Review Article
The efficacy of bipolar sealer for blood loss control after total knee arthroplasty: a meta-analysis

Hua-Zhuang Li[1], Xue-Qin Li[1], Guang-Zong Zhao[1], Jun Fang[1], Liang Chen[2]

[1]Department of Orthopedics, Yidu Central Hospital of Weifang, Weifang Medical College, 4138 Linglong Road, Weifang, Shandong, China; [2]Department of Orthopedics, Shandong Provincial Hospital Affiliated to Shandong University, 327 Jingwuweiqi Road, Jinan, China
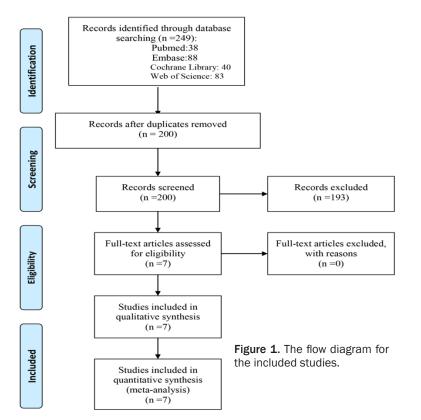
Abstract: Introduction: The purpose of this systematic review and meta-analysis of randomized controlled trials (RCTs) and non-RCTs was to evaluate the efficacy of bipolar sealer after total knee arthroplasty (TKA). Methods: In May 2016, a systematic computer-based search was conducted in the MEDLINE (PubMed), Embase, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, Google, and Chinese Wanfang database. This systematic review and meta-analysis were performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement criteria. The primary endpoint was the need for transfusion, which represents the effect of blood loss control after TKA. The total blood loss, drainage and hemoglobin drop were also used to assess the effect of bipolar sealer on the control of blood loss. Stata 12.0 software was used for meta-analysis. After testing for publication bias and heterogeneity across studies, data were aggregated for random-effects modeling when necessary. Results: A total of 7 clinical trials with 554 patients were finally included in this meta-analysis. The pooled results indicated that bipolar sealer can decrease total blood loss (MD=-165.32, 95% CI -328.78~-1.85, P=0.047). There is no significant difference between the need for a transfusion (RR=0.87, 95% CI 0.71~1.08, P=0.202), hemoglobin drop (MD=0.05, 95% CI -0.49~0.59, P=0.861), drainage (MD=-137.13, 95% CI -293.36~-19.09, P=0.085) and length of hospital stay (MD=-0.05, 95% CI -0.23~0.13, P=0.590). Conclusion: Based on the current meta-analysis, bipolar sealer is not superior to standard electrocautery and it is not recommend as a routine administration in TKA.

Keywords: Bipolar sealer, total knee replacement, blood loss, meta-analysis

Introduction

Blood loss due to extensive soft tissue release and bone cutting in total knee arthroplasty (TKA) may result in clinically relevant total blood loss and the subsequent need for a transfusion [1, 2]. Blood transfusions not only incur high costs but are also associated with complications such as immunological rejection and infection [3]. All of the concerns about complications from blood loss have encouraged new technologies minimizing perioperative blood loss. Meticulous operative techniques and tourniquets are administrated to achieve intraoperative hemostasis; however, all of those methods are not satisfactory. Standard electrocautery has been widely used to control blood loss during TKA; however, it is associated with severe patient burns, operating room fires and carcinogens in the smoke produced by the device during surgery [4]. Bipolar sealers use bipolar radiofrequency energy combined with continuous saline flow to prevent the temperature of the tissue from exceeding 100°C [5]. Theoretically, this temperature is sufficient to shrink collagen fibers in blood vessel walls, which seals their lumen, resulting in hemostasis without surrounding tissue damage. Another advantage of bipolar sealer is that it can be used to broadly paint surfaces that could ooze after the soft tissues have been closed. There have been several random controlled trials published; however, there is no consensus about the efficacy of bipolar sealer in reducing blood loss after TKA. Thus, a systematic review and meta-analysis is necessary to further identify the efficacy of bipolar sealer after TKA.

Figure 1. The flow diagram for the included studies.

Study selection was performed according to the following inclusion criteria: (1) published RCTs and non-RCTs about patients who underwent primary total knee arthroplasty; (2) intervention and comparison groups were bipolar sealer and standard electrocautery respectively, (3) reported outcomes, including postoperative total blood loss, drainage, the hemoglobin drop, length of hospital stay and the occurrence of need for transfusion. All of the included studies must include at least one of the outcomes above. Two reviewers independently scanned the quality of the eligible studies and discrepancies were solved by a senior reviewer. The Cochrane Handbook for Systematic Reviews of Interventions was used to evaluate the methodological quality and risk bias, which includes (1) the randomization method, (2) allocation concealment, (3) blinding of participant, personnel, and assessor; and (4) complete outcome data and other bias. The quality of evidence of outcomes was judged according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) criteria. Two independent authors evaluated five factors (risk of bias, inconsistency, indirectness, imprecision, publication bias) that may downgrade the quality level of evidence. The recommendation level of evidence was classified into four categories: high, moderate, low or very low.

Data extraction

The following data were extracted and recorded: (1) demographic data about the patients in the literature, author's name, publication date, the patient sample size, the number of female patients; (2) transfusion criteria, type of prosthesis, operative approach and the thromboprophylaxis to prevent the occurrence of DVT; and (3) postoperative total blood loss, blood loss in drainage, the hemoglobin drop, blood

Materials and methods

Search strategy

Electronic databases including MEDLINE (PubMed), Embase, Cochrane Central Register of Controlled Trials (CENTRAL), and Web of Science were searched for relevant studies published from the time of the establishment of these databases up to May 2016. In addition, the Google database was searched for additional literature. The reference lists of all the full-text literatures were reviewed to identify any initially omitted studies, and there is no restriction on the language of the publication. The search keywords were bipolar sealer, total knee arthroplasty, total knee replacement, TKA, and TKR. The relevant medical subject heading (MeSH) terms were used to maximize the specificity and sensitivity of the search. These keywords and mesh terms were combined with the Boolean operators AND or OR. The detailed search strategies can be seen in Appendix A. Since this is a meta-analysis, no ethics committee or institutional review board approval was necessary for the study.

Table 1. The general characteristic of the included studies

Author and years	Case (BP/C)	Mean age (BP/C)	Male patients (BP/C)	Transfusion criteria	Operative approach	Prosthesis	Prophylactic antithrombotic	Follow-up (Month)	Type of studies
Diedo 2013	30/90	65.7/67.3	NS	NS	NS	NS	NS	3 day	RCS
Marulanda 2009	35/34	66/66	22/23	NS	NS	NS	NS	3 month	RCT
Pfeiffer 2005	20/20	72/NS	13/NS	NS	NS	Cemented	LMWH	NS	PMT
Plymale 2012	50/61	38/51	64.9/66.3	NS	NS	Cemented	LMWH	2 day	RCT
Seviciu 2016	31/32	64.8/62.9	14/14	Hb<7 g/dl	Mini-midvastus	Cemented	NS	3 day	RCT
Kamath 2014	29/42	59.1/63.4	15/28	Hb<8 g/dl	NS	NS	Aspirin or warfarin	NS	Case control
Derman 2013	40/40	59.9/64.2	8/18	NS	Standard medial parapatellar approach	Cemented	Enoxaparin 30 mg	NS	Cohort

NS: not stated; LMWH: low molecular weight heparin, RCT: randomized controlled studies, RCS: retrospective compared studies, PMT: prospective matched-pair trials.

Table 2. The quality of the included RCTs

Study	Random Sequence Generation	Allocation Concealment	Blinding	Incomplete Outcome Data	Selective Reporting	Other Sources of Bias
Marulanda 2009	Computer-generated	Sealed envelopes	Randomized block design	Yes	Unclear	Unclear
Plymale 2012	No	No	No	Yes	Unclear	Unclear
Seviciu 2016	Block randomization	Pharmacy	Block randomization	Yes	Unclear	Unclear

Table 3. The minors quality score of the non-RCTs

First Author, Year	Minors Scale												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Diedo 2013	2	1	1	2	0	2	2	0	2	2	2	2	18
Pfeiffer 2005	2	2	2	2	2	2	2	2	2	2	2	2	24
Kamath 2014	2	2	0	2	0	2	2	0	2	1	2	2	17
Derman 2013	2	2	1	2	2	2	2	2	2	2	2	2	23

Note: Numbers 1-12 in heading signified: 1, a clearly stated aim; 2, inclusion of consecutive patients; 3, prospective collection of data; 4, endpoints appropriate to the aim of the study; 5, unbiased assessment of the study endpoint; 6, follow-up period appropriate to the aim of the study; 7, loss to follow-up less than 5%; 8, prospective calculation of the study size; 9, an adequate control group; 10, contemporary groups; 11, baseline equivalence of groups; and 12, adequate statistical analyses.

units transfused per patient and the number of patients receiving blood transfusion.

Outcome measures and statistical analysis

The main outcomes were total blood loss, drainage and hemoglobin drop. The second outcomes were the need for a transfusion and length of hospital stay. Continuous outcomes (total blood loss, drainage and hemoglobin drop and length of hospital stay) were expressed as the mean differences (MD) and respective 95% CIs. Dichotomous outcomes (the need for transfusion) were expressed as relative risks (RR) with 95% confidence (CIs). Statistical significance was set at $P<0.05$ to summarize findings across the trials. Risk of bias assess-

ment of each involved RCTs were conducted according to the Cochrane Handbook for Systematic Reviews of Interventions and list in tables. Non-RCTs were assessed by Newcastle-Ottawa Scale (NOS) [6]. The meta-analysis was performed using Stata software, version 12.0 (Stata Corp., College Station, TX). Statistical heterogeneity was tested using the chi-squared test and I^2 statistic. When there was no statistical evidence of heterogeneity ($I^2<50\%$, $P>0.1$), a fixed-effects model was adopted; otherwise, a random-effects model was chosen. If the heterogeneity is large, a sensitivity analysis was conducted to further seek out the source of heterogeneity. Publication bias was assessed by funnel plot and quantitatively assessed by Begg's test. Publications were considered to have no publication bias if the funnel plot was symmetrical and the *P* value was >0.05.

Results

According to the search strategies and inclusion criteria, there are a total of 249 references generated: PubMed, n=38; Embase, n=88; Web of Science, n=83; Cochrane Library, n=40. Of these, we included 7 clinical trials with 554 patients (235 patients in bipolar sealer group
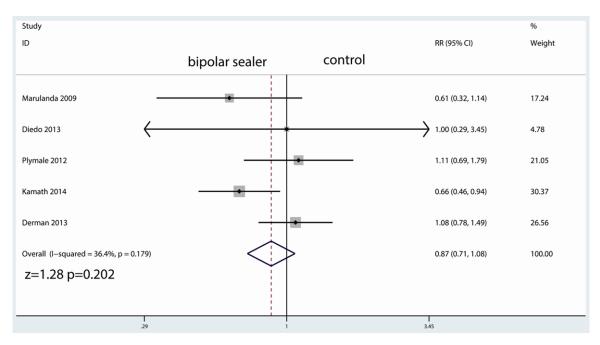
Figure 2. The forest plot that comparing the bipolar sealer with control group for need for transfusion.
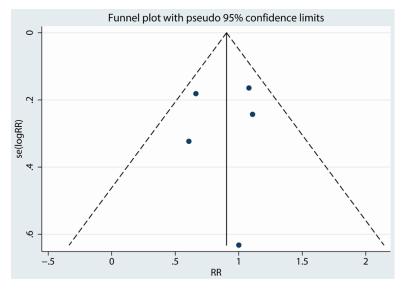

Figure 3. The forest plot that comparing the need for transfusion.

and 319 in control group) in the meta-analysis [5, 7-13]. Six studies compared the bipolar sealer versus standard electrocautery in total knee arthroplasty and the additional one in revision knee arthroplasty [12]. The search process can be seen in **Figure 1**. The sample size from each study ranged from 20 to 90 and the mean age ranged from 55.9 to 72.2. Only two trials referenced the transfusion criteria; one trial set the trigger at Hb<7 g/dl, and the other set the trigger at Hb<8 g/dl. Two studies state the operative approach; one study performed the TKA in the mini-midcastus approach and the other performed in standard medial parapatellar approach. Four trials inserted the cemented prosthesis and three studies did not state the prosthesis type. The detailed characteristic for the included studies can be seen in **Table 1**. The quality assessment of RCTs was shown in **Table 2** and non-RCTs were shown in **Table 3**.

Results of meta-analysis

Need for transfusion: A total of five trials tested the need for transfusion after TKA, and pooled meta-analysis indicated that there is no significant difference between the bipolar sealer and standard electrocautery in terms of the need for transfusion (RR=0.87, 95% CI 0.71~1.08, P=0.202, **Figure 2**).

A funnel plot was drawn and shows that there is no bias between the included studies indicating a need for transfusion; moreover, the *P* value obtained from the Begg's test is 0.806 and this also indicated that there is no bias (**Figures 3** and **4**).
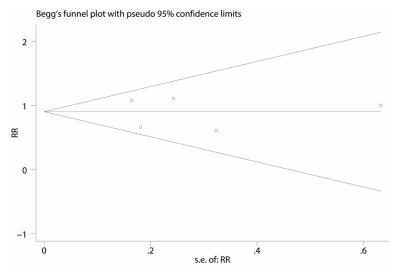
Figure 4. The Begg's test for need for transfusion.

Total blood loss: A total of five trials reported the total blood loss after TKA and pooled results indicating that the bipolar sealer can decrease the total blood loss in a statistically significant manner with a mean of 165.32 ml (MD=-165.32, 95% CI -328.78~-1.85, P=0.047, **Figure 5**).

The results of sensitivity analysis show that no studies affected the heterogeneity of the total blood loss, and the detail of this information can be seen in **Figure 6**.

Drainage

Four trials were performed about the drainage after TKA, and pooled meta-analysis indicated that there is no significant difference between the bipolar and standard electrocautery in terms of drainage after TKA (MD=-137.13, 95% CI -293.36~-19.09, P=0.085, **Figure 7**).

Hb drop

A total of five trials with 394 patients reported the Hb drop after TKA, and pooled meta-analysis indicated that there is no significant difference between the bipolar sealer and standard electrocautery in terms of Hb drop (MD=0.05, 95% CI -0.49~0.59, P=0.861, **Figure 8**).

Length of hospital stay

Three trials with 203 patients reported the length of the hospital stay after the use of the bipolar sealer and standard electrocautery. Results indicated that there is no significant difference between the length of hospital stay (MD=-0.05, 95% CI -0.23~0.13, P=0.590, **Figure 9**).

Subgroup analysis

All of the variables show a large heterogeneity between the included studies, and thus a subgroup analysis was conducted to further analyze the results. Since RCTs and non-RCTs were both included in this meta-analysis, subgroup analysis was based on the research type of the included studies. The final results were shown in **Table 4**.

Quality of evidence assessment

A summary of the quality of the evidence according to the GRADE approach is shown in **Table 5**. The GRADE level of evidence was low for need for transfusion, total blood loss and length of hospital stay; and moderate for drainage and Hb drop.

Discussion

This is the first systematic review and meta-analysis comparing bipolar sealer for reducing blood loss after TKA. From the results of our meta-analysis, bipolar sealer can decrease the total blood loss, but bipolar sealer did not reduce hemoglobin drop, need for transfusion or hospital stay. A total of seven trials were satisfied to define eligibility criteria for this meta-analysis. The overall methodological quality of the included 3 RCTs was relatively high. Only one study did not state the randomized sequential generation and did not reveal the allocation concealment and blinding. Another two trials give detailed information on the randomized sequential generation, allocation concealment and blinding. Though 4 non-RCTs were included in our meta-analysis, the baseline of the included non-RCTs was relative with one accord and relatively high quality.

Perioperative blood loss during TKA is reported at about 715 ml to 3030 ml, and postoperative anemia has an adverse effect on morbidity and mortality of affected patients [14]. In addition, a low level of hemoglobin is always associated
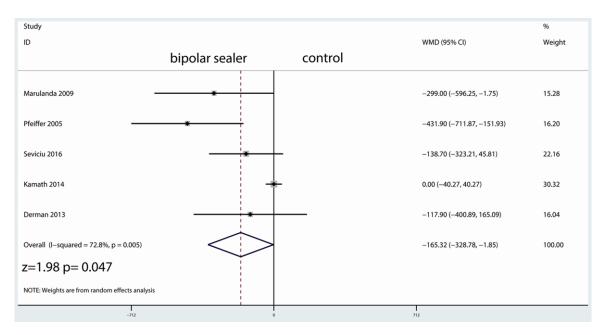
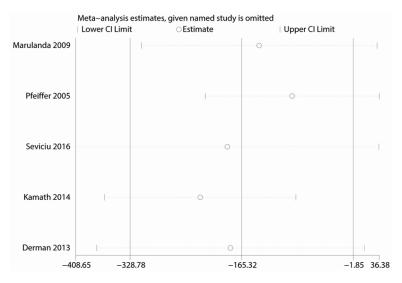**Figure 5.** The forest plot that comparing total blood loss for bipolar sealer with control.

Figure 6. The sensitivity analysis that comparing the total blood loss.

pooled results indicated that bipolar sealer can decrease the total blood loss in a statistically significant manner with a mean of 165.32 ml (MD= -165.32, 95% CI -328.78~ -1.85, P=0.047). The *P* value in this outcome is 0.047 and is close to 0.05 which is not statistically significant, but it should be cautiously treated and there is a need for further studies. Subgroup analysis was conducted to try to eliminate the heterogeneity according to the study type. The results indicated that there is still heterogeneity between the studies in terms of hemoglobin drop and the need for transfusion. Meanwhile, the results conform with the previous results.

There is no significant difference between hemoglobin drop, need for transfusion, drainage and length of hospital stay. Seviciu et al [11] conducted an RCT to compare the combination of bipolar sealer with tranexamic acid (TXA). The results indicated that using bipolar sealer did not add to the effect of TXA in reducing hemoglobin drop in TKA. All of the successful criteria of hemostasis and these devices is
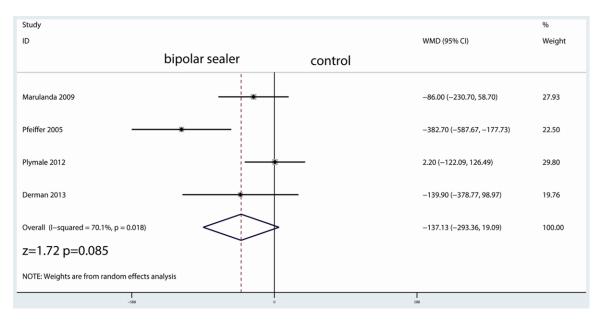
with decreased patient participation in rehabilitation programs and prolongs the length of the hospital stay. Therefore, many strategies were utilized to decrease blood loss, including controlling intraoperative blood loss during TKA. Yang et al [15] conducted a meta-analysis to compare the bipolar sealer with standard electrocautery in primary total hip arthroplasty, and the results indicated that bipolar sealer is not superior to standard electrocautery. Our results also indicated that bipolar sealer is not superior to standard electrocautery in TKA. The

Figure 7. The forest plot that comparing drainage between bipolar sealer versus control.
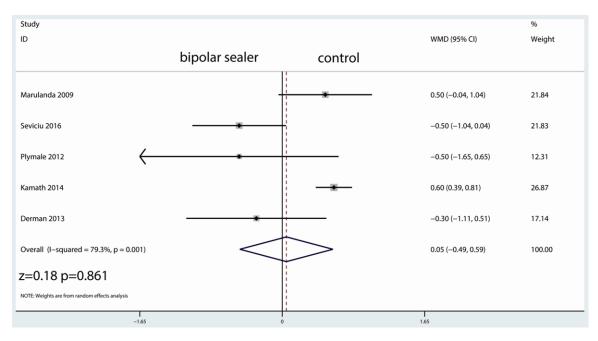

Figure 8. Forest plot that comparing Hb drop between the two groups.

to decrease the need for a transfusion and decrease the hemoglobin drop. The results of meta-analysis indicated that there is no significant difference between the need for transfusion in the two groups. However, all of the final outcomes show heterogeneity between the studies. This may due to the inclusion of revision TKA and bilateral TKA. Marulanda et al [5, 8] compared the bipolar sealer with a control group in two studies, since the latest article contains more samples and the latest published article was included for meta-analysis. In the two studies, bipolar sealer can decrease the total blood loss and increase the hemoglobin level; however, there is no statistically significant need for a transfusion. Min et al [16] conducted an updated meta-analysis comparing bipolar sealer with a control group in terms
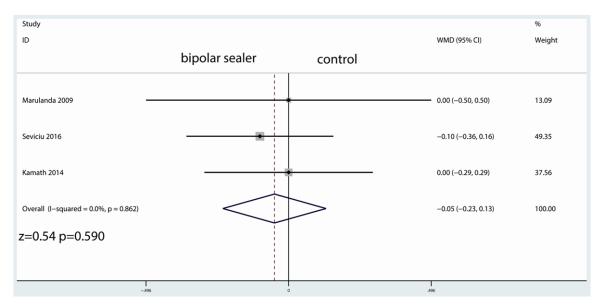
Figure 9. The forest plot that comparing the length of hospital stay between the two groups.

Table 4. The results of subgroup analysis

Variables	Studies (n)	Patients (n)	P-value	Incidence		
				95% CI	Heterogeneity P-value (I²)	Model
Hb drop						
RCT	3	244	0.79	-0.414, 0.315	72.1	Random
Total blood loss						
RCT	2	132	0.022	-340.05, -26.52	0	Fixed
Drainage						
RCT	2	180	0.464	-129.53, 59.04	0	Fixed
LOS						
RCT	2	132	0.496	-0.306, 0.148	0	Fixed
Need for transfusion						
RCT	2	180	0.593	0.474, 1.531	55	Random

of need for transfusion in THA, and the results indicated that bipolar sealer can decrease the need for transfusion and total blood loss.

Meanwhile, complications associated with bipolar sealer have also emerged, including the concern of early postoperative periprosthetic femoral condyle fracture after extensive administration in revision TKA. The occurrence of complications were attempted to be compiled to assess the safety of bipolar sealer; however, there is insufficient data to support the safety of bipolar sealer in TKA.

There were several limitations in this meta-analysis: (1) only 3 RCTs and 4 non-RCTs were included, and the sample sizes in each trial

were not large enough, which affects the final results; (2) the duration of follow-up in some studies was unclear, and long-term follow-up was needed for this analysis; (3) the publication bias that existed in the meta-analysis influenced the results; (4) the time of bipolar sealer TXA administration differs among the included trials, which affects the final conclusion; and (5) the heterogeneity among the studies will also affect the final conclusion, although we tried to use subgroup analysis to solve it.

Conclusion

In conclusion, the administration of bipolar sealer can decrease the total blood loss; however, there is no significant difference between

Table 5. Analysis and quality of the evidence using grading of recommendations, assessment, development and evaluation (GRADE)

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of Participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Outcomes				
Need for transfusion	Study population		RR 0.87 (0.71 to 1.08)	451 (5 studies)	⊕⊕⊖⊖ low	
	401 per 1000	349 per 1000 (285 to 433)				
	Moderate					
	471 per 1000	410 per 1000 (334 to 509)				
Total blood loss		The mean total blood loss in the intervention groups was 165.32 lower (328.78 to 1.85 lower)		323 (5 studies)	⊕⊕⊖⊖ low	
Drainage		The mean drainage in the intervention groups was 137.13 lower (293.36 lower to 19.09 higher)		300 (4 studies)	⊕⊕⊕⊖ moderate	
Hb drop		The mean hb drop in the intervention groups was 0.05 higher (0.49 lower to 0.59 higher)		394 (5 studies)	⊕⊕⊕⊖ moderate[1]	
Length of hospital stay		The mean length of hospital stay in the intervention groups was 0.05 lower (0.23 lower to 0.13 higher)		203 (3 studies)	⊕⊕⊖⊖ low[2,3]	

*The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI). CI: Confidence interval; RR: Risk ratio; GRADE Working Group grades of evidence. High quality: Further research is very unlikely to change our confidence in the estimate of effect. Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate. Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. Very low quality: We are very uncertain about the estimate. [1]I^2=79.3%. [2]no concealment. [3]sample size is limited.

the need for transfusion, hemoglobin drop and length of hospital stay. Overall, there is no superiority of bipolar sealer in the intraoperative hemostasis than standard electrocautery. There is still a need for high-quality RCTs to further identify the effect of bipolar sealer on the blood loss in TKA.

Disclosure of conflict of interest

None.

Address correspondence to: Liang Chen, Department of Orthopedics, Shandong Provincial Hospital Affiliated to Shandong University, 327 Jingwuweiqi Road, Jinan, China. E-mail: 2845257592@qq.com

References

[1] Nielsen CS, Jans O, Orsnes T, Foss NB, Troelsen A and Husted H. Combined intra-articular and intravenous tranexamic acid reduces blood loss in total knee arthroplasty: a randomized, double-blind, placebo-controlled trial. J Bone Joint Surg Am 2016; 98: 835-841.

[2] Fillingham YA, Kayupov E, Plummer DR, Moric M, Gerlinger TL and Della Valle CJ. A randomized controlled trial of oral and intravenous tranexamic acid in total knee arthroplasty: the same efficacy at lower cost? J Arthroplasty 2016; 31 Suppl: 26-30.

[3] Oei W, Neslo R and Janssen MP. A consensus-based tool for ranking the risk of blood-transmissible infections. Transfusion 2016; 56: 2108-14.

[4] Wang X, Sun G, Sun R, Ba C, Gong X, Liu W and Zhai R. Bipolar sealer device reduces blood loss and transfusion requirements in posterior spinal fusion for degenerative lumbar scoliosis: a randomized control trial. Clin Spine Surg 2016; 29: E107-111.

[5] Marulanda GA, Ragland PS, Seyler TM and Mont MA. Reductions in blood loss with use of a bipolar sealer for hemostasis in primary total knee arthroplasty. Surg Technol Int 2005; 14: 281-286.

[6] Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol 2010; 25: 603-605.

[7] Diedo N, Moore G and Otten C. Effectiveness of the bipolar sealer in reducing blood loss in total knee arthroplasty. International Journal of Orthopaedic and Trauma Nursing 2013; 17: 29-37.

[8] Marulanda GA, Krebs VE, Bierbaum BE, Goldberg VM, Ries M, Ulrich SD, Seyler TM and Mont MA. Hemostasis using a bipolar sealer in primary unilateral total knee arthroplasty. Am J Orthop (Belle Mead NJ) 2009; 38: E179-183.

[9] Pfeiffer M, Bräutigam H, Draws D, Sigg A. A new bipolar blood sealing system embedded in perioperative strategies vs. a conventional regimen for total knee arthroplasty: results of a matched-pair study. Ger Med Sci 2005; 3: Doc10.

[10] Plymale MF, Capogna BM, Lovy AJ, Adler ML, Hirsh DM and Kim SJ. Unipolar vs bipolar hemostasis in total knee arthroplasty: a prospective randomized trial. J Arthroplasty 2012; 27: 1133-1137, e1131.

[11] Seviciu A, Gross I, Fathima S and Walsh SM. Effects of tranexamic acid and bipolar sealer alone or in combination in primary total knee arthroplasty: a prospective, randomized, controlled trial. Arthroplasty Today 2016.

[12] Derman PB, Kamath AF and Lee GC. Saline-coupled bipolar sealing in revision total knee arthroplasty for infection. Am J Orthop (Belle Mead NJ) 2013; 42: 407-411.

[13] Kamath AF, Austin DC, Derman PB, Clement RC, Garino JP and Lee GC. Saline-coupled bipolar sealing in simultaneous bilateral total knee arthroplasty. Clin Orthop Surg 2014; 6: 298-304.

[14] Kalairajah Y, Simpson D, Cossey AJ, Verrall GM and Spriggins AJ. Blood loss after total knee replacement: effects of computer-assisted surgery. J Bone Joint Surg Br 2005; 87: 1480-1482.

[15] Yang Y, Zhang LC, Xu F, Li J and Lv YM. Bipolar sealer not superior to standard electrocautery in primary total hip arthroplasty: a meta-analysis. J Orthop Surg Res 2014; 9: 92.

[16] Min JK, Zhang QH, Li HD, Li H and Guo P. The efficacy of bipolar sealer on blood loss in primary total hip arthroplasty: a meta-analysis. Medicine (Baltimore) 2016; 95: e3435.