopedic surgeon concerning deciding on whether a specific fracture needs to be treated as soon as possible, if the proposed treatment must be definitive, or whether there is the need to delay orthopedic surgery (Dei et al., 2015).

We believe that early definitive surgery or ETC depends on the physiological situation after resuscitation. The following conditions are necessary criteria for early definitive surgery: (i) New Injury Severity Score (NISS) <50; (ii) no shock; (iii) no one of the "lethal triad": acidosis (pH <7.3), body temperature <35.0°C, and coagulopathy. DCO is a treatment concept for patients with a poor response to resuscitation, or those with progressively worsening physiological condition. Only when the patient has become physiologically stable would the final therapeutic surgery be decided (Chatrath et al., 2015).

Long bone fractures, particularly tibial shaft fractures, are common in polytrauma patients. The necessity for primary or secondary definitive osteosynthesis of tibial shaft fractures is still a matter of discussion (Rixen et al., 2005). Here, we retrospectively studied 33 cases of closed fracture of the tibia shaft in patients with severe polytrauma from August 2004 to April 2015, to discuss the clinical conditions for the early application interlocking intramedullary nails in these patients.

Materials and Methods

General information

Thirty-three cases of closed tibial shaft fractures in severe polytrauma patients were collected in our study. These cases included 23 male and 10 female patients, aged 19–72 years and with NISS 18–48. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Capital Medical University. There were no statistically significant differences in age and NISS the between intramedullary nail group and the external fixator group (40.9 ± 16.8 vs. 49.3 ± 13.3 years, 31.3 ± 7.2 vs. 33.5 ± 7.6, respectively, P > 0.05). The types of injury were as follows: traffic injuries in 23 cases, fall injuries in 6 cases, high-fall injury in 2 cases, crush injury in 1 case, and other injury in 1 case. Nine cases had three anatomical injuries and 24 cases had two anatomical injuries. The predominant injuries were traumatic brain injury, chest injury, abdominal injuries, and limb fractures in 7, 8, 1, and 17 cases, respectively. All patients had closed tibial shaft fractures. The patients were admitted to the hospital in 15 min to 6 h after the injury, with an average of 2.5 ± 1.9 h. The time to hospital admission showed no statistically significant difference between the intramedullary nail group and the external fixator group (2.4 ± 1.8 vs. 3.1 ± 2.1 h, P > 0.05).

Inclusion criteria

The outcomes of treatments for closed tibial shaft fractures in severe polytrauma patients have not yet reached the limits of physiological potential. The patients had the following characteristics: (i) NISS <50; (ii) no shock; and (iii) no one of the lethal triad conditions: acidosis (pH <7.3), body temperature <35.0°C, and coagulopathy (prothrombin time [PT] >16 s or activated partial thromboplastin time [APTT] >50 s).

Treatment program

Eighteen cases of the first group were given early nonreamed intramedullary nail fixation. Then, the patients were allowed to recover in the ICU. Any bleeding was controlled and fluid resuscitation was provided. Life-threatening injuries were given emergency treatment. For example, traumatic brain injury was treated with hematoma cavity puncture and drainage; thoracic cavity or chest wall injury was treated with closed drainage or external fixation; bleeding of the abdomen and pelvis was managed with pressure tamponade, vascular bypass, or embolization; and hollow organs were given external drainage. The second group comprising 15 cases was given the classic DCO three-stage treatment. In the first stage, necessary treatment for fatal injury was provided and hemodynamic stability was maintained. Tibial shaft fractures were given external fixation (unilateral multifunctional external fixator). In the second stage, the patients were allowed to recover in the ICU. In the third stage, reamed intramedullary nail fixation was performed (5–10 days after injury). All early treatments were completed within 8 h after the injury.

Monitoring indicators

The following parameters were monitored: intraoperative blood loss and operative time; systemic conditions in the preoperative and postoperative 3 days: pH (two times per day), temperature (four times per day), and PT and APTT (two times per day); time to callus occurrence; time to fracture healing; complications; mortality; and Johner-Wruhs function score.

Statistical analysis

SPSS17.0 statistical software was used for statistical analysis. Measurement data were represented as x ± S and analyzed with the t-test. For count data, the χ^2 test was used. $P < 0.05$ was considered statistically significant.

Results

There were no deaths in the two groups. The intramedullary nail group had higher intraoperative blood loss and operative time than the DCO external fixation group ($P < 0.05$). However, the time to callus occurrence and time to fracture healing of the intramedullary nail group were better than those of the external fixation group ($P < 0.05$) (Table 1). The preoperative and postoperative pH, body temperature, PT, and APTT were not significantly different between the two groups (Table 2). There were no significant differences in severe complications between the two groups, including systemic inflammatory response syndrome, acute respiratory distress syndrome, multiple organ dysfunction syndrome, and disseminated intravascular coagulation ($P > 0.05$). There were two cases of pin tract infections and two cases of pin loosening in the DCO external fixation group, with no significant angular and displacement. The Johner-Wruhs function score of the intramedullary nail group was better than that of the DCO external fixation group; however, the difference was not statistically significant (Table 3).

Discussion

To achieve a precise classification in polytrauma, scoring systems have been developed, with the Injury Severity Score (ISS), Abbreviated Injury Scale (AIS), and NISS being the most commonly used (Guerado et al., 2015). The AIS-NISS can reflect the main injury and the specific severities in multiple injuries. The ISS and NISS have been validated and shown to be reasonable predictors of the probability of death (Cryer, 2006). In patients who die at admission, the ISS was reported to be around 40 points and the NISS was around 50 (Mica et al., 2013). Therefore, we set NISS <50 as one of the indicators in this study.

Trauma is both a local and a systemic disease. As hemorrhage accounts for approximately 40% of trauma-related deaths, mechanisms and protocols needed to treat this form of shock are paramount (Hess et al., 2008). These types of polytraumatic pathophysiological changes are based on traumatic hemorrhagic shock. The presence of hypotension defined as systolic blood pressure (SBP) ≤90 mm Hg is a widely accepted hallmark of possible circulatory failure, and, if persistent, will lead to shock, characterized by inadequate tissue perfusion, cellular damage and metabolic changes, and ultimately death unless circulation is restored (Vincent et al., 2014). Short-term mortality has been shown to increase at SBP levels <110 mm Hg for a population of trauma patients (Eastridge et al., 2007) and <100 mm Hg in a cohort of patients in a prehospital setting (Seymour et al., 2013). Mortality began to increase at SBP of around 110–120 mm Hg and was greatly increased at 90 mm Hg (Kristensen et al., 2015). These findings were consistent with those of previous studies on acutely ill medical patients in the prehospital setting (Seymour et al., 2013), and on trauma patients in the emergency department and in the prehospital setting (Eastridge et al., 2007).

Signs of deterioration of the conditions of the lethal triad are highly valued. Large, well-conducted retrospective studies have shown that a core temperature of <35°C on admission is an independent predictor of mortality after a major trauma (Martin et al., 2005). The origin of hypothermia can differ fundamentally and classified as endogenous, controlled, or accidental hypothermia (Hildebrand et al., 2014). Endogenous hypothermia results either from metabolic dysfunctions with decreased heat production (e.g., hypothyroidism) or central nervous system dysfunctions with insufficient thermoregulation (e.g. tumor or trauma) (Hildebrand et al., 2014). According to pathophysiological reasoning, hypothermia induces platelet dysfunction and impairs the plasmatic coagulation system, especially at temperatures below the threshold of 33°C (Hildebrand et al., 2014). This hypothermia-induced coagulopathy was shown to be associated with significantly increased blood loss (Schmied et al., 1996). Therefore, the reversal of the lethal triad of acidosis, coagulopathy, and accidental hypothermia is indispensable for the successful treatment of bleeding trauma patients (Hildebrand et al., 2014).

Coagulopathy was identified as an independent risk factor for acute renal failure and multiorgan failure, and was associated with a trend toward acute respiratory distress syndrome (Salim et al., 2006). Massive hemorrhage can be compounded by trauma-induced coagulopathy (TIC) that is present in nearly one-third of all severely injured trauma patients and carries a 50% mortality rate (Maegele, 2013). TIC is an endogenous response by the host that occurs immediately after a severe trauma (Simmons et al., 2014). The severity of trauma correlates with the degree of the coagulopathy (Simmons et al., 2014). TIC is a complex pathophysiological condition, some mechanisms of which have been characterized; however, much remains to be understood in order to translate such knowledge into improved outcomes for the injured patients.

Not surprisingly, severely injured patients with impaired acid-base regulation and prolonged exposure to acidotic environment were found to be at an increased risk for complications and, in other studies, mortality (Odom et al., 2013). A decrease in pH by itself impairs the function of plasma proteases (Jacob and Kumar, 2014). A decrease in pH from 7.4 to 7.0 has been shown to reduce the activity of FVIIa by >90% and that of FVIIa/tissue factor by >60% (Meng et al., 2003). Administration of buffer solutions to correct acidosis has not been shown to correct the coagulopathy that has already set in, indicating that acidosis does not merely reduce the activity of the coagulation protease (Jacob and Kumar, 2014). Engström et al. found that by artificially reducing normal human serum pH by adding hydrochloric acid, the rate of maximal clot strength on thromboelastography was slowed. At a pH of 6.8, the clot formation time was prolonged by 168% compared with that at a normal pH of 7.4 (Engstrom et al., 2006);. Serum acidemia is both an effect of crystalloid volume resuscitation and hypoperfusion, and can be difficult to delineate (Simmons et al., 2014). Significant acidemia in a patient was observed to be further compounded by excessive administration of chloride-containing fluids (Jacob and Kumar, 2014). The pH level is determined through arterial blood gas analysis on hospital admission. Arterial blood gas levels are easy to determine, and the results are quickly available; thus, this test is useful in emergency or trauma departments.

Risk-adapted approaches based on the anatomic location and the severity of the injury have been suggested for making the decision on whether to perform primary definitive treatment within the first 24 h after trauma (ETC), or rapid provisional stabilization of the fracture in the immediate state (external fixation or traction) and postponing the definitive surgery until a more stable condition is achieved (i.e., DCO) (Kucukdurmaz and Alijanipour, 2015). Intramedullary nail fixation is still the preferred early method for closed tibial shaft fractures in severe polytrauma patients. Our study showed that nonreamed intramedullary nails can produce better effects than external fixators. However, there is no universally agreed criteria for indicating either ETC or DCO (Caba-Doussoux et al., 2012). We present only the necessary conditions for early treatment. Resuscitation should be given early in patients with severe multiple trauma. If the patient reacted positively to resuscitation and the condition remained stable on secondary inspection, the general requirements for early comprehensive treatment of fractures may be followed. Patients who respond well to resuscitation and with gradually improving physiological conditions may be indicated for early definitive surgery.

Nevertheless, it should be kept in mind that surgery itself is a trauma and confers the risks of hypothermia, coagulopathy, metabolic acidosis, and other complications, especially in complex major surgeries. Therefore, the prognosis of severe trauma not only depends on the surgery, but also, more important, on the trauma itself and the physiological limits of the patient.

The limitations of this study include the retrospective nature of the investigation and the inherent flaws of this study design. We were unable to control for patient demographics, concomitant injures, and other factors. In addition, the number of study patients was limited. We only presented the necessary conditions for early application of interlocking intramedullary nails in closed fractures of the tibial shaft in severe polytrauma patients. Therefore, a higher level of evidence is needed to support our findings.

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Conflicts of interest

All of the authors declare that they have no conflicts of interest regarding this paper.

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Table 1 **Comparison of intraoperative and postoperative situation**

group	Intramedullary nail group(n=18)	external fixation group(n=15)
Intraoperative blood loss(ml)	239.4±69.1	139.3±82.2
Operation time(min)	52.8±11.3	40.7±11.0
Callus occurrence time (W)	4.7±0.8	5.5±0.5
Fracture healing time(W)	13.2±1.4	15.4±2.0

Table 2 **Preoperative and postoperative PH, T, PT and APTT**

group	Intramedullary nail group(n=18)		external fixation group(n=15)	
	Preoperative	postoperative	Preoperative	postoperative
PH	7.41±0.04	7.40±0.05	7.45±0.07	7.41±0.06
T	36.6±0.4	36.8±0.3	36.6±0.5	36.9±0.3
PT	11.89±0.96	12.17±1.43	11.73±1.49	12.0±1.20
APTT	26.39±3.63	29.44±7.77	25.80±3.63	29.07±7.60

Table3 **Comparison of Postoperative Johner-Wruhs scores**

group	n	Excellent	Good	Medium	Poor	Excellent Rate（%）
Intramedullary nail group	18	4	12	2	0	88.9
external fixation group	15	4	8	3	0	80.0