Analysis of curative effect of low position tourniquet in calcaneal fracture surgery

Xu fang-lei (13501792610@163.com)
Tongji Hospital
Yao Ying
Tongji University
Zhang yue
Tongji Hospital
Zhou lu-yi
Tongji Hospital
Shi ting-ting
Tongji Hospital
Zhou li-yu
Tongji Hospital
Fan Jian
Tongji Hospital
Yu Guang-rong
Tongji Hospital

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Abstract

This study was designed to investigate the role and curative effect of low position tourniquet in calcaneal fracture surgery. We studied a total of 42 calcaneal fracture patients who underwent reduction and internal fixation with plate via L-shaped approach with low position tourniquets using a retrospective analysis between January 2018 and July 2020. The fractures were all unilateral and fresh, and they were classified Sanders III and IV. All patients, with mean age of 47.2 years, had no medical complications. Two groups were categorized based on the position of tourniquets during surgery. Tourniquets were put on proximal thighs in one group (high position tourniquet group n=22), and above ankles in another (low position tourniquet group n=20). Observation index were as follows: operation time, tourniquet time, intraoperative bleeding and incision healing, postoperative fracture healing, ankle-hindfoot scoring system (AOFAS score) and visual analogue scale (VAS score), tourniquet complications such as soft tissue injury and deep venous thrombosis (DVT). No significant differences in general condition, fracture type and complications of the two groups before surgery were noted between the two groups ($P>0.05$). The low position tourniquet group had significantly less foot pain within two weeks after surgery and higher AOFAS scores of motion pain within 4 weeks after surgery than the high position tourniquet group ($P<0.05$). However, there was no significant difference in AOFAS function scores twelve weeks after surgery between the two groups ($P>0.05$). In addition, there were one case of DVT and two cases of soft tissue injuries in the high position tourniquet group, while no related complications were found in the low position tourniquet group ($P<0.05$). The use of low position tourniquet in calcaneal fracture can ensure a clear vision surgery, reduce the incidence of early postoperative pain and related complications, and promote functional rehabilitation. It is a new method worth recommending.

1. Introduction

Calcaneal fracture is one of the most common clinical traumatic orthopedics. A lateral L-shaped approach is considered to be the most commonly used surgical method for Sanders III and IV calcaneal fracture[1]. Enhanced recovery after surgery (ERAS) has been successfully adopted among traumatic orthopedics which can obtain painless exercise and early rehabilitation. Consequently, how to reduce complications and create conditions and environments that promote early functional recovery depends on multiple factors such as perioperative preparation, surgical operation, and anesthesia. Among them, the use of intraoperative tourniquet is an essential component. At present, the use of tourniquet put on proximal thighs is the most commonly and traditional method, which can reveal a clear vision surgery to perform smoothly. However, aggravated postoperative pain, incidence of DVT, and the soft tissue injury are found after years, which affects the overall efficacy[2]. The reaction after the temporary ischemia of the extensive tissue caused by the relatively high pressure of the high position tourniquet is considered to be one of the main reasons for the occurrence of complications[3].

Recently, tourniquets are improved by setting charging time, ultrasonic guidance and intelligent control, which significantly reduced the incidence of related complications, the problem of soft tissue injury and

DVT remains unresolved nevertheless[4, 5, 6]. High pressure of the thigh tourniquet leads to temporary bone tissue ischemia, which is considered to be one of the main reasons for the occurrence of complications. Therefore, we explored a new method of low position tourniquets which can effectively alleviate the damage of tissue ischemia and theoretically reduce such complications. This study is designed to explore the effect of low position tourniquet in open reduction and internal fixation by comparing with high position tourniquet and confirm whether it has advantages on ensuring a clear vision surgery and alleviating related complications.

2. Methods

2.1 Study population

A total of 42 patients in the Shanghai Tongji Hospital were included in the current study from May 2018 to December 2020. The ages ranged from 19 to 62 years old, with an average of 47.2 years. The causes of injury were traffic injury in 25 cases, falling injury in 9 cases and walking sprain in 8 cases. The time from injury to operation was 6–12 days (mean 7.8 days). Inclusion criteria: (1) fresh unilateral closed fracture. (2) There was no soft tissue damage around ankle and foot. (3) No surgical history of ankle and foot trauma. (4) Preoperative basic diseases were well controlled. Exclusion criteria: (1) patients with mental diseases. (2) Patients with intractable essential hypertension, arrhythmia and diabetes. (3) Patients with arteriosclerotic occlusive disease, lumbar disc herniation and other diseases that may affect blood supply, sensation and movement of lower limbs. The 42 patients were divided into two groups based on the position of tourniquets during surgery. low position tourniquet group (n = 20): 12 males and 8 females, 48.6 (21–58) years old, 12 cases with Sanders type III and 8 cases with Sanders type IV. High position tourniquet group (n = 22): 13 males and 9 females, 45.2 (19–62) years old, 13 cases with Sanders type III and 9 cases with Sanders type IV. No skin and soft tissue injury and no neurovascular injury were found in two groups. And there was no statistically significant difference between the two groups in age, time since injury, fracture type, and multiple injuries (Table 1).

Table 1
Comparison of preoperative general data between two groups

Variable	**Low position tourniquet (n = 20)**	**High position tourniquet (n = 22)**	**statistic**	***P* value**
Gender (male/female)	12/8	13/9	0.089	0.641
Mean age (year)	48.6 ± 8.7	45.2 ± 9.1	1.023	0.142
time from injury to operation (d, x ± s)	6.2 ± 1.2	8.7 ± 1.8	-0.576	0.595
Type of fracture	20	22	1.549	0.508
Sanders III	12	13		
Sanders IV	8	9		
Multiple injuries	Multiple rib fracture (1) craniocerebral trauma (1)	craniocerebral trauma (2)	0	0.986

2.2 Surgical methods

2.2.1 low position tourniquet group

Patients were put in the side-lying position, then disinfected to the mid-thigh spread the drapes routinely. Germless tourniquets with a width of about 10cm were put on the ankle joint 10cm above, and 2–3 layers of gauze were placed under the tourniquets(Fig. 1). After blood evacuation, the tourniquet pressure was increased 30% according to the patient's systolic blood pressure.[4] A modified L-shaped incision (8-12cm in length) on the lateral side of the calcaneus was taken. Tissue was cut layer by layer, with the sural nerve and the small saphenous vein protected. The peroneus longus approach was performed in the lateral malleolus. Then the lateral plate was fixed after the fracture was precisely reducted. The space between the peroneus brevis longus and the flexor pollicis longus was entered in the posterior malleolus. Volkmann fracture was exposed to be reducted, with a screw or buttress plate being inserted. A curved incision was choosed in the medial malleolus. Two hollow screw type or a buttress plate were inserted after reduction. As to the injury of flexible medial malleolus, the deltoid ligament was explored and repaired.

2.2.2 High position tourniquet group

The automatic pneumatic tourniquets (type AST) were put on the proximal thighs, with pressure 100 mmHg higher than the patient's systolic blood pressure. Surgical procedure was the same as that of the low tourniquet group.

2.3 Postoperative treatment

All patients used patient-controlled analgesia (PCA) after surgery instead of additional analgesics. Prophylactic antibiotic was routinely performed 24–48 hours after operation. The drainage tube was removed after 24 hours, with volumee of drainage recorded. On the second day after surgery, ankle flexion and extension exercise were performed, increasing range gradually according to pain conditions. The colour-doppler ultrasound of lower limbs was performed to check the occurrence of DVT on the 3-7th day after operation. Passive and active activities such as forward flexion, extension, adduction, and valgus were performed two weeks after operation. Active exercises training was gradually increased according to the X-ray and internal fixation after one month.

2.4 Postoperative follow-up and observation indicators

2.4.1 Operation time, tourniquet time and bleeding volume

Operation time (tourniquet time) was recorded. Whether there was obvious bleeding in the operation field and whether it affected the operation were evaluated. Intraoperative bleeding volume was calculated by weighing gauze before and after blood sucking. Postoperative bleeding volume was calculated by recording the bleeding volume of the gauze and the drainage.

2.4.2 Fracture healing, ankle range of motion and clinical function scores

X-rays or CT were performed at 4 weeks, 12 weeks, 6 months and 12 months after operation to determine fracture healing. The ankle range of motion and function scores were measured. The function was evaluated using AOFAS scores.

2.4.3 Pain and complications

VAS scores (0–10) were used to evaluate the pain of the affected limb within two weeks after operation. The colour-doppler ultrasound of lower limbs were performed to check the occurrence of DVT within one week after operation. On the 1st and 7th day after operation, ecchymosis, soft tissue masses, blisters and skin ulcers at the compression site of the tourniquet were observed and recorded.

2.5 Statistical analysis

All data in the article were analyzed using SPSS 13.0. Independent samples t-test was used to compare the measurement data such as age, operation time, total bleeding, fracture healing time, hindfoot mobility and functional score. Gender, fracture type, multiple injuries, postoperative pain, deep vein thrombosis and other complications were tested by the exact probability method. For all data, statistical significance was considered at $P < 0.05$.

3. Results

All patients were followed up for 4–22 months, with an average of 12.6 months. There were no significant differences in operation time, blood loss, and fracture healing time between the two groups

(Table 2). Four weeks postoperatively, the low position tourniquet group had higher hind foot mobility and AOFAS scores than the high position tourniquet group (Table 3). However, there was no significant difference in AOFAS scores twelve weeks after operation (Table 4). Although there was no significant difference in limb pain before operation between the two groups, VAS scores of the low position tourniquet group were significantly lower than those of the high position tourniquet group within two weeks after surgery (Table 5). In the high position tourniquet group, there were one case of DVT and two cases of soft tissue injuries at the thigh binding area. Conversely, no related complications were found in the low position tourniquet group (Table 6). A typical case was present at Fig. 1.

Table 2
Comparison of operation time, tourniquet time, and blood loss between two groups

Variable	Low position tourniquet (n = 20)	High position tourniquet (n = 22)	statistic	*P* value
operation time (min, x ± s)	57.2 ± 14.5	54.6 ± 16.5	-0.679	0.379
tourniquet time (min, x ± s)	50.2 ± 14.5	47.6 ± 16.5	0.734	0.292
intraoperatve bleeding(g)	52.3 ± 9.0	59.3 ± 7.0	0.376	0.718
postoperative bleeding(g)	102.5 ± 15.2	106.9 ± 19.4	0.205	0.714
Total bleeding(g)	102.5 ± 15.2	106.9 ± 19.4	0.205	0.714

Table 3
Comparison of hind foot mobility and AOFAS scores four weeks after operation between two groups

Variable	Low position tourniquet (n = 20)	High position tourniquet (n = 22)	statistic	*P* value
fracture healing time (W, x ± s)	10.2 ± 3.1	11.4 ± 4.3	0.895	0.316
ankle flexion (degree)	34.2 ± 9.0	31.1 ± 8.5	2.431	0.011
ankle dorsiflexion (degree)	30.4 ± 7.2	27.4 ± 6.7	2.253	0.037
motion of ankle (degree)	61.0 ± 15.3	48.1 ± 20.2	2.407	0.029
AOFAS scores	72.1 ± 11.8	64.26 ± 15.9	2.576	0.016

Table 4
Comparison of hind foot mobility and AOFAS scores twelve weeks after operation between two groups

Variable	Low position tourniquet (n = 20)	High position tourniquet (n = 22)	statistic	*P* value
ankle flexion (degree)	37.0 ± 8.1	34.5 ± 6.5	0.261	0.751
ankle dorsiflexion (degree)	38.2 ± 4.6	37.6 ± 5.7	1.845	0.177
motion of ankle (degree)	72.6 ± 1.9	71.6 ± 8.1	0.825	0.379
AOFAS scores	87.4 ± 1.9	85.8 ± 2.4	1.710	0.124

Table 5
Comparison of postoperative limb pain (VAS scores) between two groups

Variable	Low position tourniquet (n = 20)	High position tourniquet (n = 22)	statistic	*P* value
pre-operation	6.4 ± 2.1	7.2 ± 1.9	-0.675	0.486
1 day after operation	5.1 ± 2.2	5.0 ± 1.9	0.145	0.872
3 days after operation	4.8 ± 2.0	4.5 ± 2.1	-0.208	0.731
7 days after operation	2.8 ± 1.4	3.1 ± 1.2	-1.421	0.221
14 days after operation	2.4 ± 0.8	3.1 ± 1.1	-2.191	0.026

Table 6
Comparison of tourniquet related complications between two groups

Variable	Low position tourniquet (n = 20)	High position tourniquet (n = 22)	statistic	*P* value
skin ecchymosis	0	1	1.023	0.312
soft tissue mass	0	1	1.023	0.312
skin blisters	0	0	/	/
skin ulcer	0	0	/	/
DVT	0	1	1.023	0.312
total	0	3	3.220	0.073

4. Discussion And Conclusion

The calcaneus, as one of tarsal bones, is a part of the hind foot. Though calcaneus fracture is rare, it occupies most of the tarsal fractures. Successful surgical treatment and reduction of postoperative pain and complications are undoubtedly important factors for ERAS. Proximal thigh tourniquets are currently used during most of the alcaneal fracture surgery to ensure a clear vision surgery and increase surgical comfort. Simultaneously, the incidence of small vessel and nerve damage such as the small saphenous vein and the sural nerve are dramatically decreased. However, related complications impede postoperative rehabilitation such as aggravated postoperative pain, incidence of DVT, and the soft tissue injury.[7]

4.1 Unique characters of Low position tourniquet

The placement of low tourniquets is generally 10cm above the ankle, where tourniquet inflation pressure is significantly reduced due to little soft-tissue and the blood superficial vessels. The ischemic area induced by low position tourniquets is significantly reduced, which effectively aviods ischemia reperfusion injury. The low position tourniquet is personally put on the thigh, thus decreasing the interval time between tourniquet running and operation taking place.

In this study, no significant difference in surgical fields, operation time, bleeding volume, and fracture healing time was found between two groups. Even though there is no difference in AOFAS scores on the whole, the scores of low position tourniquet group were higher than those of high position tourniquet group within 4 weeks after surgery, indicating that the former has more advantages. In addition, VAS scores of low position tourniquet group was significantly lower than those of high position tourniquet group within two weeks after surgery, which also indicates that the application of low position tourniquet group is conductive to ERAS. Similar study was researched that the use of tourniquets in knee joint replacement was beneficial to the early rehabilitation of knee joint function.[8] In terms of complications, although, any tourniquet has complications theoretically, the related complications of the traditional high position tourniquet group were significantly higher than those of the low position tourniquet group in this study.

4.2 Analysis of superiority of the low position tourniquet group

This study focused on minimizing the impact of the tourniquet on normal tissues instead of traditional thinking mode.

Results of VAS scores were comprehensively analyzed as followed. Firstly pression of tourniquets and Ischemic tissues were significantly decreased so that the compression of skin, quadriceps, sciatic nerve and muscle necrosis was greatly reduced. secondly, the hypoxic harmful substances and myoglobin in the blood were effectively reduced, which can attenuate the ischemia-reperfusion injury. [9]

The motion of ankle and AOFAS scores of low position tourniquet group were higher than the high position tourniquet group four weeks after surgery. Postoperative pain in the affected limb was reduced, and patients passively or actively accepted early functional exercises, which created conditions for patients to perform early functional recovery or ERAS, improving their early ankle range of motion and functional scores.

As for soft tissue complication, the patients in the low position tourniquet group did not have skin caking and congestion. There were fewer muscles at the binding site of the low position tourniquet. The anterior tibial artery and vein were superficial, which significantly reduced the inflation pressure of the tourniquet, and thus effectively reduced the tissue damage. In addition, DVT mostly occurred in the long tubular veins of the lower limbs instead of the short veins far from ankle, thus the low position tourniquet not directly invading the proximal part. The lower tourniquet pressure reduced the damage of the blood vessels, which was also an important reason for the reduction of DVT.

4.3 Precautions and prospects

In summary, the use of tourniquets, whatever low position or high position, can meet the the requirements of surgical field in ankle fracture surgery so that the clinician can smoothly complete the operation under safe conditions, even though the lower position tourniquet may perform better, nevertheless. The primary reasons why most clinicians still choose high position tourniquets in the current clinical practice are that the high position tourniquets are not required to operate by clinicians and that low complications are not paid attention to by clinicians. It is conceivable that with the gradual deepening of the concept of ERAS and the increasing requirements of society, the use of low position tourniquets may become more and more widespread. However, we experientially choose the pressure setting of 1.5 times systolic pressure and the holding time of no more than 1.5 hours in view of little literature in this field before. Moreover, small sampling and short-term following up limit the research. Further studies are required to explore tourniquets more accurately in future.

Declarations

Ethics approval and consent to participate

This retrospective research protocol was approved by the Institutional Review Board of Tongji Hospital, and informed consent was obtained from all study participants before participation in the study. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Acknowledgements

Not applicable.

Author contribution

Yao Ying and Zhang Yue contributed equally to this study.

Yao Ying and Zhang Yue designed the study and contributed to analyzing the data, writing of the manuscript. Yu Guang-rong, Xu fang-lei provided the technical assistance. Zhou lu-yi, Shi ting-ting, Zhou li-yu collected the data. Fan Jian contributed to data interpretation and provided general support. All authors have read and approved the manuscript.

Availability of data and materials

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

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Figures

Figure 1

A 49 year old man with a traffic injury on his right ankle and foot with a fracture of his right calcaneus. (A)-(B) Intraoperative tourniquet binding (C) Intraoperative surgical field.