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Personalized tourniquet pressure may be a better choice than uniform tourniquet pressure during total knee arthroplasty

A PRISMA-compliant systematic review and meta-analysis of randomized-controlled trials

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Abstract

Background: Pneumatic tourniquets are widely used in total knee arthroplasty (TKA). Some surgeons prefer a uniform tourniquet inflation pressure (UTIP) for all patients; others use personalized tourniquet inflation pressures (PTIP) based on systolic blood pressure and limb occlusion pressure. However, no consensus exists regarding the optimal mode of inflation pressure during TKA. This review aimed to appraise if personalized tourniquet inflation pressures are better than uniform tourniquet inflation.

Methods: The databases (Web of Science, Embase, PubMed, Cochrane Controlled Trials Register, Cochrane Library, Highwire, CBM, CNKI, VIP, Wanfang) were searched on March 2021 to systematically identify and screen the literature for randomized controlled trials involving PTIP and UTIP during total knee arthroplasty.

Results: Thirteen randomized controlled trials, involving 1204 TKAs (1201 patients) were included in the systematic review. The meta-analysis identified a trend toward less visual analogue scale (VAS) score at rest with PTIP group at 1 day ($P = .002$), 2 to 3 days ($P = .01$), and less VAS score at activity 1 day ($P < .0001$), 2 to 3 days after the operation ($P < .00001$), and discharge ($P < .0001$). No significant difference was found between the groups in terms of VAS score at rest when discharge ($P = 1.0$). We also found no significant difference in terms of intraoperative blood loss ($P = .48$), total blood loss ($P = .15$), lower limb vein thrombosis ($P = .42$), and thigh bullae ($P = .17$). However, in the PTIP group, we found a significant higher hospital for special surgery (HSS) score ($P = .007$), broader knee Range of motion ($P = .02$), less rate of thigh ecchymosis ($P = .00001$), and shorter thigh circumference at 1 day ($P = .006$), 2 to 3 days ($P = .0005$), and discharge ($P = .02$).

Conclusion: PTIP provides a similar bloodless surgical field compared with the conventional UTIP. Furthermore, PTIP provides less pain intensity, thigh circumference, rate of thigh ecchymosis, higher hospital for special surgery, and better initial recovery of knee flexion in total knee arthroplasty. Therefore, we recommend using a PTIP method during TKA. More adequately powered and better-designed randomized controlled trials studies with long-term follow-up are required to produce evidence-based guidelines regarding the PTIP method.

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XC and YZ contributed equally to this work.

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Abbreviations: CIs = confidence intervals, HSS = hospital for special surgery, LOP = limb occlusion pressure, PTIP = personalized tourniquet inflation pressures, RCTs = randomized controlled trials, ROM = range of motion, SBP = systolic blood pressure, TKA = total knee arthroplasty, UTIP = uniform tourniquet inflation pressure.

Keywords: limb occlusion pressure, personalized tourniquet inflation pressure, systolic blood pressure, total knee arthroplasty

1. Introduction

Pneumatic tourniquets that are used in total knee arthroplasty (TKA) may lead to soft tissue damage, including the skin, vessels, muscles, nerves, and fibrinolytic activity due to unnecessarily excessive inflation pressure.[1–4] However, many orthopedic surgeons use it. A study of the American Association of Hip and Knee Surgeons found that approximately 95% of surgeons used tourniquets during TKA.[5]

The tourniquet can provide a clear bloodless field, which potentially reduces intraoperative blood loss, operative time, and better prepares the cement–bone interface, despite the possible adverse effects associated with its use during TKA.[6] The tourniquet use is almost indispensable in orthopedic practice. Although a lot of procedures employ the use of a tourniquet, there is still a lack of evidence-based guidelines of standard practice regarding optimal inflation pressures.[7–9] While some prefer a uniform tourniquet inflation pressure (UTIP) for all patients,[10–12] others use personalized tourniquet inflation pressures (PTIP), which based on systolic blood pressure (SBP)[3,13,14] or limb occlusion pressure (LOP). This study aimed to compare the effects of the PTIP with conventional UTIP on rehabilitation outcomes in TKA patients.

2. Methods

Our meta-analysis was registered on PROSPERO (International prospective register of systematic reviews), and the registration number was CRD42020168432. We assessed the quality of the included studies according to the items recommended in Cochrane Collaboration (Revman 5.3; http://handbook.cochrane.org/), and Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.

2.1. Search strategy

We identified relevant randomized controlled trials involving PTIP or conventional UTIP in total knee arthroplasty in electronic databases, including PubMed, Web of Science, Embase, Cochrane Controlled Trials Register, Cochrane Library, Highwire, CBM, CNKI, VIP, Wanfang database, up to March 2021. The keywords included "total knee arthroplasty," "total knee replacement," "tourniquet," "pressure," in conjunction with Boolean operators "AND" or "OR." Review Manager Software was used to perform our meta-analysis.

2.2. Inclusion criteria

The inclusion criteria were: the intervention was PTIP, based on SBP or LOP in TKA; the comparator was the UTIP based on surgeon experience; randomized controlled trial studies; the outcomes are intraoperative blood loss, total blood loss, visual analogue scale (VAS) score, hospital for special surgery (HSS) score, knee range of motion (ROM), thigh circumference, complication rates including lower limb vein thrombosis, thigh bullae, and thigh ecchymosis; the follow-up rate was at least 80%. At least one outcome was included in the study.

The exclusion criteria were as follows: observational studies; non-randomized controlled trials (RCTs); the included studies have insufficient outcome data.

2.3. Data extraction process

Two reviewers independently extracted the available data from each study. The primary data were based on the following: first author, year of publication, country, number of TKAs and participants, age, gender, body mass index, the primary indication for TKA, prosthesis, anesthesia, operation time, mean tourniquet time, mean inflation pressure, practices of tourniquet pressure, the time for loosening the tourniquet. The primary outcome consisted of intraoperative blood loss, total blood loss, VAS score, HSS score, complications such as lower limb vein thrombosis, thigh bullae, and thigh ecchymosis. Secondary outcomes included knee ROM and thigh circumference. We resolved the disagreements by discussion to reach a consensus.

2.4. Quality assessment

We used the Cochrane risk of bias tool to assess the risk of bias in the RCTs and determine whether biases might have affected the results.

2.5. Ethical consideration

Ethical approval is not required, because this study is based on existed literature. The findings of this systematic review will be disseminated through a peer-reviewed journal.

2.6. Statistical analysis

Review Manager 5.3 software (The Nordic Cochrane Collaboration, Copenhagen) was used to perform the meta-analysis. The Q test and I^2 were used to evaluate the heterogeneity between studies. The random-effects model was in the place of the fixed effects model for heterogeneity test, P values $\leq .1$ or $I^2 \geq 50\%$. The mean difference (MD) or standard mean difference (SMD) was used to assess continuous outcomes such as VAS, blood loss, HSS, knee ROM, and thigh circumference with a 95% confidence interval (CI). We used relative risks with a 95% CI to assess dichotomous outcomes such as rate of lower limb vein thrombosis, thigh bullae, and thigh ecchymosis. We considered the results as a statistically significant difference when P values were $<.05$.

3. Results

3.1. Search results

The detailed literature screening process is shown as the PRISMA flow diagram in Fig. 1. The literature search identified 489 citations. Of these, we removed 330 duplicates. Upon reviewing the

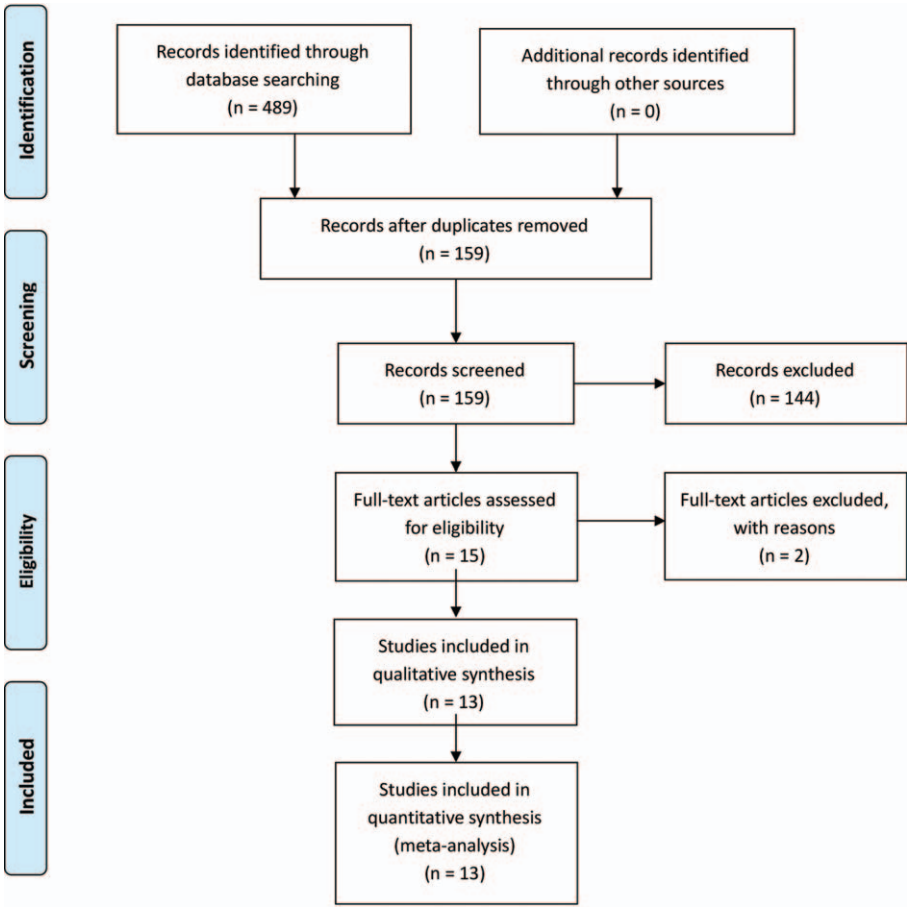

Figure 1. The search results and selection procedure. The literature search identified 489 citations. Of these, we removed 330 duplicates. Upon reviewing the titles and abstracts of the 159 remaining articles, we excluded 144 papers according to the inclusion criteria and retrieved the full text of 13 articles. Finally, we identified 1204 TKAs (1201 patients) assessed in 13 randomized controlled trials. TKA = total knee arthroplasty.

titles and abstracts of the 159 remaining articles, we excluded 144 papers according to the inclusion criteria and retrieved the full text of 13 articles. Finally, we identified 1204 TKAs (1201 patients) assessed in 13 randomized controlled trials.[15–27] We presented the detailed baseline characteristics in Table 1, detailed information in Table 2, and tourniquet intervention information in Table 3. All the studies were double-arm RCTs and were published in English and Chinese between the years 2005 and 2021.

Table 1

The detailed baseline characteristics information.

Author/yr	Patients	Knees	Mean age, y	Female gender (%)	BMI	Outcome
Ishii 2005	29/28	30/30	71/68	93.1/85.7	25.5/26.6	1 (1.1; 1.2); 3 (3.1)
Unver 2013	17/21	17/21	68/67.3	82.4/85.7	30.8/32	2 (2.1; 2.2; 2.3; 2.4; 2.5; 2.6); 3.1
De Souza Leão 2016	30/30	30/30	66/65.4	73.3/76.7	NA	2 (2.2; 2.3); 5
Geng 2014	61/60	61/60	NA	NA	NA	3 (3.2; 3.3)
Lei 2019	36/35	36/35	67.42/68.86	80.6/80	24.67/24.84	1 (1.1; 1.2); 2 (2.1; 2.2; 2.3); 3 (3.2; 3.3); 4; 6 (6.1;6.2)
Si 2018	88/82	88/82	NA	NA	NA	3 (3.1;3.2)
Wu 2014	30/30	30/30	65.97/65.67	NA	23.26/23.74	6.1
Zhang 2016	80/80	80/80	NA	NA	NA	3.2
Zhou 2019	50/50	50/50	67/65.8	52/54	22.9/23	1 (1.1; 1.2); 2 (2.1; 2.2; 2.3; 2.4; 2.5; 2.6); 3.1
Pan 2019	50/50	50/50	66.35/65.43	64/58	NA	3.2
Yang 2020	50/50	50/50	69.44/70.35	40/30	NA	2.1; 3 (3.2; 3.3)
Zhang 2021	42/42	42/42	58.91/59.89	40.5/38.1	NA	1 (1.1; 1.2); 3.2; 4
Tao 2018	40/40	40/40	63.5/64.3	62.5/60	NA	3.2

1. Blood loss (1.1 intraoperative blood loss; 1.2 total blood loss); 2. VAS (2.1 VAS at rest 1 day; 2.2 VAS at rest 2–3 day; 2.3 VAS at rest discharge; 2.4 VAS at activity 1 day; 2.5 VAS at activity 2–3 days; 2.6 VAS at activity discharge); 3. Complications (3.1 lower limb vein thrombosis; 3.2 thigh ecchymosis; 3.3 thigh bullae); 4. Hospital for Special Surgery score; 5. Range of motion; 6. Thigh circumference (6.1 thigh circumference at 1 day; 6.2 thigh ecchymosis at 3 days; 6.2 thigh ecchymosis at 5 days).

The detailed baseline characteristics information, including the number of TKAs, age, gender, BMI, and outcomes of 2 groups.

Table 2

The detailed information of surgery.

Author/yr	Diagnosis	Prothesis	Anesthesia	Operation time, min
Ishii 2005	290A,1RA/270A,3RA	Cementless TKA with New Jersey LCS	Spinal	71/72
Unver 2013	170A/210A	(Nexgen; Zimmer, Warsaw, IN).	General	NA
De Souza Leão 2016	300A/300A	Modular III (MDT, Rio Claro, SP, Brazil),	Spinal	NA
Geng 2014	610A/600A	NA	NA	NA
Lei 2019	360A/350A	CR Gemi MK (LINK, Germany)	General	NA
Si 2018	88 0A/82 0A	NA	General	
Wu 2014	30 0A/300A	NA	Spinal	NA
Zhang 2016	80 0A/800A	NA	General	NA
Zhou 2019	50 0A/500A	A3 (AKMEDICAL)	General	NA
Pan 2019	50 0A/500A	NA	Spinal	NA
Yang 2020	NA	NA	NA	NA
Zhang 2021	42 0A/420A	NA	Spinal	NA
Tao 2018	40 0A/400A	NA	Spinal	NA

The detailed information of surgery including diagnosis, prothesis, anesthesia, and operation time of 2 groups. OA = osteoarthritis.

3.2. Risk of bias assessment

The risk of bias summary and bias graph for RCTs is shown in Figs. 2 and 3. The correct randomization and sufficient allocation concealment were adequately described in 10 studies. The blinding of outcome assessment was described in 13 studies, and the blinding of participants and personnel was described in 3 studies. Each study retained complete outcome data and avoided selective reporting. Other potential biases of all studies cannot be ignored. Therefore, we rated them as having an unclear risk of other bias. As a result, the included studies' overall quality was considered adequate (Figs. 2 and 3).

3.3. Pooled analysis of blood loss between the PTIP group and UTIP group

Patients in both groups experienced similar intraoperative blood loss (MD = –1.41, 95% CI [–5.36, 2.54], $P = .48$, Fig. 4) and total blood loss (MD = –87.23, 95% CI [–206.86, 32.40], $P = .15$, Fig. 4).

3.4. Pooled analysis of VAS between PTIP group and UTIP group

We were able to detect a significantly lower VAS at rest 1 day after operation (MD = –1.23, 95% CI [–2.03, –0.44], $P = .002$ Fig. 5), 2 to 3 days after operation (MD = –1.02, 95% CI [–1.8, –0.23], $P = .01$ Fig. 5) and lower VAS at activity 1 day after operation (MD = –0.69, 95% CI [–1.02, –0.37], $P < .0001$, Fig. 5), 2 to 3 days after operation (MD = –1.18, 95% CI [–1.49, –0.87], $P < .00001$, Fig. 5), and discharge (MD = –2.29, 95% CI [–3.33, –1.25], $P < .0001$, Fig. 5) in patients with personalized pressure group. The results of the meta-analysis showed that patients in both groups experienced similar VAS at rest when discharge from hospital (MD = –0.00, 95% CI [–0.74, 0.74], $P = 1.0$, Fig. 5).

3.5. Pooled analysis of complication rates between PTIP group and UTIP group

Our results showed that patients in both groups experienced similar rates of lower limb vein thrombosis (MD = –0.03, 95% CI

Table 3

The tourniquet intervention information.

Personalized tourniquet pressurel/Conventional tourniquet pressure				
Author/yr	Mean tourniquet time, min	Mean inflation pressure, mm Hg	Practices of tourniquet pressure	The time for loosening the tourniquet
Ishii 2005	48/50	238/350	100 mm Hg above SBP/350 mm Hg	Before the incision was closed
Unver 2013	60/58.3	169.7/304.7	AOP /300 mm Hg	After the application of a wool and crepe bandage to the limb.
De Souza Leão 2016	118/110	NA	100 mm Hg above SBP/350 mm Hg	After Robert Jones dressing was made
Geng 2014	NA	245/250	LOP /250 mm Hg	NA
Lei 2019	55.79/57.23	181.72/270	LOP /270 mm Hg	After the application of a bandage to the limb.
Si 2018	59/59	340.425/487.5	LOP/ 487.5 mm Hg	After the application of a bandage to the limb.
Wu 2014	81.77/81.23	360.28/500	LOP/500 mm Hg	NA
Zhang 2016	59.61/59.84	333/487.5	LOP/487.5 mm Hg	After the application of a bandage to the limb.
Zhou 2019	NA	NA	LOP/525 mm Hg	After the application of a bandage to the limb.
Pan 2019	NA	NA	112.5 mm Hg above SBP /450 mm Hg	NA
Yang 2020	NA	413.83/450	LOP/450 mm Hg	NA
Zhang 2021	NA	NA	112.5 mm Hg above SBP /450 mm Hg	After the application of a bandage to the limb.
Tao 2018	NA	NA	150 mm Hg above SBP /450 mm Hg	After the application of a bandage to the limb

The tourniquet intervention information including the mean tourniquet time, mean inflation pressure, practices of tourniquet pressure, the time for loosening the tourniquet of 2 groups. LOP = limb occlusion pressure, SBP = systolic blood pressure.

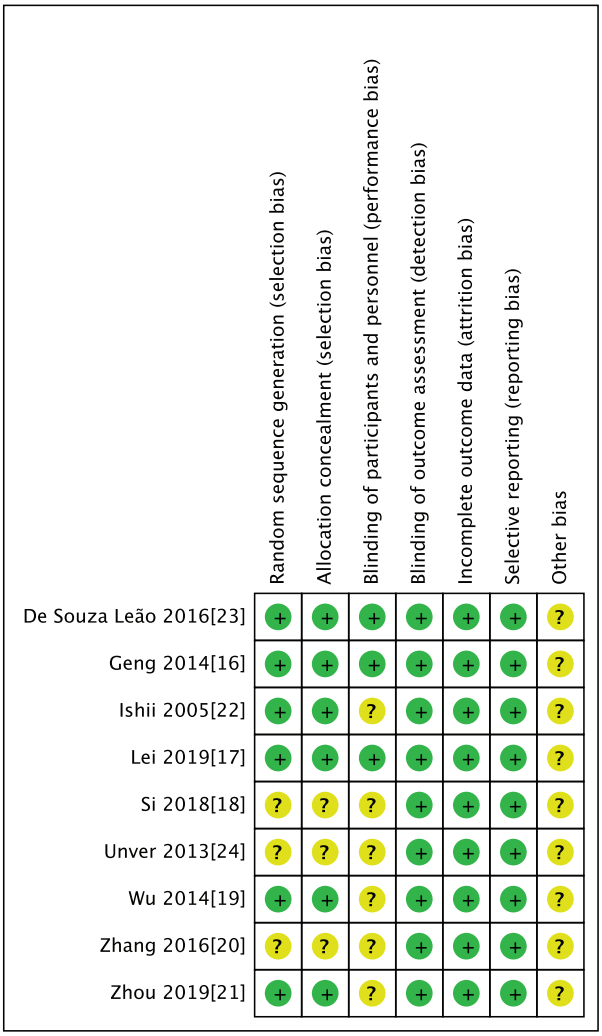

Figure 2. The risk of bias summary for RCTs. +: no bias; –: bias; ?: bias unknown. The correct randomization and sufficient allocation concealment were adequately described in 10 studies. The blinding of outcome assessment was described in 13 studies, and the blinding of participants and personnel was described in 3 studies. Each study retained complete outcome data and avoided selective reporting. Other potential biases of all studies cannot be ignored. Therefore, we rated them as having an unclear risk of other bias. As a result, the included studies' overall quality was considered adequate.

[–0.1, 0.04], $P = .42$, Fig. 6) and thigh bullae (MD = –0.08, 95% CI [–0.17, 0.02], $P = .1$, Fig. 6), however we also detect a significantly lower rate of thigh ecchymosis (MD = –0.19, 95% CI [–0.24, –0.13], $P < .00001$; Fig. 6) in patients with personalized pressure group.

3.6. Pooled analysis of HSS between PTIP group and UTIP group

Our results showed that patients in personalized pressure group experienced higher HSS scores (MD = 1.90, 95% CI [0.51, 3.29], $P = .007$ Fig. 7).

3.7. Pooled analysis of ROM between PTIP group and UTIP group

We detected a significantly better knee ROM (MD = 3.82, 95% CI [0.58, 7.06], $P = .02$; Fig. 8) in patients with personalized pressure group.

3.8. Pooled analysis of thigh circumference between PTIP group and UTIP group

We detected a significantly shorter thigh circumference 1 day after operation (MD = –3.08, 95% CI [–5.28, –0.88], $P = 0.006$; Fig. 9), 3 days after operation (MD = –3.05, 95% CI [–4.78, –1.32], $P = .0005$; Fig. 9) and 5 days after operation (MD = –0.51, 95% CI [–0.95, –0.07], $P = .02$; Fig. 9) in patients with personalized pressure group.

4. Discussion

Although clinical efforts and advances in tourniquet technology have resulted in the use of lower inflation pressures, there was no meta-analysis comparing the effects of PTIP with UTIP on rehabilitation outcomes and postoperative complications. Our meta-analysis is the first meta-analysis to compare the impact of PTIP with conventional UTIP during TKA. The current meta-analysis's main finding was that both PTIP and conventional UTIP ensure equal blood loss in total knee arthroplasty. No significant difference was observed between the groups in terms of rate of lower limb vein thrombosis, and thigh bullae. However, in patients using a tourniquet with PTIP, we found a significant reduction in postoperative pain, thigh circumference, rate of

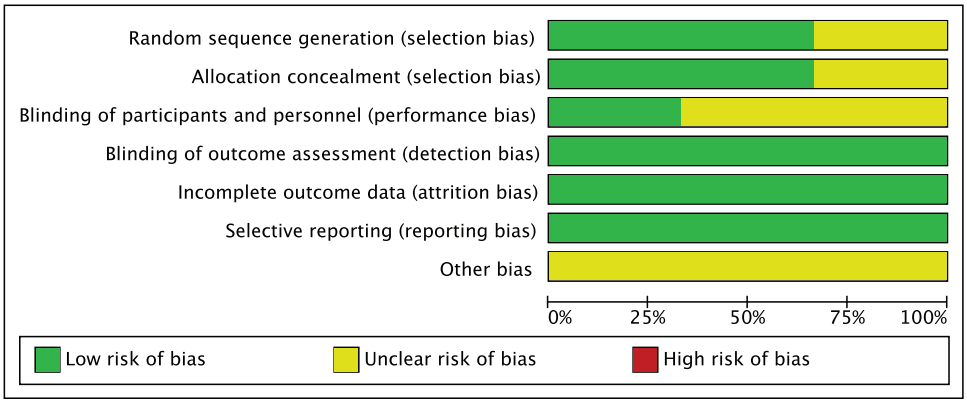

Figure 3. The risk of bias graph. The overall quality of the studies was considered adequate.

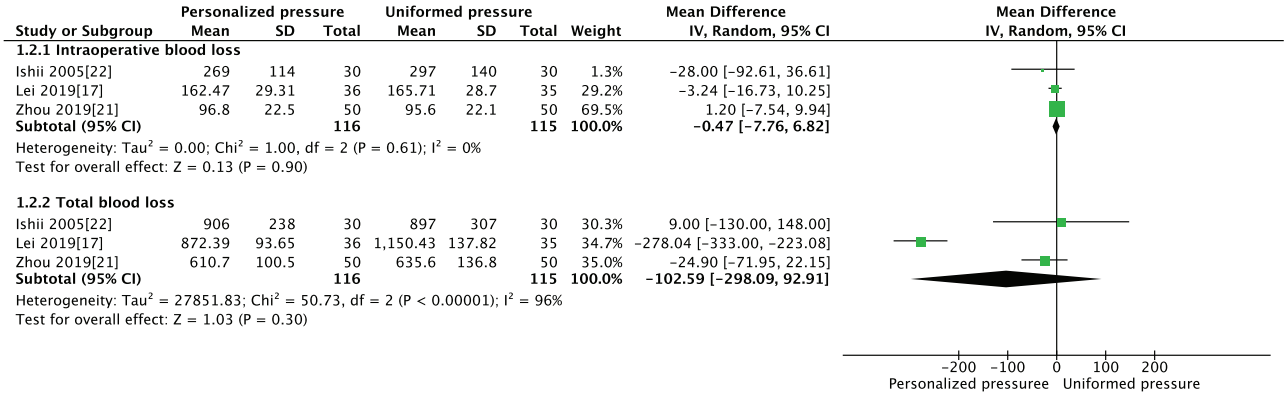

Figure 4. Pooled analysis of blood loss between the PTIP group and the UTIP group. Patients in both groups experienced similar intraoperative blood loss (MD = −1.41, 95% CI [−5.36, 2.54], $P = .48$) and total blood loss (MD = −87.23, 95% CI [−206.86, 32.40], $P = .15$). CI = confidence interval, MD = mean difference, PTIP = personalized tourniquet inflation pressures, UTIP = uniform tourniquet inflation pressure.

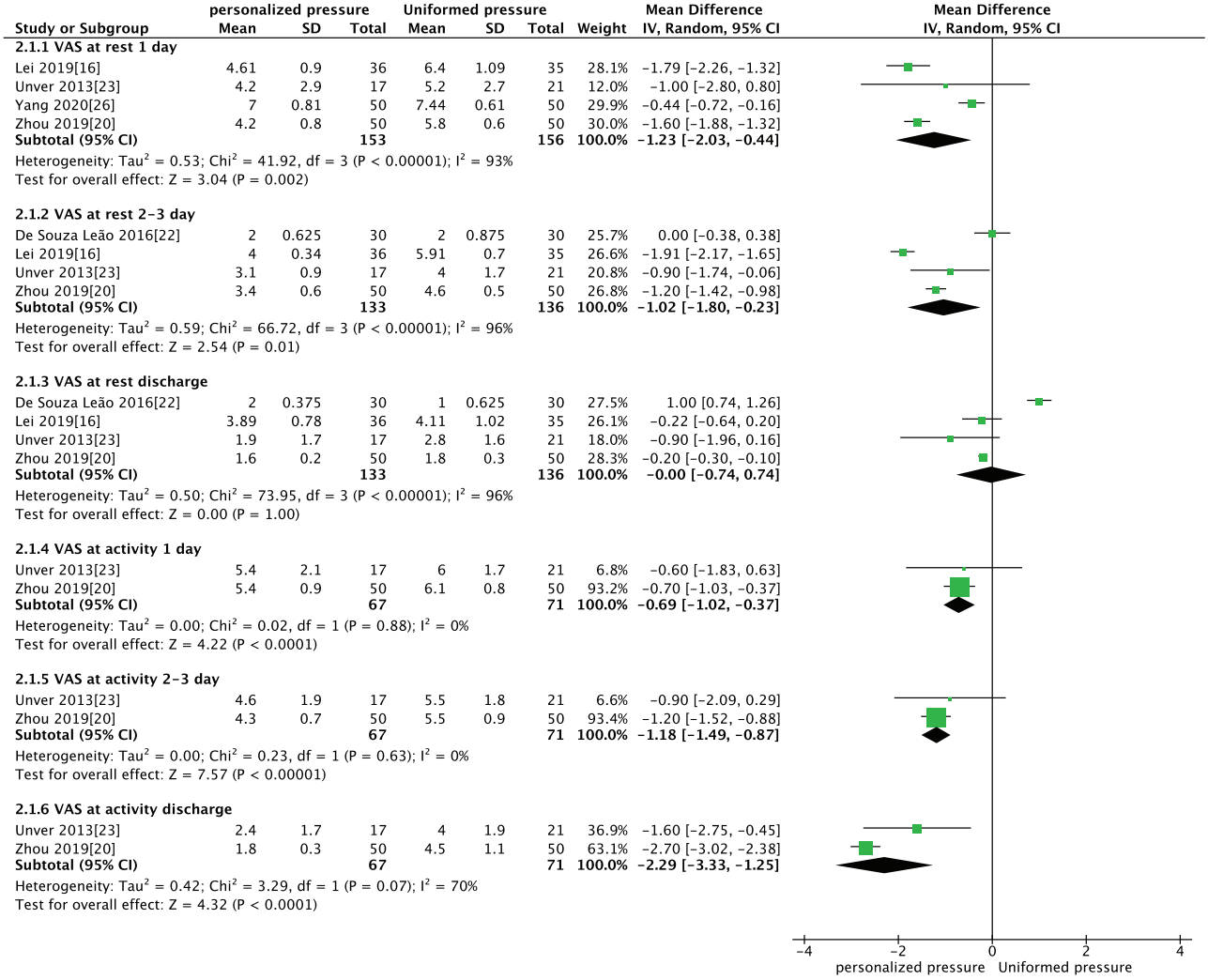

Figure 5. Pooled analysis of VAS between PTIP group and UTIP group. In personalized pressure group, there is a significantly lower VAS at rest 1 day after operation (MD = −1.23, 95% CI [−2.03, −0.44], $P = .002$), 2 to 3 days after operation (MD = −1.02, 95% CI [−1.8, −0.23], $P = .01$), and lower VAS at activity 1 day after operation (MD = −0.69, 95% CI [−1.02, −0.37], $P < .0001$), 2 to 3 days after operation (MD = −1.18, 95% CI [−1.49, −0.87], $P < .00001$) and discharge (MD = −2.29, 95% CI [−3.33, −1.25], $P < .0001$). Patients in both groups experienced similar VAS at rest when discharge from hospital (MD = −0.00, 95% CI [−0.74, 0.74], $P = 1.0$). CI = confidence interval, MD = mean difference, PTIP = personalized tourniquet inflation pressures, UTIP = uniform tourniquet inflation pressure, VAS = visual analogue scale.

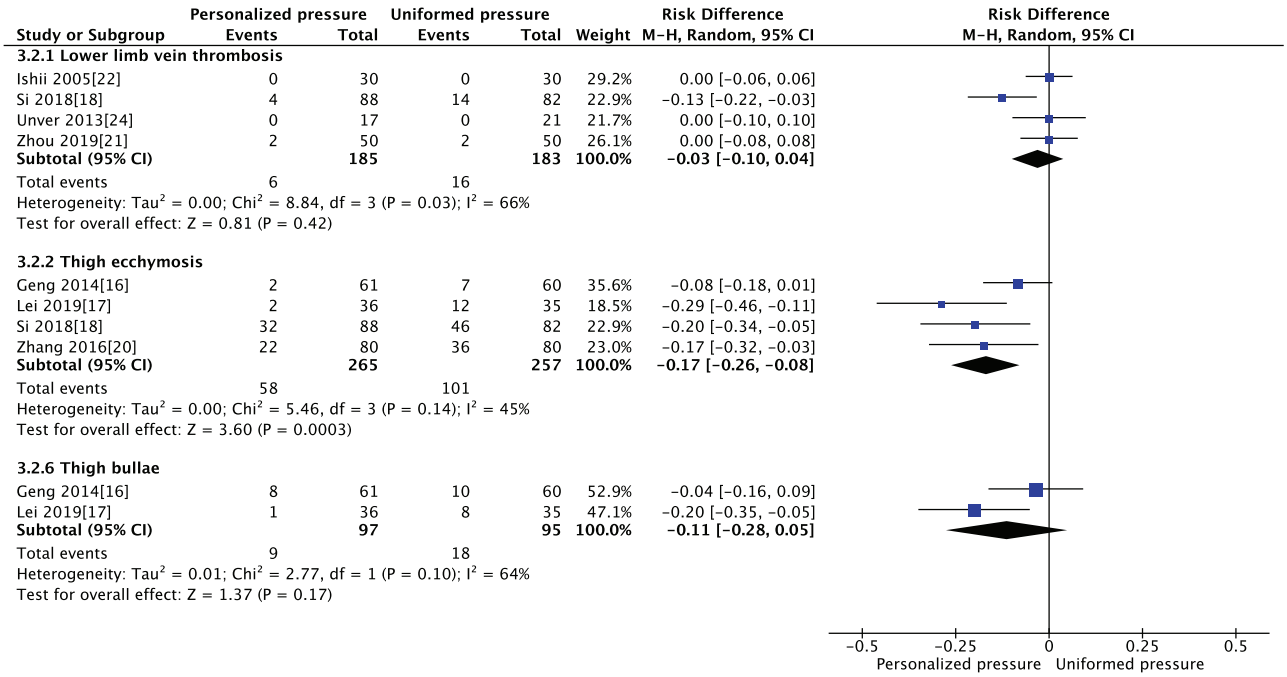

Figure 6. Pooled analysis of complication rates between PTIP group and UTIP group. Both groups experienced similar rates of lower limb vein thrombosis (MD = –0.03, 95% CI [–0.1, 0.04], $P = .42$) and thigh bullae (MD = –0.08, 95% CI [–0.17, 0.02], $P = .1$). There is a significantly lower rate of thigh ecchymosis (MD = –0.19, 95% CI [–0.24, –0.13], $P < .00001$) in patients with personalized pressure group. CI = confidence interval, MD = mean difference, PTIP = personalized tourniquet inflation pressures, UTIP = uniform tourniquet inflation pressure.

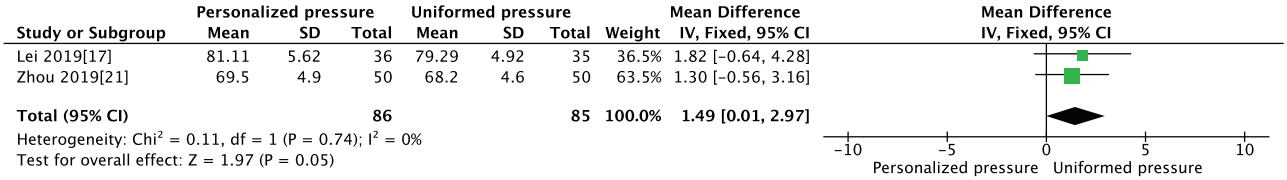

Figure 7. Pooled analysis of HSS between PTIP group and UTIP group. In personalized pressure group, there is a significantly higher HSS (MD = 1.90, 95% CI [0.51,3.29], $P = .007$). CI = confidence interval, HSS = hospital for special surgery, MD = mean difference, PTIP = personalized tourniquet inflation pressures, UTIP = uniform tourniquet inflation pressure.

thigh ecchymosis, higher HSS, and a better initial recovery of knee flexion.

The present work analysis was not able to identify any differences between the 2 groups in the case of intraoperative blood loss and total blood loss. These findings mean PTIP would provide a bloodless surgical field comparable to conventional UTIP.

Immediate postoperative pain relief following TKA is crucial in facilitating early recovery. We were able to detect a significantly lower pain intensity within 3 days after operation both at rest and during mobilization in patients with PTIP group. We also identified a significantly lower pain intensity at the activity when patients were at discharge; however, we could not identify any difference of pain intensity at rest when patients left the hospital.

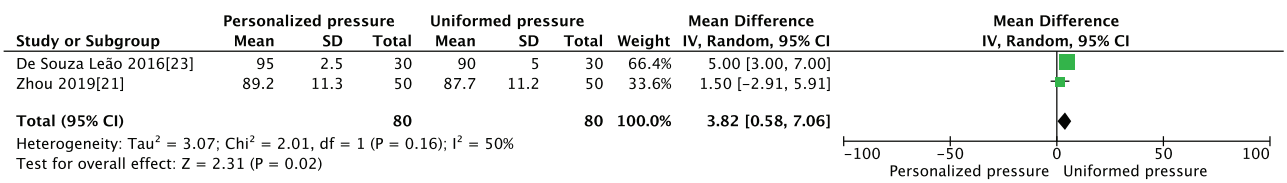

Figure 8. Pooled analysis of ROM between PTIP group and UTIP group. There is significantly better knee ROM (MD = 3.82, 95% CI [0.58, 7.06], $P = .02$) in patients with personalized pressure group. CI = confidence interval, MD = mean difference, PTIP = personalized tourniquet inflation pressures, ROM = range of motion, UTIP = uniform tourniquet inflation pressure.

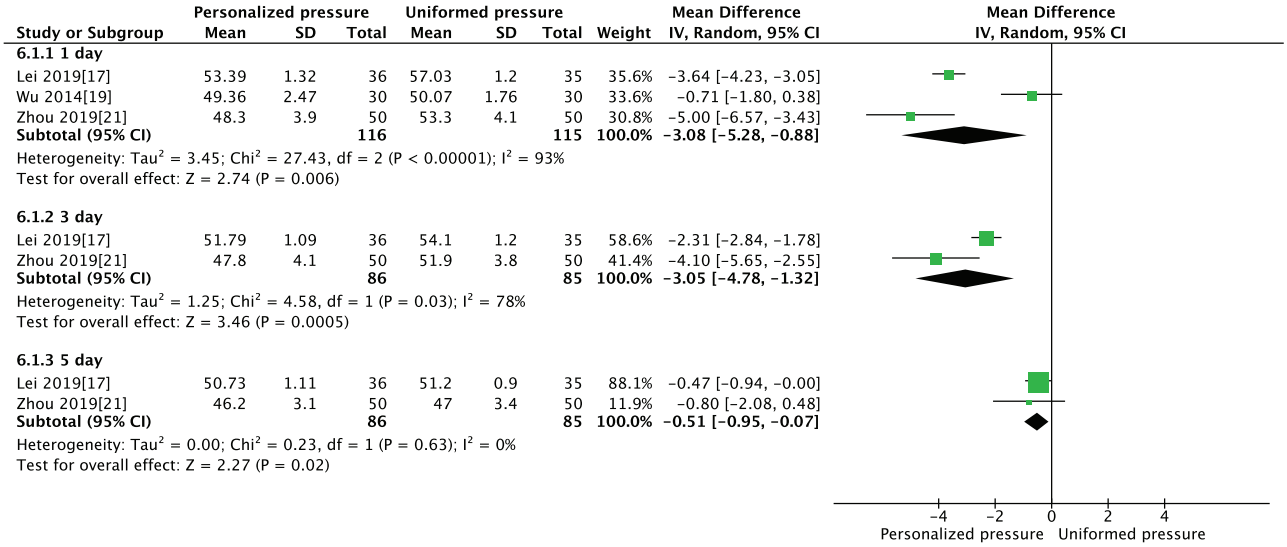

Figure 9. Pooled analysis of thigh circumference between PTIP group and UTIP group. Thigh circumference is significantly shorter 1 day after operation (MD = –3.08, 95% CI [–5.28, –0.88], $P = .006$), 3 days after operation (MD = –3.05, 95% CI [–4.78, –1.32], $P = .0005$) and 5 days after operation (MD = –0.51, 95% CI [–0.95, –0.07], $P = .02$) in patients with personalized pressure group. CI = confidence interval, MD = mean difference, PTIP = personalized tourniquet inflation pressures, UTIP = uniform tourniquet inflation pressure.

An explanation for the increased pain in the early postoperative period with conventional uniform pressure group could be direct higher pressure on the surrounding soft tissues due to the tourniquet. In our study, the pressure of the PTIP is lower than the conventional UTIP group. Worland et al[28] showed an essential correlation between tourniquet pressure and thigh pain in the immediate postoperative period. We thought that the PTIP lowers pain levels while increasing patients' adherence to rehabilitation, which resulted in earlier restoration in functions.

In patients using a tourniquet with PTIP, we found a significant reduction in thigh circumference. We think the reason may be due to less stress on the thigh muscles in the PTIP group.

Knee flexion ROM is often used to evaluate short-term effectiveness. Besides, discharge from the hospital is dependent on the mobility of patients following TKA. The PTIP group documented a significantly higher postoperative ROM. It may be related to using a conventional UTIP with higher tourniquet pressure that causes some temporary loss of flexibility in the tight thigh muscles. The PTIP group also reveal a higher HSS score. The reason may be less pain, more knee ROM in the PTIP group.

As for complications, all studies did not experience major significant complications such as symptomatic PE, thigh necrosis, nerve palsy, or delayed rehabilitation. We found no significant difference between groups regarding the rate of lower limb vein thrombosis and thigh bullae. However, in patients using a tourniquet with personalized tourniquet inflation, we found a significant reduction in the quality of thigh ecchymosis. It is possible to achieve functional benefits with decreasing some complications related to the tourniquet and to have the advantages as with the personalized tourniquet application.

The pressure for safe tourniquet use remains controversial, and no strict guidelines have been established. Most of the orthopedic surgeons routinely apply fixed tourniquet pressure in TKA based on individual experiences. It was very convenient to choose the fixed pressure value. However, it did not take patients' actual individual situation into account, so the selected pressure values were mostly on the high side. Some researchers suggested that upper limb pressure in an adult is 250 to 300 mm Hg, and lower limb pressure is 350 to 500 mm Hg.[29] A higher tourniquet pressure ensures the reliable function of the tourniquet; however, it may lead to a higher incidence of complications. The pressures higher than 350 mm Hg on the lower limbs increase neuropraxia and compression.[8,13] While a lower tourniquet pressure is safer than higher pressure, it may not provide a bloodless operative field. Optimal tourniquet pressure should be determined to balance safety and efficacy. In recent years, some investigators proposed that the tourniquet pressure setting should be personalized. Compression pressure on a pneumatic tourniquet's limb artery wall is different due to different physiological functions, such as systolic blood pressure, age, weight, limb circumference size, and muscle tissue thickness.

Setting the tourniquet pressure based on SBP or LOP allows us to use a personalized tourniquet pressure in each patient and is useful in optimizing tourniquet cuff pressures. The tourniquet beyond the SBP, allowed a certain amount of safety margin, which added to the SBP ranges widely, from 100 to 150 mm Hg in total knee arthroplasty.[21,28,30–35] LOP is the term that mean the lowest tourniquet pressure is required to cease the arterial blood flow into the extremity distal to the cuff. LOP can be determined automatically or manually by slow cuff inflation to pulse cessation with diagnostic equipment such as Doppler flowmeter or pulse oximeter.[36–39] Now, modern tourniquet systems permit an automated LOP estimation through a probe incorporated in the tourniquet system itself.[4] One cuff pressure setting method that has been used successfully in clinical studies is LOP + 40 mm Hg for LOP levels <130 mm Hg, LOP + 60 mm Hg for LOP levels between 131 and 190 mm Hg, and LOP + 80 mm Hg for LOP levels >190 mm Hg.[4,40]

Following an analysis of the current literature, this work demonstrated a relative predominance of the advantages when a tourniquet is used with the personalized application. However, the present meta-analysis has several limitations: first, there are

2 methods for personalized tourniquets, including SBP and LOP. Because of the limited data, we were not able to evaluate one of them separately. We performed a sensitivity analysis on them and found that the conclusion is stable when removing one method. Second, the studies' comparability was complicated through the different measurement methods and follow-up examination time points; however, we have tried our best to evaluate results based on time points. Third, the tourniquet time, the time for loosening the tourniquet, and the cuff pressure used were also not uniform (see Table 1). Fourth, there are no worldwide uniform guidelines for performing total knee arthroplasty. Different surgical techniques (such as the selection of approach, methods of anesthesia, drainage patterns hemostasis, and anticoagulation regimens) were used in the individual studies. Fifth, some of the RCTs were not registered in the Trial registration which may cause bias.

5. Conclusion

In conclusion, personalized tourniquet inflation pressure provides a bloodless surgical field comparable to that of a conventional uniformed method with less pain intensity, thigh circumference, rate of thigh ecchymosis, higher HSS, and better initial recovery knee flexion in total knee arthroplasty. Therefore, we recommend using personalized tourniquet inflation pressure during TKA. When use the tourniquet inflation pressure based on SBP, we can select the pressure 100 to 150 mm Hg beyond SBP. When we use the tourniquet inflation pressure based on LOP, the cuff pressure is LOP + 40 mm Hg for LOP levels <130 mm Hg, LOP + 60 mm Hg for LOP levels between 131 and 190 mm Hg, and LOP + 80 mm Hg for LOP levels >190 mm Hg. Due to the limited comparability of the studies available, more longer follow-up period and overall higher quality RCTs are needed to confirm the present meta-analysis results.

Author contributions

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