

# A Prospective Study on the Reduction of Perioperative Blood Loss in Primary Total Knee Arthroplasty with Femoral Extramedullary Positioning Osteotomy

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## Technical note

**Keywords:** Total knee arthroplasty, Femoral extramedullary positioning, Gyroscope

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# Abstract

**Purpose:** To investigate the effect of gyroscope femoral extramedullary positioning osteotomy on perioperative blood loss in primary total knee arthroplasty (TKA).

**Methods:** 71 knee-joints from 59 patients receiving primary TKA in our hospital from June 2019 to June 2020 were included. A prospective, double-blind study was conducted. The included patients were randomly assigned to the extramedullary osteotomy group (group A; 34 cases underwent femoral extramedullary positioning osteotomy using a gyroscope) and intramedullary osteotomy group (group B; 37 cases underwent traditional intramedullary guide rod for femoral positioning osteotomy). The differences in blood loss and knee function were observed.

**Results:** ☒ There was no significant difference in age, gender, body mass index, preoperative hemoglobin, preoperative Knee Society Score (KSS), and pain visual analogue scale (VAS) between the two groups of patients. ☒ The intraoperative blood loss, postoperative drainage, and total blood loss in group A were lower than those in group B ( $P < 0.001$ ). ☒ There was no significant difference in VAS and KSS between the two groups, and they were higher than those before operation. ☒ The range of knee joint motion in group A was higher than that in group B at 1 and 3 days after the operation ( $P < 0.01$ ), but there was no significant difference in the range of knee motion between the two groups at 7 days and 6 weeks after the operation.

**Conclusion:** Femoral extramedullary positioning osteotomy with a gyroscope significantly reduced perioperative blood loss in primary TKA. The functional score of the patient knee joint after this operation had no significant difference from that of traditional operation.

## Introduction

Total knee arthroplasty (TKA), as the most effective method for the treatment of end-stage knee osteoarthritis, has been applied in the clinic for decades and has achieved favorable outcomes. With the aging population and the advancement of medical technology, the number of patients receiving TKA is on the rise year by year, and the average age of these patients is also increasing. TKA involves a large amount of soft tissue loosening and osteotomy, accompanied by massive blood loss. The previous study has shown that the total perioperative blood loss of unilateral TKA can reach 1500 mL [1], which undoubtedly increases the risk of surgery and hinders perioperative management and postoperative recovery of patients.

In order to reduce the perioperative blood loss and side effects of TKA, orthopedics doctors constantly improve the surgical techniques, such as intravenous or local use of tranexamic acid [2], half-way or no use of tourniquets to fully stop bleeding during operation [3], and optimization of the use of drainage tube [4]. Traditional TKA for femoral articular surface osteotomy requires an intramedullary positioning rod to measure the femoral valgus osteotomy angle, but reaming and placement of intramedullary positioning rod will bring inevitable risks of intramedullary hemorrhage and fat embolism. Therefore, we conducted a

prospective, randomized, and double-blind study, used a measuring device with a built-in gyroscope for extramedullary positioning to measure the femoral valgus osteotomy angle, and performed osteotomy through its adapted guide device, thereby observing and analyzing the safety and efficacy of this technique in reducing perioperative blood loss in TKA.

## Materials And Methods

Totally 71 knee joints from 59 patients receiving primary TKA in the First Affiliated Hospital of Kunming Medical University from June 2019 to June 2020 were selected. The inclusion criteria were as follows: patients underwent primary TKA due to knee osteoarthritis or rheumatoid arthritis, and the same type of knee prosthesis from the same manufacturer was used in all these patients. The exclusion criteria were as follows: ☐ incomplete preoperative and postoperative follow-up data or poor quality of imaging data; ☐ obese patients (BMI > 30 kg/m<sup>2</sup>); ☐ temporary alternation of operation plan during operation (e.g. using extension rod or cushion block). The included patients were randomly assigned to the femoral extramedullary positioning osteotomy group (group A) and femoral intramedullary positioning osteotomy group (group B). All the patients and their families knew the content of this study and signed the informed consent. This study was approved by the Ethics Committee of the First Affiliated Hospital of Kunming Medical University.

A3-GT knee prosthesis provided by AK Medical Equipment Co., Ltd (Beijing, China) were used in all these patients. In vivo implantation materials included tibial prosthesis, femoral prosthesis, pad, and matching lock clip. The iKPAS positioning system for total knee surgery (femoral side) provided by i-JOIN Medical Technology Co., Ltd (Shanghai, China) was used in the navigation group. The tools included Bluetooth measuring device with aseptic packaging, adapted calibrator, positioning device, guide device, and tablet computer with corresponding software installed.

## Operation methods

All operations were performed by the same surgeon in the same treatment group. The medial parapatellar approach was taken through the median incision. The soft tissue was appropriately released and the synovium and osteophyte were cleared. For group A, femoral extramedullary positioning osteotomy was performed using a gyroscope. In the extreme flexion femoral osteotomy, the femoral positioning device was fixed on the distal end of the femoral condyle approximately parallel to the Insall line, and the calibrated measuring device was inserted into the slot of the positioning device. The gyroscope in the measuring device determined the rotation center of the femoral head through several times of flexion and external and internal extension. The angle data to be corrected were obtained by computer software processing. After adjusting the angle of the guide device according to the data (this angle, together with the positioning device, corrected the distal femoral valgus angle and anteroposterior angle), it was connected with the positioning device and fixed on the femur with Kirschner wire. Then, the positioning

device was removed. After adjusting the thickness of the osteotomy with the parallel screw holes on the osteotomy guide device, the femoral osteotomy was performed (Figure 1).

For group B, the conventional femoral intramedullary guide rod was used to localize the osteotomy. The femoral valgus osteotomy angle was determined by X-ray measurement before the operation, and the other operation steps were the same as group A. The two groups were treated with tourniquets halfway. That is, after osteotomy, the tourniquet was inflated, and then, pulse washing was performed and knee prosthesis was placed. After the bone cement was solidified, the tourniquet was deflated, and the incision was washed and sutured after sufficient hemostasis.

## **Main outcome measures**

The intraoperative blood loss, postoperative drainage volume, operation time, preoperative and postoperative minimum hemoglobin (Hb) were recorded for the evaluation of perioperative blood loss. The pain visual analogue scale (VAS), Knee Society Score (KSS), and range of knee motion were used to assess clinical outcomes.

## **Statistical analysis**

Data analysis was performed using the SPSS 26.0 software. Measurement data are expressed as  $x \pm s$ . The paired sample t-test was used for the comparison of intra-group data. The Independent sample t-test was used when the inter-group data complied with normal distribution. The rank-sum test was used for the inter-group data that were not in compliance with normal distribution. A value of  $\alpha = 0.05$  was considered statistically significant.

## **Results**

A total of 71 knees from 59 patients who underwent primary TKA were included. All cases were involved in the result analysis, and no follow-up was lost.

## **Comparison of general information between the two groups**

There was no significant difference in age, gender, BMI, preoperative Hb, VAS, range of knee motion, and preoperative KSS between the two groups of patients, which were comparable (Table 1).

## **Evaluation of perioperative blood loss**

There was no difference in preoperative Hb between the two groups of patients ( $P > 0.05$ ); the intraoperative blood loss, postoperative drainage, tourniquet use time, and total blood loss in group A

were lower than those in group B ( $P < 0.05$ ); the postoperative minimum Hb in group A was higher than that in the group B ( $P < 0.05$ ) (Table 2).

## Characteristics of postoperative recovery

VAS, KSS, and range of knee motion were used to evaluate the postoperative recovery of the two groups of patients. There was no significant difference in VAS and KSS between the two groups at 6 weeks, 12 weeks, 6 months, and 12 months after operation; the range of knee motion in group A was higher than that in the group B at 1 and 3 days after the operation ( $P < 0.01$ ), but there was no significant difference in range of knee motion between the two groups at 7 days and 6 weeks after the operation.

## Discussion

Many factors affect the perioperative blood loss of TKA. Apart from individual differences (such as long-term exposure to anticoagulants, hemophilia, etc.), the operation is also a very important reason. Tranexamic acid and tourniquet have been widely proved to be effective in reducing perioperative blood loss of TKA, but little attention has been paid to intramedullary hemorrhage caused by reaming. This study analyzed the effect of femoral extramedullary osteotomy guided by a gyroscope on the perioperative period of TKA in the case of excluding other interference factors.

This study showed that the perioperative blood loss of the extramedullary positioning group was less than that of the traditional intramedullary positioning group, which is the congenital advantage of extramedullary positioning. Extramedullary positioning does not need to open the medullary cavity, which can reduce intractable medullary hemorrhage and bleeding on the osteotomy surface, shorten the time of tourniquet use during operation, reduce the incidence of limb swelling, muscle soreness, and tension blisters during hospitalization [5, 6], as well as reduce the risk of fat embolism [7, 8] and deep vein thrombosis [9]. Reducing blood loss contributes to perioperative management, reducing postoperative limb swelling, and promoting earlier functional exercise. Moreover, it has been reported that the dry osteotomy surface can increase the adhesion between bone and bone cement [10]. Bleeding on the osteotomy surface and blood clots in the trabecular space can reduce the penetration thickness and viscosity of bone cement [11], thus affecting the stability of the prosthesis. Some scholars believe that the use of computer navigation-assisted TKA can reduce intraoperative blood loss [12, 13].

Reaming itself also has many problems. When the patient has a narrow or deformed femoral medullary cavity and has an implant in the ipsilateral femur, it will be difficult to place the intramedullary guide device during the operation, or when the patient has previous osteomyelitis and other situations that are not suitable for reaming, the advantage of extramedullary positioning can be more reflected. The position error of the intramedullary guide rod at the entrance of the femur also exerts a great influence on the anteroposterior angle of the distal femoral osteotomy. On the sagittal plane, the anteroposterior angle difference can reach  $5^\circ$ , which leads to inaccurate femoral prosthesis placement, and then affects the

knee flexion and extension activities [14]. The mismatch between the diameter of the guide rod and the diameter of the medullary cavity can also increase the error of intramedullary positioning osteotomy.

After the femoral extramedullary positioning osteotomy of TKA is proposed, many osteotomy operations such as an external positioning rod and 3D printing guide plates are successively derived [15]. However, due to the relatively complex instruments, long preoperative preparation cycle, or inaccurate positioning, they have not been widely applied. With the increasing portability of intelligent devices, extramedullary positioning technology may no longer need to rely on X-ray and CT three-dimensional reconstruction for localization. It only needs to add a Bluetooth wireless measuring device with a built-in gyroscope and two or three osteotomy modules to the conventional knee replacement surgical instruments, and use the software on the tablet computer to assist, which can replace the traditional intramedullary reaming localization by the guide rod to complete the distal femoral articular surface osteotomy.

The accuracy of osteotomy has always been the concern of orthopedics doctors. The valgus osteotomy angle of the distal femur directly affects the axial alignment of the lower extremity, and the axial alignment of the lower extremity that returns to the neutral position, that is, the angle of hip-knee-ankle of 180°, is the gold standard for obtaining better clinical efficacy after TKA [16]. The axial alignment of the lower extremity in a neutral position can balance the stress in the internal and external compartment of the knee joint and reduce pad wear and aseptic loosening rate, thereby improving the long-term survival rate of the knee prosthesis [17, 18]. At present, femoral osteotomy with fixed valgus angle is still used in most TKA, but the preoperative measurement of valgus osteotomy angle may have errors due to the non-standard imaging data. The rotation center of the femoral head can be determined by gyroscope and computer navigation during operation to determine the femoral valgus osteotomy angle, which can make the osteotomy more accurate. Although the results of the axial alignment of the lower extremity were not included in this study, there is evidence proving that the prosthesis placement deviation of computer navigation in TKA is smaller than that of traditional TKA [19–22]. It has also been reported that 95.8% of the cases using navigation osteotomy have an osteotomy angle error of less than 2° [23].

Deficiency and prospect: all the patients included in this study were treated with conventional primary TKA. Whether this operation method can be used in a complex knee arthroplasty such as knee revision, stiff knee, severe genu varum, and genu valgum remains to be studied. But to be sure, compared with the traditional intramedullary positioning osteotomy, the use of gyroscope navigation for femoral extramedullary positioning osteotomy can ensure the patient obtain a stable and reliable artificial knee joint, reduce perioperative blood loss, and accelerate the postoperative recovery.

## Abbreviations

total knee arthroplasty (TKA)

Knee Society Score (KSS)

visual analogue scale (VAS)

## **Declarations**

## **Acknowledgements**

No applicable.

## **Authors' contributions**

JHC, SFW, and BL contributed to the conception and design of the study. JHC was a major contributor for drafting the manuscript. BL was the chief surgeon responsible for operation. YY, YML, ZGL, and JHL contributed to the acquisition of the data. JHC and JHL contributed to the analysis and interpretation of the data. JHC and SFW make important revisions. JHC and BL contributed responsibly for the overall content as guarantors. All authors read and approved the final manuscript.

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## **Availability of data and materials**

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

## **Ethics approval and consent to participate**

The study has gotten approval from Medical Ethics Committee of the First Affiliated Hospital of Kunming Medical University.

## **Consent for publication**

This section is not applicable for our study.

## **Competing interests**

The authors declare that they have no competing interests.

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## Tables

**Table 1****General information and Clinical Characteristics**

	<b>Group A</b>	<b>Group B</b>
Age (years)	68.35 ± 5.69	67.78 ± 7.89
Sex (male/female)	14/20	12/25
Bmi (kg/m <sup>2</sup> )	25.63 ± 2.03	26.04 ± 2.06
<b>Preoperative laboratory data</b>		
<b>Hemoglobin (g/dL)</b>	12.49 ± 0.82	12.61 ± 0.65
<b>Platelet count (per mm<sup>3</sup>)</b>	294586 ± 46394	302526 ± 58725
<b>Preoperative knee score</b>		
Preoperative VAS	7.15 ± 1.10	7.27 ± 0.96
Preoperative knee flexion (°)	81.32 ± 11.30	80.41 ± 12.21
Preoperative KSS	44.32 ± 6.94	44.11 ± 5.17

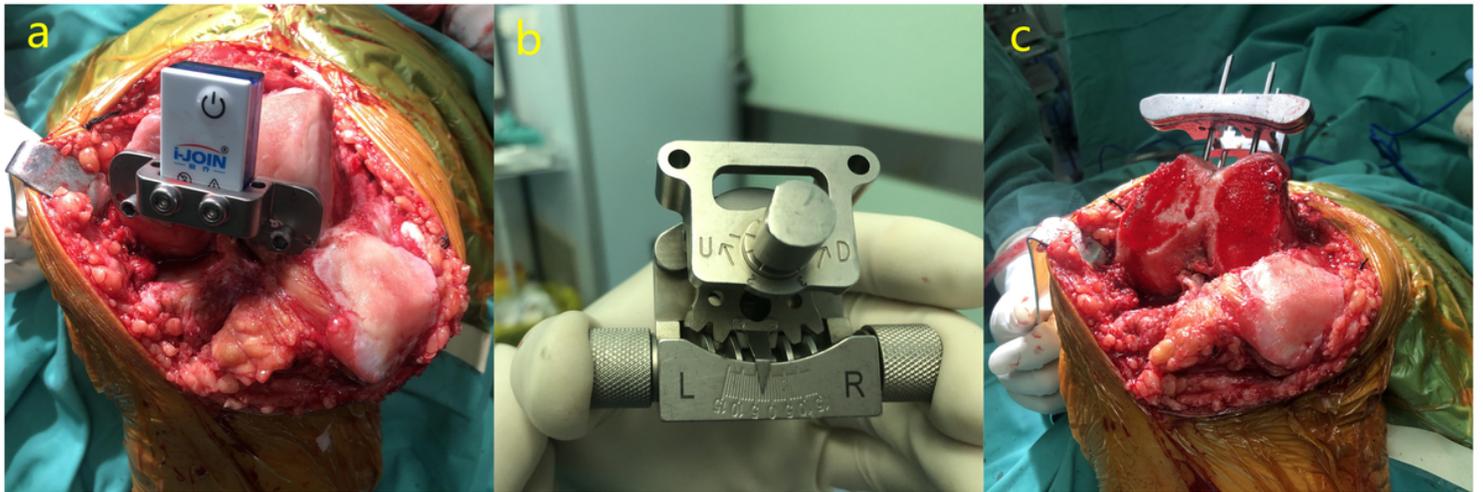
**Table 2****Evaluation of perioperative blood loss**

	<b>Group A</b>	<b>Group B</b>
Intraoperative blood loss (mL)	120.89 ± 16.90	177.70 ± 22.19
Postoperative drainage volume (mL)	132.35 ± 21.04	215.41 ± 26.52
<b>Preoperative hemoglobin (g/dL)</b>	12.49 ± 0.82	12.61 ± 0.65
Postoperative minimum hemoglobin (g/dL)	11.23 ± 0.95	10.71 ± 0.91
Tourniquet time (min)	42.17 ± 6.07	51.51 ± 7.02
Total blood loss (mL)	483.5	731.5
Blood transfusion (case)	0	3

**Table 3****Characteristics of postoperative recovery**

	<b>Group A</b>	<b>Group B</b>	<b>P value</b>
<b>VAS</b>			
6 weeks after operation	4.68 ± 0.81	4.76 ± 0.95	0.702
12 weeks after operation	2.38 ± 0.74	2.46 ± 0.80	0.675
6 months after operation	1.74 ± 0.90	1.68 ± 1.03	0.795
12 months after operation	1.24 ± 0.65	1.27 ± 0.84	0.845
<b>KSS</b>			
6 weeks after operation	77.74 ± 5.46	76.05 ± 6.77	0.252
12 weeks after operation	83.09 ± 6.09	82.60 ± 6.79	0.748
6 months after operation	86.21 ± 4.18	86.57 ± 4.06	0.713
12 months after operation	86.97 ± 3.54	87.16 ± 4.87	0.849
<b>Knee flexion (°)</b>			
1 day after operation	102.35 ± 10.68	90.03 ± 7.84	< 0.001
3 day after operation	115.15 ± 12.40	106.08 ± 8.99	< 0.001
7 day after operation	124.12 ± 11.31	123.92 ± 10.55	0.939
6 weeks after operation	130.29 ± 8.07	129.86 ± 8.78	0.831
<b>Length of hospital stay (days)</b>	6-12 (mean 8.7)	7-14 (mean 9.6)	
<b>Infection (cases)</b>	0	0	
<b>Deep vein thrombosis (cases)</b>	0	5	

## Figures



**Figure 1**

a: Install the orthopedic positioning device roughly parallel to the install line, and insert the calibrated gyroscope into the slot of the positioning device. b: Osteotomy guide device with adjustable angle. c: Extramedullary osteotomy was performed on the articular surface of the femur.