The influence of a half-course tourniquet strategy on peri-operative blood loss and early functional recovery in primary total knee arthroplasty

Sen Chen · JianPing Li · Hao Peng · Jianlin Zhou ·
Hongsong Fang · Huifeng Zheng

Received: 21 October 2013 / Accepted: 30 October 2013 / Published online: 21 November 2013
© Springer-Verlag Berlin Heidelberg 2013

Abstract

Purpose The aim of this study was to explore the influence of a half-course tourniquet strategy on the peri-operative blood loss and early functional recovery in primary total knee arthroplasty.

Methods A prospective clinical randomised controlled study was carried out in which 64 patients were equally divided into two groups: half-course group and whole-course group. A series of indicators were observed and recorded. These included operation time, peri-operative blood loss, visual analogue scale (VAS) score of the thigh or knee, limb swelling index, rehabilitation progress and occurrence of deep venous thrombosis cases.

Results There was no significant difference in operation time between the two groups. The intra-operative blood loss was slightly more in the half-course group, while the difference was not significant. The post-operative blood loss and calculated blood loss were less in the half-course group and the difference was significant. The thigh VAS score, limb swelling and time intervals required for patients to achieve straight leg raises and 90° of knee flexion in the half-course group were better than in the whole-course group. No case of symptomatic deep venous thrombosis happened in this study, while occult incidence of deep venous thrombosis happened in both groups, but no significant difference between the groups was confirmed.

Conclusions The half-course tourniquet strategy could decrease the total peri-operative blood loss in primary total knee arthroplasty. It was beneficial in helping patients to achieve earlier functional recovery by improving the pain experience and limb swelling early in the post-operative period.

Keywords Total knee arthroplasty · Pneumatic tourniquet · Blood loss · Early functional recovery

The pneumatic tourniquet is widely used in total knee arthroplasty (TKA) because surgeons enjoy the bloodless surgical field. However, it has been reported that tourniquet application may lead to some undesirable complications, such as aggravation of post-operative pain, delay of functional recovery and increased incidence of deep venous thrombosis (DVT), etc. [1–7]. Some surgeons even believe that a tourniquet would increase the total peri-operative blood loss [8, 9]. We hypothesised that the half-course pneumatic tourniquet strategy may possess advantages and minimise the disadvantages of tourniquet application in primary TKA. Therefore, we conducted a prospective randomised clinical trial to explore the clinical significance of the half-course pneumatic tourniquet strategy in primary TKA.

Sen Chen and JianPing Li contributed equally to this work.

S. Chen · J. Li · H. Peng (✉) · J. Zhou · H. Fang · H. Zheng
Department of Orthopedics, Renmin Hospital of Wuhan University,
Wuhan 430060, Hubei Province, People's Republic of China
e-mail: ph5868@163.com

S. Chen
Dongfeng General Hospital, Hubei University of Medicine,
Shiyan 442008, Hubei Province, People's Republic of China

Patients and methods

The Consolidated Standards of Reporting Trials (CONSORT) statement was followed to conduct this prospective, randomised, patient- and observer-blinded controlled study [10]. The protocol was registered and approved by the Review Board of the Human Experimental and Ethics Committee of the Renmin Hospital of Wuhan University.

Patients

A total of 64 patients who met the inclusion and exclusion standards were recruited. The inclusion criteria included osteoarthritis or rheumatic arthritis and primary unilateral TKA. The exclusion criteria included diabetes mellitus, haemorrhagic haematologic diseases, haemoglobin (Hb) <100 g/L, peripheral nerve or vascular diseases, malignant tumour, history of vascular thrombosis and local or systemic infectious diseases. The patients were randomly allocated to either the half-course tourniquet group or the whole-course tourniquet group immediately before the surgery by opening a sealed envelope. There were 32 patients in both of the two groups.

Operative techniques and procedures

The tourniquet pressure was equal to systolic blood pressure plus 100 mmHg. In the half-course group, the tourniquet was inflated from osteotomy until the leg was wrapped with elastic bandages. In the whole-course group, the tourniquet was inflated from incision until the leg was wrapped with elastic bandages. All surgical procedures were performed by the same group of surgeons under general anaesthesia. The medial parapatellar approach was used, while an intramedullary guide was used for both tibial and femoral osteotomies. The posterior stabilised cemented prosthesis (NexGen, Zimmer, Warsaw, IN, USA) was implanted, and surface repair of the patella rather than patella replacement was performed in the operation. No blood reinfusion system was used in the operation.

A wound drainage system was used and removed at 48 hours after surgery. Oral rivaroxaban was started 12 hours after surgery, 10 mg once daily. The affected limb was raised higher than the heart level and initiation of functional exercise was encouraged. A continuous passive motion (CPM) device was used for passive motion training two days after surgery.

Outcome measurements

The intra-operative blood loss (IBL) was calculated by measuring the suction volume and weighing the sponges. The post-operative blood loss (PBL) was calculated by measuring the drainage volume and weighing the dressings. Hb and haematocrit (Hct) levels were recorded. The criterion for a blood transfusion was an Hb level less than 8.5 g/dl measured

at the 24th post-operative hour, and the number of patients undergoing transfusion was recorded. Considering the measurement inaccuracy of dressing bleeding volume, Gross's method was employed to get the calculated blood loss (CBL) volume which could reflect the total blood loss perfectly [11]. The post-operative pain of knee and thigh were evaluated by a visual analogue scale (VAS) scoring system. The swelling rate of the thigh was calculated by measuring the thigh circumference 8 cm proximal to the patella. The time needed to achieve straight leg raises and 90° of knee flexion was recorded. We paid special attention to whether symptomatic pulmonary embolism (PE) or DVT happened. Occult DVT was detected by a regular bilateral lower extremity deep venous colour Doppler ultrasound examination.

Statistical analysis

The values in the text are given as the mean and the standard deviation. The level of significance was set at $p < 0.05$. Data were compared using the t test for normally distributed parameters and the chi-square test for proportional data.

Results

The statistical analysis showed no significant difference with respect to gender, age, height, weight and body mass index (BMI) between the two groups (Table 1). The inflation time of the tourniquet in the half-course group was much shorter than in the whole-course group. There was no significant difference in operation time between the two groups.

Blood loss

There was no significant difference confirmed between the two groups in pre-operative Hb (Hb pre.) and Hct (Hct pre.) levels, and in the case of post-operative Hb (Hb post.) and Hct (Hct post.) levels was similar. However, the difference was significant when comparing the pre-operative and post-operative values in both of the two groups. The IBL was slightly more in the half-course group, while the difference was not significant. The PBL and CBL were less in the half-course group and the difference was significant.

Table 1 Demographic and intraoperative data

	Male to female ratio	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m ²)	Tourniquet time (min)	Operation time (min)
Half-course group	10:22	70.3±7.1	158.1±6.4	65.1±9.8	26.1±4.6	42.8±8.5	73.1±14.7
Whole-course group	7:25	72.5±6.9	157.4±8.7	64.8±8.7	26.3±5.9	78.2±11.3	78.2±11.3
<i>p</i> value	0.5714	0.2135	0.7151	0.8974	0.8803	0.0000	0.1248

Table 2 Hb and Hct levels, blood loss and transfusion cases

	Hb pre. (g/dl)	Hct pre. (%)	IBL (ml)	PBL (ml)	Hb post. (g/dl)	Hct post. (%)	CBL (ml)	Transfusion cases
Half-course group	12.5±1.9	37.8±4.5	257.8±105.1	195.3±89.1	10.9±1.2	32.2±4.1	561±165.1	2
Whole-course group	12.3±1.6	38.1±3.9	213.8±87.4	280.2±114.5	10.4±1.4	31.8±3.7	673±201.3	1
<i>p</i> value	0.6504	0.7766	0.0734	0.0016	0.1301	0.6834	0.0178	0.5543

However, the difference between transfusion cases was not significant (Table 2).

Pain, swelling and knee function

Patients' pain experience decreased day by day after the surgery. The difference was significant in VAS score of the thigh between the two groups at one and three days, while the difference was confirmed as not significant at day seven. The VAS score of the knee in the half-course group was lower than in the whole-course group at the three time points, while no significant difference was confirmed. The swelling of the thigh peaked at day three, and then reduced day by day. The swelling rate was always lower in the half-course group than in the whole-course group, while a difference was confirmed at day three. The patients in the half-course group achieved straight leg raises and 90° of knee flexion earlier than those in the whole-course group, while the difference of achieving 90° of knee flexion was significant between the two groups (Table 3).

Incidence of DVT

No patient suffered from symptomatic PE or DVT in this study. However, occult DVT happened in both of the two groups (12 cases in the half-course group and 17 cases in the whole-course group), but no significant difference between the groups was confirmed.

Discussion

It needs to be emphasised that total blood loss includes the visible blood loss and the hidden blood loss in the operation [12, 13]. Considering the blood loss measurement, it is the

CBL rather than the total blood loss that can represent the actual blood loss in TKA [11, 12]. Lots of studies claimed that the CBL was significantly increased without the use of a tourniquet in TKA [1–4]. It was also reported that a tourniquet could reduce bleeding during TKA surgery, but was associated with greater visible and hidden blood loss, while there was no significant difference in the CBL between the two groups [14, 15]. What is more, as the tourniquet may increase the hidden blood loss, the CBL was actually higher in the tourniquet group [8, 9]. Therefore, it remains controversial whether tourniquet application could reduce the total blood loss in TKA. In addition, some scientists believed that deflating the tourniquet during the operation for haemostasis might decrease the hidden blood loss and total blood loss in TKA, but lots of clinical trials proved that it was proper to release the tourniquet as the bandages were being applied, while tourniquet release for haemostasis was not an effective strategy in reducing blood loss or transfusion need in TKA [16–23].

Our study demonstrated that the half-course tourniquet strategy did not significantly increase the IBL. What is more, it could reduce the PBL and CBL in TKA. According to our experience, it is convenient for surgical haemostasis because the anatomical structure is clear in primary TKA surgery. So, the blood loss would not be very large even without a tourniquet. Conversely, bleeding vessels, a cause of IBL and PBL, might be missed when the tourniquet was inflated during TKA surgery. In addition, the damage to skin and muscle caused by long-term application of a tourniquet may influence the venous and lymphatic drainage, and it was also a cause of PBL.

The ischaemia caused by tourniquet application in TKA surgery was proved to be a human clinical model of ischaemia/reperfusion [24]. It was found that the level of malondialdehyde (MDA), inducible nitric oxide synthase (iNOS) and NO metabolites nitrate in the muscle increased when a tourniquet was used in TKA [24–27]. Biopsy showed

Table 3 VAS score, swelling rate and functional recovery

	VAS score of thigh			VAS score of knee			Swelling rate of thigh			Straight leg raises (days)	90° of knee flexion (days)
	1 day	3 days	7 days	1 day	3 days	7 days	1 day	3 days	7 days		
Half-course group	5.3±1.2	4.1±1.3	2.9±0.9	5.2±1.4	3.9±1.2	3.2±0.7	5.4±3.6	7.1±1.7	5.6±3.3	1.5±0.9	1.8±1.1
Whole-course group	6.0±1.3	4.8±1.1	3.2±0.7	5.3±1.5	4.1±1.3	3.3±0.9	5.5±3.2	8.3±2.5	6.2±3.1	1.9±1.1	2.7±1.2
<i>p</i> value	0.0288	0.0233	0.1417	0.7837	0.5249	0.6216	0.9069	0.0283	0.4563	0.1165	0.0412

dissolved quadriceps and massive neutrophil infiltration in patients undergoing TKA surgery with a tourniquet [28]. Therefore, it is reasonable to speculate that post-operative limb pain and limb swelling might be aggravated by the inflammatory reactions caused by the ischaemia/reperfusion injury in TKA. In fact, the use of a tourniquet was related to more post-operative pain in the early stage in TKA [1, 4, 5]. And what remains controversial is whether early tourniquet release could reduce the post-operative limb pain in TKA [3, 21, 23, 29]. Short-term better flexion or extension performance in patients undergoing TKA without a tourniquet has been reported in several studies, but no significant difference was confirmed for the long-term performance [3, 9, 29, 30]. Our study showed that the limb pain and limb swelling index were better in the half-course group, and they achieved straight leg raises and 90° of knee flexion earlier than the whole-course group. However, these differences became insignificant seven days after surgery. It was demonstrated that the half-course tourniquet strategy was beneficial in helping patients to achieve earlier functional recovery by improving the pain experience and post-operative limb swelling.

Transoesophageal echocardiography examination revealed that embolic showers traversing the right atrium, the right ventricle and the pulmonary artery once the tourniquet deflated during TKA surgery were observed to various degrees in all patients and lasted three to 15 minutes [31]. It was suggested that acute PE should be considered as a diagnosis when haemodynamic collapse happened during TKA. Several trails indicated that tourniquet application would promote the risk of developing post-operative PE and/or DVT after TKA [5–7]. Furthermore, there are also studies claiming that the incidence of DVT after TKA is considerably high with or without the application of a tourniquet [30, 32, 33]. What is more, the research by Hernandez et al. proved that surgery time rather than tourniquet time was the main cause leading to DVT and that surgery lasting longer than 120 minutes increased the risk of DVT in TKA [34]. Anyhow, anticoagulant therapy and early ultrasound examination will make sense in prevention of post-operative DVT and pulmonary thromboembolism in TKA [35–38]. All patients received rivaroxaban administration after the TKA surgery, while no cases of symptomatic PE or DVT happened in our study. There was no significant difference in the incidence of occult DVT confirmed between the two groups, which indicated that the tourniquet time was not the key factor leading to DVT, and the rivaroxaban medication was helpful.

We concluded that the half-course tourniquet strategy could decrease the total peri-operative blood loss in primary TKA. It was beneficial in helping patients to achieve earlier functional recovery by improving the pain experience and limb swelling early in the post-operative period. Our new strategy did not increase the incidence of occult DVT, and the rivaroxaban administration was helpful.

References

- Vandenbussche E, Duranthon LD, Couturier M, Pidhorz L, Augereau B (2002) The effect of tourniquet use in total knee arthroplasty. *Int Orthop* 26(5):306–309. doi:10.1007/s00264-002-0360-6
- Matziolis D, Perka C, Hube R, Matziolis G (2011) Influence of tourniquet ischemia on perioperative blood loss after total knee arthroplasty. *Orthopade* 40(2):178–182. doi:10.1007/s00132-010-1727-9
- Stroh DA, Johnson AJ, Mont MA, Bonutti PM (2011) Excellent clinical outcomes in total knee arthroplasty performed without a tourniquet. *Surg Technol Int XXI*:189–193
- Tai TW, Chang CW, Lai KA, Lin CJ, Yang CY (2012) Effects of tourniquet use on blood loss and soft-tissue damage in total knee arthroplasty: a randomized controlled trial. *J Bone Joint Surg Am* 94(24):2209–2215. doi:10.2106/jbjs.k.00813
- Abdel-Salam A, Eyres KS (1995) Effects of tourniquet during total knee arthroplasty. A prospective randomised study. *J Bone Joint Surg Br* 77(2):250–253
- Reikerås O, Clementsen T (2009) Time course of thrombosis and fibrinolysis in total knee arthroplasty with tourniquet application. Local versus systemic activations. *J Thromb Thrombolysis* 28(4):425–428. doi:10.1007/s11239-008-0299-6
- Wauke K, Nagashima M, Kato N, Ogawa R, Yoshino S (2002) Comparative study between thromboembolism and total knee arthroplasty with or without tourniquet in rheumatoid arthritis patients. *Arch Orthop Trauma Surg* 122(8):442–446. doi:10.1007/s00402-002-0404-9
- Tetro AM, Rudan JF (2001) The effects of a pneumatic tourniquet on blood loss in total knee arthroplasty. *Can J Surg* 44(1):33–38
- Li B, Wen Y, Wu H, Qian Q, Lin X, Zhao H (2009) The effect of tourniquet use on hidden blood loss in total knee arthroplasty. *Int Orthop* 33(5):1263–1268. doi:10.1007/s00264-008-0647-3
- Turner L, Shamseer L, Altman DG, Weeks L, Peters J, Kober T, Dias S, Schulz KF, Plint AC, Moher D (2012) Consolidated standards of reporting trials (CONSORT) and the completeness of reporting of randomised controlled trials (RCTs) published in medical journals. *Cochrane Database Syst Rev* 11:MR000030. doi:10.1002/14651858.MR000030.pub2
- Gross JB (1983) Estimating allowable blood loss: corrected for dilution. *Anesthesiology* 58(3):277–280
- Sehat KR, Evans RL, Newman JH (2004) Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. *J Bone Joint Surg Br* 86(4):561–565
- Sehat KR, Evans R, Newman JH (2000) How much blood is really lost in total knee arthroplasty? Correct blood loss management should take hidden loss into account. *Knee* 7(3):151–155
- Zhang FJ, Xiao Y, Liu YB, Tian X, Gao ZG (2010) Clinical effects of applying a tourniquet in total knee arthroplasty on blood loss. *Chin Med J* 123(21):3030–3033
- Ledin H, Aspenberg P, Good L (2012) Tourniquet use in total knee replacement does not improve fixation, but appears to reduce final range of motion. *Acta Orthop* 83(5):499–503. doi:10.3109/17453674.2012.727078
- Harvey EJ, Leclerc J, Brooks CE, Burke DL (1997) Effect of tourniquet use on blood loss and incidence of deep vein thrombosis in total knee arthroplasty. *J Arthroplasty* 12(3):291–296
- Schuh A, Hausel M, Salminen S (2003) Effect of tourniquet use on blood loss in total knee arthroplasty. *Zentralbl Chir* 128(10):866–870. doi:10.1055/s-2003-44339
- Ishii Y, Matsuda Y (2005) Effect of the timing of tourniquet release on perioperative blood loss associated with cementless total knee arthroplasty: a prospective randomized study. *J Arthroplasty* 20(8):977–983. doi:10.1016/j.arth.2005.01.012

19. Yavarikia A, Amjad GG, Davoudpour K (2010) The influence of tourniquet use and timing of its release on blood loss in total knee arthroplasty. *Pak J Biol Sci* 13(5):249–252
20. Dutton T, De-Souza R, Parsons N, Costa ML (2012) The timing of tourniquet release and ‘retransfusion’ drains in total knee arthroplasty: a stratified randomised pilot investigation. *Knee* 19(3): 190–192. doi:[10.1016/j.knee.2011.02.013](https://doi.org/10.1016/j.knee.2011.02.013)
21. Mittal R, Ko V, Adie S, Naylor J, Dave J, Dave C, Harris IA, Hackett D, Ngo D, Dietsch S (2012) Tourniquet application only during cement fixation in total knee arthroplasty: a double-blind, randomized controlled trial. *ANZ J Surg* 82(6):428–433. doi:[10.1111/j.1445-2197.2012.06083.x](https://doi.org/10.1111/j.1445-2197.2012.06083.x)
22. Abbas K, Raza H, Umer M, Hafeez K (2013) Effect of early release of tourniquet in total knee arthroplasty. *J Coll Physicians Surg Pak* 23(8):562–565. doi:[10.2013/jcpsp.562565](https://doi.org/10.2013/jcpsp.562565)
23. Kvederas G, Porvaneckas N, Andrijauskas A, Svensen CH, Ivaskевичius J, Mazunaitis J, Marmaite U, Andrijauskas P (2012) A randomized double-blind clinical trial of tourniquet application strategies for total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. doi:[10.1007/s00167-012-2221-1](https://doi.org/10.1007/s00167-012-2221-1)
24. Westman B, Weidenhielm L, Rooyackers O, Fredriksson K, Wernerman J, Hammarqvist F (2007) Knee replacement surgery as a human clinical model of the effects of ischaemia/reperfusion upon skeletal muscle. *Clin Sci (Lond)* 113(7):313–318. doi:[10.1042/cs20070025](https://doi.org/10.1042/cs20070025)
25. Mas E, Barden AE, Corcoran TB, Phillips M, Roberts LJ 2nd, Mori TA (2011) Effects of spinal or general anesthesia on F(2)-isoprostanes and isofurans during ischemia/reperfusion of the leg in patients undergoing knee replacement surgery. *Free Radic Biol Med* 50(9):1171–1176. doi:[10.1016/j.freeradbiomed.2011.01.021](https://doi.org/10.1016/j.freeradbiomed.2011.01.021)
26. Hori K, Tsujii M, Iino T, Satonaka H, Uemura T, Akeda K, Hasegawa M, Uchida A, Sudo A (2013) Protective effect of edaravone for tourniquet-induced ischemia-reperfusion injury on skeletal muscle in murine hindlimb. *BMC Musculoskelet Disord* 14:113. doi:[10.1186/1471-2474-14-113](https://doi.org/10.1186/1471-2474-14-113)
27. Iltar S, Kilinc CY, Alemdaroglu KB, Ozcan S, Aydogan NH, Surer H, Kilinc AS (2013) Does the method of expression of venous blood affect ischaemia/reperfusion damage in tourniquet use? An experimental study on rabbits. *Injury* 44(11):1493–1497. doi:[10.1016/j.injury.2013.02.010](https://doi.org/10.1016/j.injury.2013.02.010)
28. Bao H, Wang J, Cai Y, Chu X, Lv C, Dong P (2011) Tourniquet ischemia reperfusion injury after total knee arthroplasty in clinical research. *Chin J Orthop Trauma* 13(3):242–246. doi:[10.3760/cma.j.issn.1671-7600.2011.03.011](https://doi.org/10.3760/cma.j.issn.1671-7600.2011.03.011)
29. Barwell J, Anderson G, Hassan A, Rawlings I (1997) The effects of early tourniquet release during total knee arthroplasty: a prospective randomized double-blind study. *J Bone Joint Surg Br* 79(2):265–268
30. Wakankar HM, Nicholl JE, Koka R, D’Arcy JC (1999) The tourniquet in total knee arthroplasty. A prospective, randomised study. *J Bone Joint Surg Br* 81(1):30–33
31. Berman AT, Parmet JL, Harding SP, Israelite CL, Chandrasekaran K, Horrow JC, Singer R, Rosenberg H (1998) Emboli observed with use of transesophageal echocardiography immediately after tourniquet release during total knee arthroplasty with cement. *J Bone Joint Surg Am* 80(3):389–396
32. Fukuda A, Hasegawa M, Kato K, Shi D, Sudo A, Uchida A (2007) Effect of tourniquet application on deep vein thrombosis after total knee arthroplasty. *Arch Orthop Trauma Surg* 127(8):671–675. doi:[10.1007/s00402-006-0244-0](https://doi.org/10.1007/s00402-006-0244-0)
33. Kato N, Nakanishi K, Yoshino S, Ogawa R (2002) Abnormal echogenic findings detected by transesophageal echocardiography and cardiorespiratory impairment during total knee arthroplasty with tourniquet. *Anesthesiology* 97(5):1123–1128
34. Hernandez AJ, de Almeida AM, Fávoro E, Sguizzato GT (2012) The influence of tourniquet use and operative time on the incidence of deep vein thrombosis in total knee arthroplasty. *Clinics (Sao Paulo)* 67(9):1053–1057
35. Aggarwal AK, Shashikanth VS, Marwaha N (2013) Platelet-rich plasma prevents blood loss and pain and enhances early functional outcome after total knee arthroplasty: a prospective randomised controlled study. *Int Orthop*. doi:[10.1007/s00264-013-2136-6](https://doi.org/10.1007/s00264-013-2136-6)
36. Iwai T, Tsuji S, Tomita T, Sugamoto K, Hideki Y, Hamada M (2013) Repeat-dose intravenous tranexamic acid further decreases blood loss in total knee arthroplasty. *Int Orthop* 37(3):441–445. doi:[10.1007/s00264-013-1787-7](https://doi.org/10.1007/s00264-013-1787-7)
37. Sasaki H, Ishida K, Shibamura N, Tei K, Tateishi H, Toda A, Yamashiro Y, Matsumoto T, Kuroda R, Kurosaka M (2013) Retrospective comparison of three thromboprophylaxis agents, edoxaban, fondaparinux, and enoxaparin, for preventing venous thromboembolism in total knee arthroplasty. *Int Orthop*. doi:[10.1007/s00264-013-2132-x](https://doi.org/10.1007/s00264-013-2132-x)
38. Schousboe JT, Brown GA (2013) Cost-effectiveness of low-molecular-weight heparin compared with aspirin for prophylaxis against venous thromboembolism after total joint arthroplasty. *J Bone Joint Surg Am* 95(14):1256–1264. doi:[10.2106/jbjs.l.00400](https://doi.org/10.2106/jbjs.l.00400)