Association of tourniquet utilization with blood loss, pain, rehabilitation, and complications patients with hypertension undergoing TKA—A Randomized, Controlled, Clinical Trial

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Research Article

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Abstract

Purpose: The primary aim was to compare the effects of different tourniquet application methods during the TKA surgery of patients with hypertension and determine the best technique of using a tourniquet.

Methods: A total of 100 patients were divided into three groups. Patients in group A who underwent TKA with tourniquet using before skin incision, and released after the skin was closed, and patients in group B with tourniquet using before the knee prosthesis was placed, and leased after the skin was closed. Patients in group C with tourniquet use before placing knee prosthesis, the tourniquet was leased after bone cement solidified. The following medical outcomes of the three groups were monitored and recorded: the operation time, intraoperative blood loss volume, postoperative complication, the amount of hidden blood loss, total blood loss, blood transfusion, swelling rate, visual analogue scale (VAS) and the knee society score (KSS).

Results: The intraoperative blood loss in Group A was significantly low than that in Group B and Group C($P<0.05$). In terms of hidden blood loss, total blood loss and blood transfusion, the difference among the three groups was statistically significant which Group A was higher than group B and group C($P< 0.05$); No significant differences were observed between Group A, Group B and Group C when we compared operation time. The swelling rate and VAS score in group A 3 days after operation was significantly higher than that of group B and group C ($P<0.05$); KSS score three weeks after operation in group A were significantly lower than those in group B and group C($P<0.05$). There was no significant difference in KSS scores between the three groups one year after operation ($P > 0.05$).

Conclusion: Tourniquets could be used before placing the cement knee prosthesis, and loosened after the suture is completed and the pressure bandage is applied, which can obviously improve the intraoperative blood loss and the short-term postoperative functional effect of the patient, with fewer postoperative complications, but the long-term clinical effect needs further observation.

Introduction

As the population ages, the morbidity of knee osteoarthritis is increasing rapidly, causing a large social and economic burden. The end stage of gonarthritis is characterized by pain, deformity and dyskinesia. Total knee arthroplasty (TKA) is the most effective treatment for the end stage osteoarthritis of knee which could improve the quality of human life significantly[1, 2]. There are, however significant blood loss because of extensive soft tissue and bone damage during surgery, resulting in complications such as surgical site infection (SSI), anemia and poor postoperative functional recovery, which affects early functional exercise and eventually leads to increased incidence of thrombosis after surgery[3, 4]. Therefore, how to control intraoperative bleeding is a problem that orthopaedic surgeons have been paying close attention to.

Tourniquet is widely used in TKA to decrease intraoperative bleeding, make the osteotomy surface dry and clean, reduce the mixing of bone cement and blood, increase the surgeon comfort, and facilitate the

fixation of the implant with bone cement[5, 6]. However, the using of tourniquets also cause hidden blood loss, thigh pain, nerve palsy, ischemia, soft tissue damage, thromboembolic complications, poor wound healing, and patella maltracking. Furthermore, patient's recovery may be delayed due to the reduced quadriceps femoris muscle strength, reduced the range of motion(ROM) of knee, and increased pain caused by tourniquet using[7, 8].

Hypertension has a great influence on TKA. Patients are prone to have cardiovascular accidents which increases the risks during surgery. Apart from that, it increases the risk of intraoperative bleeding during operation and make the prognosis poor. Several randomized controlled trials and meta-analyses dealing with the effects of tourniquet during TKA have been published but controversy still remains about the releasing time of tourniquet and whether using it during the surgery[9–11]. In addition, all these studies were just focused on the effect of patients under TKA but not classify the patients who may have more intraoperative blood loss or were more susceptible to the blood loss, say, hypertension samples. We have even never saw some reports about the using methods of tourniquets on the patients with hypertension so far. Based on the above background, the purpose of this study was to compare the effects of different tourniquet application methods during the TKA surgery of the patients with hypertension and determine the best technique of using a tourniquet.

Data And Methods

Clinical background

Before this study began, approval was obtained from the appropriate institutional review board of Capital Medical University. All patients provided written consent and were enrolled in the study in accordance with the Consolidated Standards of Reporting Trials (CONSORT) and the Helsinki Declaration. The authors are accountable for all aspects of the work in ensuring the study's integrity and data accuracy. Total of 100 hypertensive patients with knee osteoarthritis who undergoing TKA for the first time in Beijing Rehabilitation Hospital, Capital Medical University and Qilu Hospital of Shandong University Dezhou Hospital from July 2019 to December 2020 were included in this study. The patients enrolled were divided into three groups: Patients in Group A[18 males, 15 females; median age = 68.81 ± 8.17 years (range, 65–90 years)] included 15 cases with affected knee joint on the left side and 18 cases on the right side. Patients in Group B[15 males, 17 females; median age = 69.63 ± 8.75 years (range, 67–89 years)] included 16 cases with affected knee joint on the left side and 16 cases on the right side. Patients in Group C[17 males, 18 females; median age = 67.86 ± 8.26 years (range, 67–88 years)] included 16 cases with affected knee joint on the left side and 19 cases on the right side. Compared with the general clinical data of the patients among the three groups, the difference was no statistical significance ($P > 0.05$), and is comparable.

Selection criteria

Inclusion criteria are as follows: (1) complete clinical data, (2) Kellgren–Lawrence radiological classification scale grades III-IV, (3) patients with hypertension, (4) ineffective conservative treatment before undergoing primary TKA. Exclusion criteria are as follows: (1) patients undergoing bilateral TKA, or revision, (2) the varus or valgus deformity of the patient's knee joint is greater than 15°, (3) patients with rheumatoid arthritis.

Preoperative intervention

In patients with hypertension were treated by the following protocol to control the blood pressure. (1) All patients must take antihypertensive drugs according to the habit of patients as usually at home until the eve of surgery. (2) For patients with grade 1 and grade 2 hypertension would continue to be treated with antihypertensive drugs and not necessary to pay more attend before operation. (3) For patients with grade 3 hypertension, we should try to control the level of blood pressure within normal limits. (4) If necessary, consultations were requested from relevant departments to help making the treatment regimen. (5) The TKA surgery was not performed until the blood pressure decreased to normal.

Surgical procedure

To avoid bias, all operations were performed by the same surgeon. In all patients, we used the same cemented knee prosthesis (NexGen, Complete Knee Solution, Zimmer, Warsaw, IN, USA). Group A comprised 33 patients who underwent TKA with tourniquet using before skin incision, and released after the skin was closed, and Group B comprised 32 patients who underwent TKA with tourniquet using before the knee prosthesis was placed, and leased after the skin was closed. Group C comprised 35 patients who underwent TKA with tourniquet use before placing knee prosthesis, and the tourniquet was leased after bone cement solidified.

All patients were placed in a supine position and a conventional anterior medial incision for the knee was applied in all cases. The medial parapatellar approach was used to cut the joint capsule to expose the joint cavity and remove the synovium, part of the fat pad, the meniscus, the anterior cruciate ligament, and osteophytes. Then, osteotomy of tibia, femur and patella was performed. The knee prosthesis trial was performed to achieve soft tissue balance, eversion stability and lower limb mechanical axis recover before the knee prosthesis was implanted and the wound was closed in a standard layered fashion.

Postoperative intervention

All patients were treated with intravenous patient-controlled analgesia (PCA) and received routine anti-inflammatory and anticoagulation treatment after surgery. Blood transfusion would be considered if the haemoglobin (Hb) concentration was below 70 g/L. For patients with hypoproteinemia [albumin (ALB) < 30g/l], intravenous infusion of ALB (Behring, Germany) was given. On the day of surgery, walking functional exercise was allowed with the assisted devices such as a cane or walker. Patients began rehabilitation training under the supervision of a physiotherapist at the second day after operation until hospital discharge. A home-based exercise program was followed after patients were discharged.

Observation indicators

The patient's operation time, intraoperative blood loss volume and postoperative complications was recorded. The amount of hidden blood loss, total blood loss, blood transfusion, swelling rate, visual analogue scale (VAS) were measured on the third day. The total blood loss was calculated on the basis of the validated Gross formula[12, 13]. The knee society score (KSS) were recorded and compared among the three groups at 4 weeks and 12 monthes after operation.

Statistical analysis

All measurement data were processed by SPSS 23.0 (IBM, U.S.) statistical software,. The inter-group and intra-group data was analyzed by using the one-way analyses of variance (ANOVA) and Student-Newman-Keuls test, and were expressed as the mean value ± standard deviation (SD). Kolmogorov–Smirnrov test and Levene test were first performed to confirm the normality and equal variance assumptions of the data were notviolated. A confidence level of 95% ($p < 0.05$) was considered significant.

Results

Comparison of intraoperative blood loss, hidden blood loss, total blood loss, and blood transfusion between the three groups

The intraoperative blood loss in Group A (239.26 ± 53.83 ml) was significantly low than that in Group B (353.72 ± 61.36 ml) and Group C (394.28 ± 39.61 ml) ($P < 0.05$). In terms of hidden blood loss, total blood loss and blood transfusion, the difference among the three groups was statistically significant which Group A was higher than group B and group C ($P < 0.05$), as shown in Table 1.

Table 1
Comparison of differences in blood loss of the study participants (ml)

	intraoperative blood loss	hidden blood loss	total blood loss	blood transfusion
Group A	239.26 ± 53.83	528.21 ± 51.95	804.28 ± 33.65	281.82 ± 75.61
Group B	353.72 ± 61.36	325.15.28 ± 43.91	683.38 ± 31.73	189.73 ± 35.77
Group C	394.28 ± 39.61	255.28 ± 41.83	636.771 ± 37.26	153.82 ± 31.29
t value	2.452	1.764	3.136	2.133
P value	0.025	0.037	0.021	0.029

Comparison of operation time, swelling rate, pain level between the three groups

No significant differences were observed between Group A, Group B and Group C when we compared operation time. However, the swelling rate (17.52 ± 2.17) and VAS (4.15 ± 0.38) in group A 3 days after

operation was significantly higher than that of group B [(9.28 ± 1.85), (3.18 ± 1.72)] and group C [(7.21 ± 1.37), (3.11 ± 1.52)] (P < 0.05), as shown in Table 2.

Table 2
Comparison of differences in operation time, swelling rate, pain level

	operation time(min)	swelling rate (%)	VAS score
Group A	71.21 ± 15.16	17.52 ± 2.17	4.15 ± 0.38
Group B	73.29 ± 11.95	9.28 ± 1.85	3.18 ± 1.72
Group C	71.51 ± 15.94	7.21 ± 1.37	3.11 ± 1.52
t value	2.231	2.635	1.683
P value	0.028	0.023	0.039

perioperative complications

All patients recovered well after operation and all surgical wounds healed well. In Group A, there was one deep vein thrombosis (DVT) and three anemia. one venous thrombosis occurred in group B. No other postoperative complications such as acute myocardial infarction, cerebral infarction and pulmonary embolism occurred in the three groups.

Follow-up results

Patients in all groups were followed up for 12 months. KSS score 4 weeks after operation in group A (43.56 ± 5.71) were significantly lower than those in group B (63.15 ± 7.56) and group C (68.29 ± 4.19) (P < 0.05). There was no significant difference in KSS scores between the three groups one year after operation (P > 0.05).

Discussion

As the main target for high blood pressure, the structure of blood vessel wall of patients is destroyed. At the same time, the blood pressure of patients is relatively high, and the amount of bleeding during or after operation is relatively larger for patients with hypertension[14, 15]. Multiple studies have confirmed that the intraoperative blood loss of patients with knee osteoarthritis complicated with hypertension undergoing TKA surgery is significantly higher than that of patients without hypertension, and the postoperative blood loss of hypertensive patients is significantly increased[16–18]. *Jai Hyung Park* et al. reported that reported that hypertension was the second most common preoperative complication after anemia in arthroplasty patients and had a significant impact on perioperative blood loss[3]. When other diseases are complicated with hypertension, the blood transfusion volume of the surgical patients can be obviously increased. Patients with hypertension have more blood loss during TKA skin incision exposure. The reasons for that may be although the patient's blood pressure has been controlled within a reasonable range, the fluctuation range of the patient's blood pressure during operation is relatively large, and the

systolic blood pressure is often higher, increasing the blood loss during operation[18]. In addition, when patients with hypertension use electrocoagulation or gauze for hemostasis during operation, the hemostasis effect is worse than that of normal patients, resulting in more blood loss during operation. Therefore, for patients with hypertension, it is of great significance to use tourniquet during TKA to reduce perioperative blood loss[17].

Tourniquet, as an important hemostasis device in surgery, is widely used in TKA surgery. In this study, the total blood loss of tourniquet used in TKA was significantly reduced compared with that of tourniquet used in simple osteotomy and osteotomy to the end of suture skin. Hypertension has no obvious effect on functional exercise and recovery after TKA operation. Patients who use tourniquets will suffer from pain and functional swelling in the early stage after operation, but will not have obvious effect on long-term effect. It is necessary to pay special attention to the fact that the use of tourniquets can significantly increase the risk of DVT and intermuscular vein thrombosis of patients[18].

Long-duration tourniquet use can lead higher pain scores and reduce functional recovery after TKA. *Olivecrona et al.* reported a study involving 577 patients for the first time TKA and a prospective study of 46 knee revision patients[19]. The results showed that when the risk of complications increased with each additional 10 min of barometric tourniquet use, the risk of various complications is significant after 100 min increased. *Okan Ozkunt et al.* conducted a prospective randomized study of 69 patients using three different tourniquet usage methods during TKA process and found that long-duration doesn't show the advantage of bone cement infiltration, but it also does VAS score increased and KSS score decreased[20]. In another randomized, double-blind, controlled study, *Wang* et al. found that instead of using the tourniquet throughout, using the tourniquet only during the implant placement procedure do not increase the amount of transfusions and surgical time[21]. Patients experienced less pain on the first postoperative day, were able to start straight leg raising training earlier, and had fewer minor complications via limiting the time of tourniquet using time[21]. Cai et al. also found that periodical use can reduce postoperative blood loss and total blood loss, limb relief body swelling and help with early rehabilitation training[22]. In this study, tourniquets used during osteotomy, prosthesis installation and osteotomy to suture can significantly reduce postoperative hemorrhage and postoperative swelling rate. This may be due to the injury of vascular wall, muscle ischemia-reperfusion injury and rhabdomyolysis of the patient caused by tourniquet during operation, resulting in increased postoperative hemorrhage and severe limb swelling, affecting postoperative functional recovery.

The use of tourniquets will lead to an increase in the operative risks of hypertensive patients. Hypertensive patients have fragile vascular walls, reduced regulatory function, and are more prone to sudden cardiovascular events under stress. The use of tourniquets can stimulate sympathetic nerves and cause violent fluctuations in hemodynamics, thus increasing the risk of myocardial ischemia or acute myocardial infarction during operation[23, 24]. Anesthesiologists need to effectively control the stress response and maintain the stability of the operation with drugs inhibiting sympathetic nerves during operation. Tourniquet can also cause lung function damage to a certain extent[23]. Vascular endothelial

dysfunction in hypertensive patients leads to endothelin/nitric oxide imbalance, which may affect lung function[6]. In this study, it can be seen that the incidence of postoperative anemia, DVT and intermuscular venous thrombosis in patients who use tourniquets throughout the course are significantly higher than those in the other two groups. When using tourniquets in patients with hypertension undergoing TKA, the use time of tourniquets should be carefully selected, and at the same time, the tourniquets should be closely monitored by anesthesiologists to avoid tourniquet reactions in patients.

To sum up, tourniquets could be used before placing the cement knee prosthesis, and loosened after the suture is completed and the pressure bandage is applied, which can obviously improve the intraoperative blood loss and the short-term postoperative functional effect of the patient, with fewer postoperative complications, but the long-term clinical effect needs further observation. The use of tourniquets in hypertension patients during operation will lead to increased probability of heart and lung injury and thrombosis. Patients with hypertension should be cautious in using tourniquets and use tourniquets individually.

Declarations

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Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of Beijing Rehabilitation Hospital, Capital Medical University. Written informed consent was obtained from all the study subjects before enrollment.

Consent for publication

All participants including patients and control group have permitted to share and publish their information with their own willingness via a declaration form signed by themselves.

Competing Interests

The authors declare that they have no competing interests.

Author contributions

Study conception and design: Huqing Yang, Feng Guo, Bing Song Acquisition of data: Feng Guo, Bing Song Analysis and interpretation of data: Liping Zhang, Yaohua Zhang Huanxin Xie, Hongyue Zhang Critical revision: Huaqing Yang

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Availability of data and materials

The datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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