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The efficacy and safety of autologous blood transfusion drainage in patients undergoing total knee arthroplasty: a meta-analysis of 16 randomized controlled trials

Jian-ke Pan[1†], Kun-hao Hong[2†], Hui Xie[1†], Ming-hui Luo[1], Da Guo[1] and Jun Liu[1*]

Abstract

Background: Autologous blood transfusion drainage (ABTD) has been used for many years to reduce blood loss in total knee arthroplasty (TKA). We evaluate the current evidence concerning the efficiency and safety of ABTD used in TKA compared with conventional suction drainage (CSD).

Methods: We performed a systematic literature search of the PubMed, Embase, Cochrane Library and four Chinese databases. All randomized controlled trials (RCTs) that compared the effects of ABTD versus CSD in TKA were included in the meta-analysis.

Results: Sixteen RCTs involving 1534 patients who compared the effects of ABTD versus CSD were included. Five of the RCTs were performed in Asia, ten in Europe, and one in North America. Patients in the ABTD group had a lower blood transfusion rate (OR: 0.25 [0.13, 0.47]; $Z = 4.27$, $P < 0.0001$) and fewer units transfused per patient (WMD: -0.68 [-0.98, -0.39]; $Z = 4.52$, $P < 0.00001$) than did patients in the CSD group. Wound complications, deep vein thrombosis, febrile complications, post-operative hemoglobin days 5–8, drainage volume, and length of hospital stay did not differ significantly between the two types of drainage systems.

Conclusion: This meta-analysis suggests that ABTD is a safe and effective method that yields a lower blood transfusion rate and fewer units transfused per patient in TKA compared with CSD.

Keywords: Autologous blood transfusion drainage, Total knee arthroplasty, Meta-analysis, Randomized controlled trials

Background

Total knee arthroplasty (TKA) can result in significant blood loss [1, 2]. One study estimated the average blood loos in TKA to be 1500 mL [3]. The average reduction in Hb concentration after TKA has been estimated to be 3.85 g/dL [4]. Blood transfusion may be considered necessary in some patients to avoid symptomatic anemia and subsequent delays in postoperative rehabilitation [5]. The blood transfusion rate in TKA reach 39 % [2, 6, 7].

Conventional suction drainage (CSD) is used worldwide for postoperative wound blood collection in TKA

[8]. Formerly, CSD was believed to be effective in decreasing hematoma formation [9–11] and potentially able to decrease postoperative pain, swelling, and the incidence of infection [12]. However, a closed suction drainage system increases bleeding because it eliminates the tamponade effect of a closed, undrained wound [8]. Surgeons use adjunctive measures such as autologous blood transfusion drainage (ABTD) to reduce excessive blood loss from the drain [13], and recent studies have shown that ABTD can decrease the rate of blood transfusion [14–16].

The efficacy and safety of ABTD in the management of a patient's blood during TKA surgery was assessed in a previous meta-analysis of eight randomized controlled trials (RCTs) [17]. The meta-analysis showed that ABTD was superior to CSD with respect to the blood

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transfusion rate (OR: 0.25 [0.13, 0.47]; $P < 0.0001$), the number of units transfused per patient (WMD: −0.84 [−1.13, −0.56]; $P < 0.0001$), and the length of hospital stay (WMD: −0.25 [−0.48, −0.01]; $P = 0.04$). However, data extraction errors involving the number of patients requiring homologous blood transfusion occurred with two of the studies [18, 19] included in the meta-analysis. Furthermore, the meta-analysis did not employ intention-to-treat (ITT) analysis, which may have led to anti-conservative estimates of treatment effectiveness. In addition, systematic reviews that fail to search non-English databases may miss relevant studies and cause selection bias [20]. As trials with statistically significant results are more likely to be published in English than are those with non-significant results [21], systematic reviews that include studies published only in English might overestimate true effects, In addition, the previous meta-analysis did not evaluate the outcomes of additional measures such as wound complications (including wound infection, wound abscess, wound dehiscence, and wound hematoma) and febrile complications.

In recent years, several studies comparing ABTD and CSD have reported conflicting outcomes [1, 22–24]. Whether the benefits of ABTD are limited to the reduction of the blood transfusion rate is unclear. Therefore, we comprehensively searched several bibliographic databases to identify RCTs conducted to date. We then analyzed the clinical evidence to evaluate the effectiveness and safety of ABTD relative to CSD. We also investigated the potential benefits of ABTD.

Methods

In accordance with Preferred Reporting Items for Systematic Reviews and Meta-analysis [25], we made a prospective protocol of objectives, literature-search strategies, inclusion and exclusion criteria, outcome measurements, and methods of statistical analysis before the research began.

Data sources and search strategies

A systematic literature search of the Pubmed (1950–February 2016), Embase (1974–February 2016), Cochrane Library (February 2016 Issue 2), Chinese Biomedical Literature (CBM) (1990 to February 2016), China National Knowledge Infrastructure (CNKI) (1979 to February 2016), Chinese Scientific Journals (VIP) (1989 to February 2016) and Wanfang (1982 to February 2016) databases was conducted. The following MeSH terms or Emtree terms and their combinations were searched in [Title/Abstract]: "Drainage", "Suction", "Blood Transfusion, Autologous", "Operative Blood Salvage", "Arthroplasty, Replacement, Knee" or "wound drainage", "closed
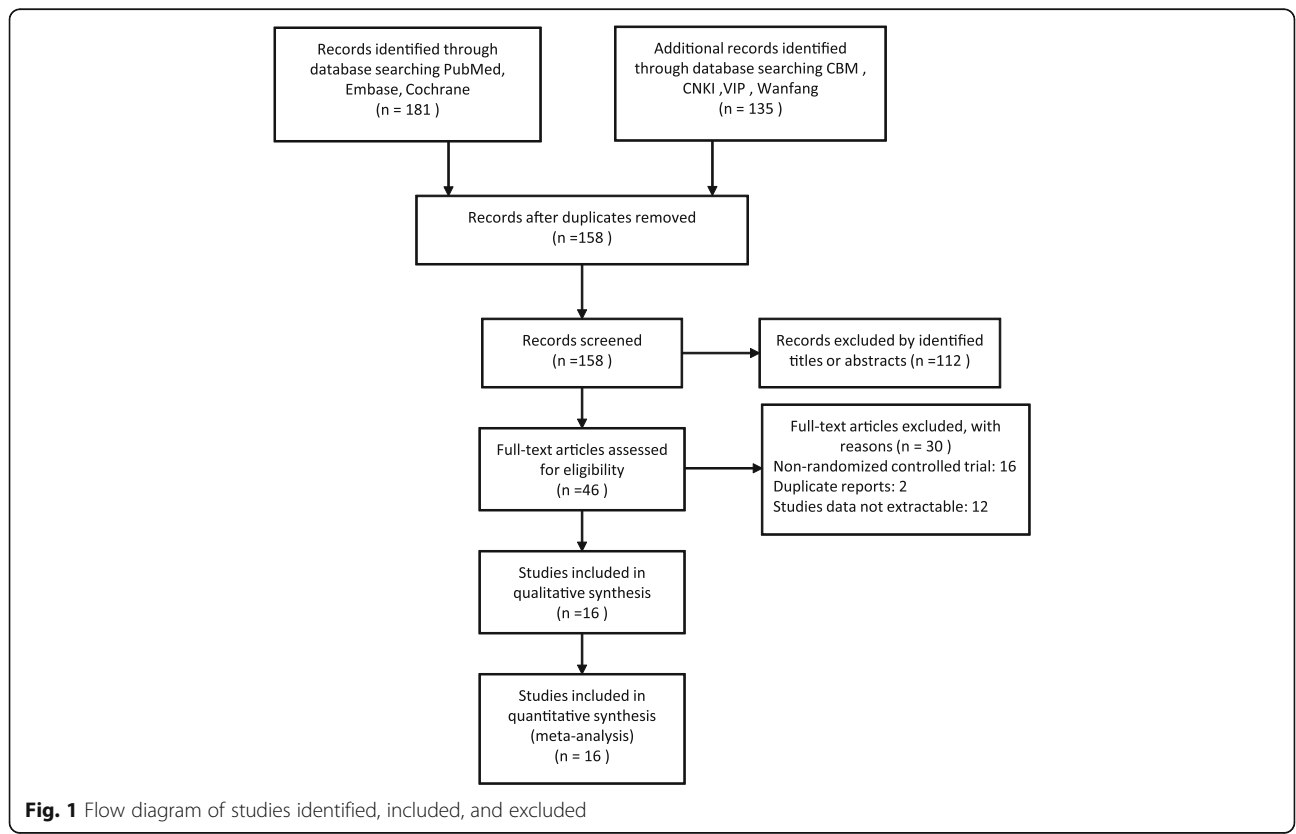

Fig. 1 Flow diagram of studies identified, included, and excluded

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Table 1 Characteristics of the included studies

Study	Country	Jadad score	Patients, no.		Surgical method	Age[a]		M:F ratio		Pre-op Hb[a]	
			ABTD	CSD		ABTD	CSD	ABTD	CSD	ABTD	CSD
Deng YJ 2015 [40]	China	1	11	12	B-TKA	57.7 ± 16.3	60.7 ± 17.3	5:6	5:7	13.4 ± 3.6	13.5 ± 3.7
Jin CH 2014 [42]	China	1	70	70	SU-TKA	66 ± 4	64 ± 4	12:58	13:57	13.1 ± 1.3	13. 2 ± 1. 4
Sun YT 2014 [39]	China	1	72	60	SU-TKA	65.3	64.7	15:57	13:47	13.1 ± 1.4	13.4 ± 2.0
Amin A 2008 [29]	UK	2	92	86	SU-TKA	70.3	70.4	43:49	39:47	13.2 ± 1.2	13.4 ± 1.3
Shen Y 2007 [41]	China	0	60	60	SU-TKA	NA	NA	NA	NA	NA	NA
Zacharopoulos A 2007 [30]	Greece	1	30	30	SU-TKA	69.2	70.2	6:24	7:23	NA	NA
Abuzakuk T 2007 [31]	UK	2	52	52	SU-TKA	NA	NA	21:31	22:30	13.6 ± 1.5	13.5 ± 1.2
Kirkos JM 2006 [32]	Greece	0	78	77	SU-TKA	69.1 ± 5.5	68.9 ± 5.1	18:60	10:67	13.0 ± 1.4	13.1 ± 1.4
Dramis A 2006 [33]	UK	1	25	24	SU-TKA	NA	NA	NA	NA	NA	NA
Cheng SC 2005 [34]	China	2	26	34	SU-TKA	72	69.6	6:20	12:22	12.4	12.8
Thomas D 2001 [35]	UK	2	115	116	SU-TKA	NA	NA	44:71	55:61	NA	NA
Breakwell LM 2000 [36]	UK	1	14	19	B-TKA	66.8	73.7	8:6	8:11	12.9	12.8
Adalberth G 1998 [18]	Sweden	3	30	30	SU-TKA	71 ± 5.4	72 ± 8.0	NA	NA	13.8 ± 1.1	14.3 ± 1.3
Newman J 1997 [37]	UK	2	35	35	SU-TKA	NA	NA	NA	NA	13.4 ± 1.2	13.2 ± 1.4
Heddle NM 1992 [19]	Canada	3	39	40	SU-TKA	69.3 ± 6.9	71.0 ± 9.0	25:14	26:14	NA	NA
Majkowski RS 1991 [38]	UK	1	20	20	SU-TKA	71.3	70.3	6:14	6:14	13.2	12.7

SU-TKA selective unilateral total knee replacement, *B-TKA* bilateral total knee replacement, *ABTD* autologous blood transfusion drainage, *CSD* conventional suction drain, *NA* data not available, *M* male, *F* female, *Pre-op Hb* pre-operative hemoglobin
[a]Mean or Mean ± SD

drainage", "drainage catheter", "drainage tube", "suction drain", "surgical drainage", "drain", "wound drain", "blood autotransfusion", "autotransfusion unit", "blood salvage", "knee arthroplasty". (See Additional file 1 for details on the search strategies.) Only articles that were originally written in English or Chinese or that had been translated into English were considered. Unpublished trials were not included. When multiple reports describing the same population were published, the most recent or complete report was used. Additional eligible studies were sought by searching the reference lists of primary articles and relevant reviews.

Inclusion criteria

All available RCTs that compared ABTD with CSD in TKA and for which one or more comparable quantitative outcomes (the quantitative data must be presented as means and standard deviations or 95 % confidence intervals) could be extracted and analyzed were included.
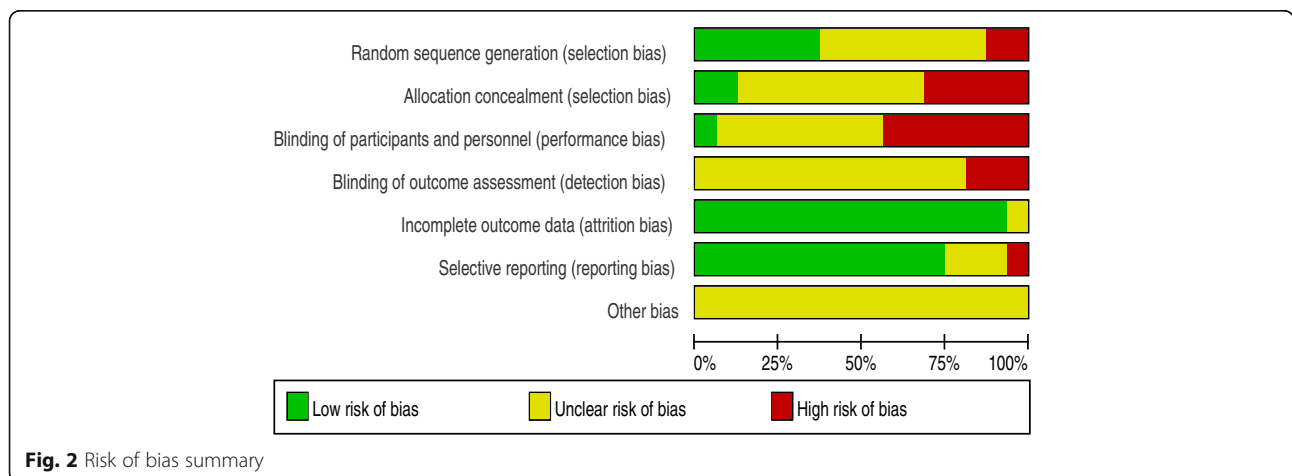

Fig. 2 Risk of bias summary

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Exclusion criteria

We excluded case reports, non-original research (e.g., review articles, editorials, letters to the editor), non-human animal studies, and duplicate publications.

Data extraction and analysis

Data abstraction was conducted by two authors (Hong and Xie) independently. In cases of disagreement, consensus was established through discussion with two other experienced authors (Pan and J. Liu).

The primary outcomes were blood transfusion rate, mean number of units transfused per patient, wound complications, and deep vein thrombosis.

The secondary outcomes were febrile complications, post-operative hemoglobin on days 5–8, drainage volume, and length of hospital stay.

Quality assessment

The Jadad quality scale [26] and the Cochrane risk of bias tool [27] were used to assess the methodological quality of the included RCTs. Studies with a Jadad score ≥ 3 were considered high quality, and those with a Jadad score ≤2 were considered low quality.

Data synthesis and analysis

We based our analysis on intent-to-treat (ITT) or modified ITT data. Review Manager 5.3.5 (Cochrane) was employed for the meta-analysis. Odds ratios (ORs) and 95 % confidence intervals (CIs) were calculated for blood transfusion rate, wound complications, deep vein thrombosis and febrile complications. Weighted mean differences (WMDs) and 95 % CIs were calculated for the mean number of units transfused per patient, post-operative hemoglobin on days 5–8, drainage volume, and length of hospital stay. We regarded the volume of one unit of transfused blood as approximately 300 mL [18, 28]. When continuous data from the included studies were presented as means and 95 % confidence intervals, standard deviations were calculated by using Review Manager 5.3.5 (Cochrane).

Heterogeneity among the studies was assessed using the I-square test. Where heterogeneity ($I^2 > 50$ %) was detected, a random-effects model was applied; otherwise, a fixed-effects model was applied [27]. For outcome measures with I^2 values greater than 50 %, we conducted sensitivity analyses to determine the source. Funnel plots were inspected visually to assess the possibility of publication bias.

Results

Study selection

Sixteen [18, 19, 29–42] studies including 1534 cases (769 cases for ABTD and 765 cases for CSD) met the inclusion criteria and were included in the final analysis

(Fig. 1). Search of the reference lists revealed no additional studies that met the inclusion criteria.

Characteristics of the included studies

The characteristics of the included studies are summarized in Table 1. Four studies [39–42] were identified from Chinese databases, and 12 studies [18, 19, 29–38] were identified from international databases. Geographically, five RCTs were performed in Asia, 10 in Europe, and one in North America.

Fig. 3 Risk of bias assessment

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Study or Subgroup	Experimental Events	Total	Control Events	Total	Weight	Odds Ratio M-H, Random, 95% CI	Odds Ratio M-H, Random, 95% CI
Abuzakuk T 2007 [31]	13	52	12	52	9.3%	1.11 [0.45, 2.73]	
Adalberth G 1998 [18]	8	30	10	30	8.5%	0.73 [0.24, 2.21]	
Amin A 2008 [29]	12	92	13	86	9.5%	0.84 [0.36, 1.96]	
Cheng SC 2005 [34]	4	26	13	34	7.9%	0.29 [0.08, 1.05]	
Dramis A 2006 [33]	3	25	10	24	7.2%	0.19 [0.04, 0.82]	
Heddle NM 1992 [19]	10	39	27	40	9.0%	0.17 [0.06, 0.44]	
Jin CH 2014 [42]	9	70	19	70	9.4%	0.40 [0.16, 0.95]	
Majkowski RS 1991 [38]	7	20	19	20	4.8%	0.03 [0.00, 0.26]	
Newman J 1997 [37]	3	35	28	35	7.2%	0.02 [0.01, 0.10]	
Sun YT 2014 [39]	14	72	48	60	9.4%	0.06 [0.03, 0.14]	
Thomas D 2001 [35]	12	115	33	116	9.9%	0.29 [0.14, 0.60]	
Zacharopoulos A 2007 [30]	5	30	10	30	8.0%	0.40 [0.12, 1.36]	
Total (95% CI)		**606**		**597**	**100.0%**	**0.25 [0.13, 0.47]**	
Total events	100		242				

Heterogeneity: Tau² = 0.94; Chi² = 48.42, df = 11 (P < 0.00001); I² = 77%
Test for overall effect: Z = 4.27 (P < 0.0001)

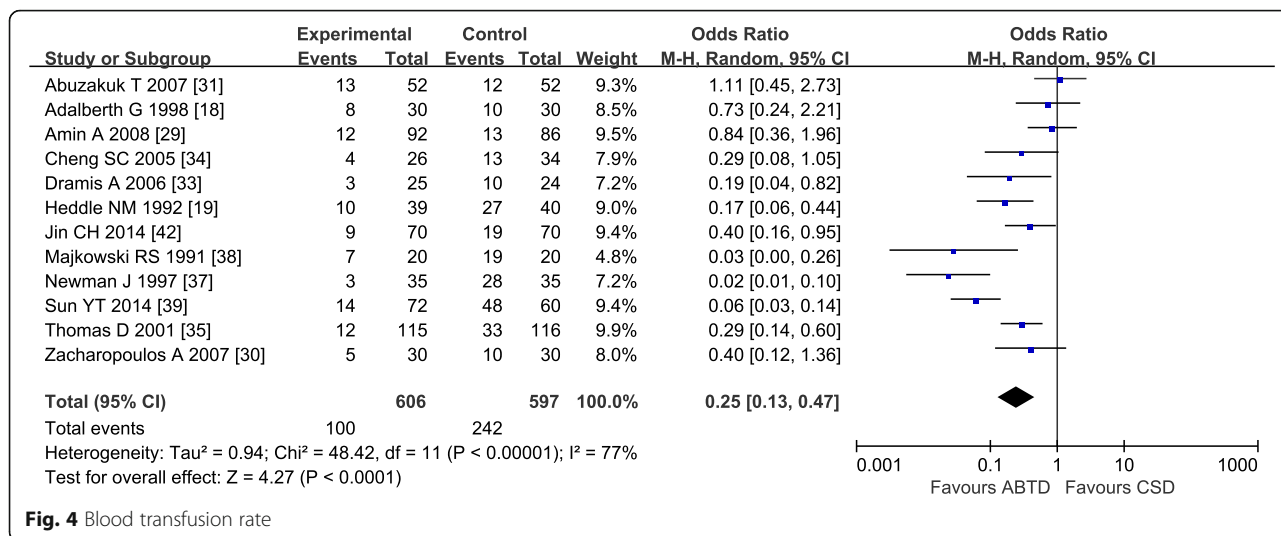0.001   0.1   1   10   1000
Favours ABTD   Favours CSD

Fig. 4 Blood transfusion rate

We evaluated the methodological quality of all of the included studies using the Jadad quality scale and Cochrane risk of bias criteria (Table 1, Figs. 2 and 3). The Jadad scores ranged from 0 to 3 points, with an average score of 1.4. Only two RCTs [18, 19] were of high quality. Six studies [18, 19, 29, 31, 34, 37] reported a method of randomization, and two studies [32, 41] used a method of quasi-randomization. The remaining eight studies [30, 33, 35, 36, 38–40, 42] did not report the method of randomization. None of the included studies used the double-blinded method. The two RCTs [18, 19] of high quality described the number of cases and the reasons for drop-out in detail. Two studies [18, 34] reported the method of allocation concealment. One study [34] provided information regarding the blinding method. None of the 16 studies [18, 19, 29–42] reported the method of blinding outcome assessment. Fifteen studies [18, 19, 29–35, 37–42] reported the complete analysis. One study [37] was at high risk of selective reporting.

Patients in 14 studies [18, 19, 29–35, 37–39, 41, 42] were undergoing selective unilateral TKA, and those

of the remaining two [36, 40] were undergoing bilateral TKA.

The majority of the RCTs reviewed in this meta-analysis were of low quality. All of the included studies reported that the baseline characteristics of the study groups, including age, gender and pre-operative hemoglobin, were comparable, as shown in Table 1.

Primary outcomes
Blood transfusion rate

Twelve trials [18, 19, 29–31, 33–35, 37–39, 42] compared ABTD with CSD in the number of patients requiring homologous blood transfusion. Ten trials [18, 19, 29–31, 33–35, 37–39, 42] showed substantial heterogeneity in the trial results (chi-square = 48.42, $P < 0.00001$; $I^2 = 77$ %). Therefore, a random effects model was used for statistical analysis. The meta-analysis showed a significant beneficial effect of ABTD compared with CSD on blood transfusion rate (16.50 and 40.54 %, respectively; OR: 0.25 [0.13, 0.47]; $Z = 4.27$, $P < 0.0001$) (Fig. 4). Due to marked heterogeneity in the blood transfusion rate data, sensitivity analysis was conducted by excluding
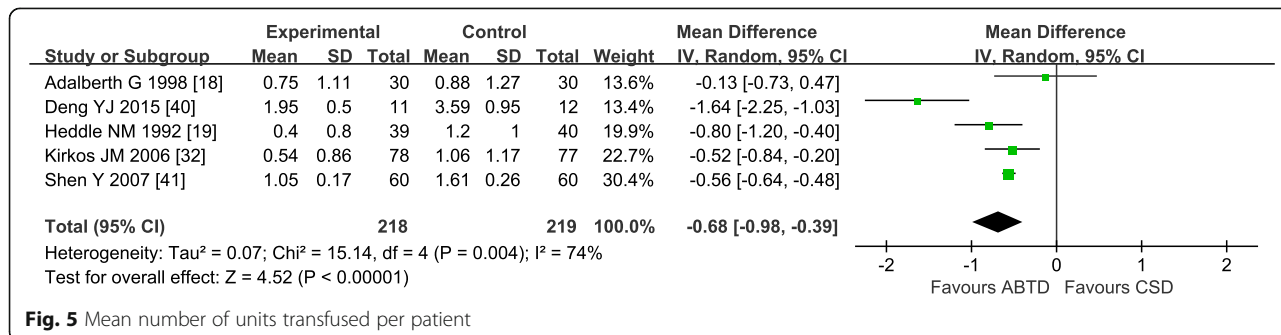
Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI	Mean Difference IV, Random, 95% CI
Adalberth G 1998 [18]	0.75	1.11	30	0.88	1.27	30	13.6%	-0.13 [-0.73, 0.47]	
Deng YJ 2015 [40]	1.95	0.5	11	3.59	0.95	12	13.4%	-1.64 [-2.25, -1.03]	
Heddle NM 1992 [19]	0.4	0.8	39	1.2	1	40	19.9%	-0.80 [-1.20, -0.40]	
Kirkos JM 2006 [32]	0.54	0.86	78	1.06	1.17	77	22.7%	-0.52 [-0.84, -0.20]	
Shen Y 2007 [41]	1.05	0.17	60	1.61	0.26	60	30.4%	-0.56 [-0.64, -0.48]	
Total (95% CI)			**218**			**219**	**100.0%**	**-0.68 [-0.98, -0.39]**	

Heterogeneity: Tau² = 0.07; Chi² = 15.14, df = 4 (P = 0.004); I² = 74%
Test for overall effect: Z = 4.52 (P < 0.00001)

-2   -1   0   1   2
Favours ABTD   Favours CSD

Fig. 5 Mean number of units transfused per patient

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Study or Subgroup	Experimental Events	Total	Control Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Odds Ratio M-H, Fixed, 95% CI
Amin A 2008 [29]	4	92	2	86	20.1%	1.91 [0.34, 10.70]	
Majkowski RS 1991 [38]	4	20	5	20	40.6%	0.75 [0.17, 3.33]	
Thomas D 2001 [35]	3	115	4	116	39.4%	0.75 [0.16, 3.43]	
Total (95% CI)		227		222	100.0%	0.98 [0.40, 2.38]	
Total events	11		11				
Heterogeneity: Chi² = 0.82, df = 2 (P = 0.66); I² = 0%							
Test for overall effect: Z = 0.04 (P = 0.97)							

0.001   0.1   1   10   1000
Favours ABTD   Favours CSD

Fig. 6 Wound complication

one study randomly. Dropping any one study did not reduce the heterogeneity, suggesting that the result was robust against the heterogeneity.

Mean number of units transfused per patient

Five trials [18, 19, 32, 40, 41] that included a total of 437 patients reported the mean number of units transfused per patient (Fig. 5). These five trials [18, 19, 32, 40, 41] showed moderate heterogeneity in the results (chi-square = 15.14, $P = 0.004$; $I^2 = 74$ %). Therefore, a random effects model was used for statistical analysis. The meta-analysis showed a significant beneficial effect of ABTD compared with CSD; i.e., a lower mean number of units transfused per patient (WMD: −0.68 [−0.98, −0.39]; $Z = 4.52$, $P < 0.00001$). Due to marked heterogeneity in blood transfusion rate, sensitivity analysis was conducted by excluding one study [40] of lower quality, which reduced the heterogeneity ($I^2 = 12$ %, $P = 0.33$). The random effects model also showed a significant beneficial effect of ABTD relative to CSD (WMD: −0.56 [−0.68, −0.44]; $Z = 9.39$, $P < 0.00001$). Dropping any one study did not influence the qualitative result.

Wound complications

The analysis of data extracted from three studies [29, 35, 38] that assessed wound complications in 449 patients revealed no significant difference between the ABTD and CSD groups (4.85 and 4.95 %, OR: 0.98 [0.40, 2.38]; $Z = 0.04$, $P = 0.97$). No significant heterogeneity was detected ($P = 0.66$, $I^2 = 0$ %) (Fig. 6).

Deep vein thrombosis

Data extracted from four studies [18, 29, 35, 38] that assessed deep vein thrombosis in 509 patients showed no significant difference between the ABTD and CSD groups (1.56 and 2.38 %, OR: 0.69 [0.21, 2.24]; $Z = 0.61$, $P = 0.54$). No significant heterogeneity was detected ($P = 0.64$, $I^2 = 0$ %) (Fig. 7).

Secondary outcomes
Febrile complications

Six trials [19, 31, 32, 34, 36, 37] compared ABTD with CSD with respect to febrile complications. These six trials showed substantial heterogeneity in the results (chi-square = 11.28, $P = 0.05$; $I^2 = 56$ %); therefore, a random effects model was used. The meta-analysis showed no significant difference between the two groups (20.49 and 25.68 %, OR: 0.78 [0.25, 2.40]; $Z = 0.43$, $P = 0.67$) (Fig. 8). Due to marked heterogeneity in the febrile complications data, sensitivity analysis was conducted by excluding one study [37] of lower quality, which reduced the heterogeneity ($I^2 = 30$ %, $P = 0.22$). The random effects model also showed no significant difference between the ABTD and CSD groups (21.01 and 22.52 %, OR: 1.21 [0.39, 3.68]; $Z = 0.33$, $P = 0.74$). Dropping any one study did not qualitatively alter the result.

Post-operative hemoglobin on days 5–8

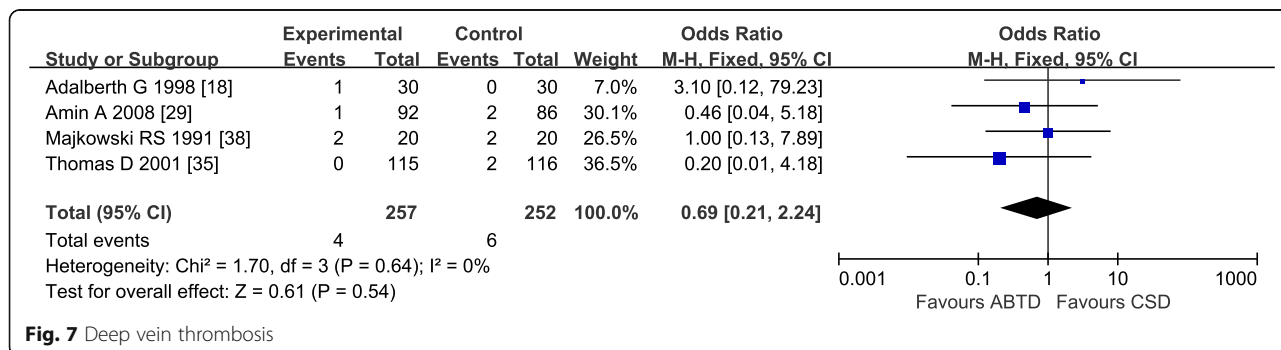Four studies [18, 31, 37, 42] reported post-operative hemoglobin on days 5–8. Among these studies, one [31]

Study or Subgroup	Experimental Events	Total	Control Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Odds Ratio M-H, Fixed, 95% CI
Adalberth G 1998 [18]	1	30	0	30	7.0%	3.10 [0.12, 79.23]	
Amin A 2008 [29]	1	92	2	86	30.1%	0.46 [0.04, 5.18]	
Majkowski RS 1991 [38]	2	20	2	20	26.5%	1.00 [0.13, 7.89]	
Thomas D 2001 [35]	0	115	2	116	36.5%	0.20 [0.01, 4.18]	
Total (95% CI)		257		252	100.0%	0.69 [0.21, 2.24]	
Total events	4		6				
Heterogeneity: Chi² = 1.70, df = 3 (P = 0.64); I² = 0%							
Test for overall effect: Z = 0.61 (P = 0.54)							

0.001   0.1   1   10   1000
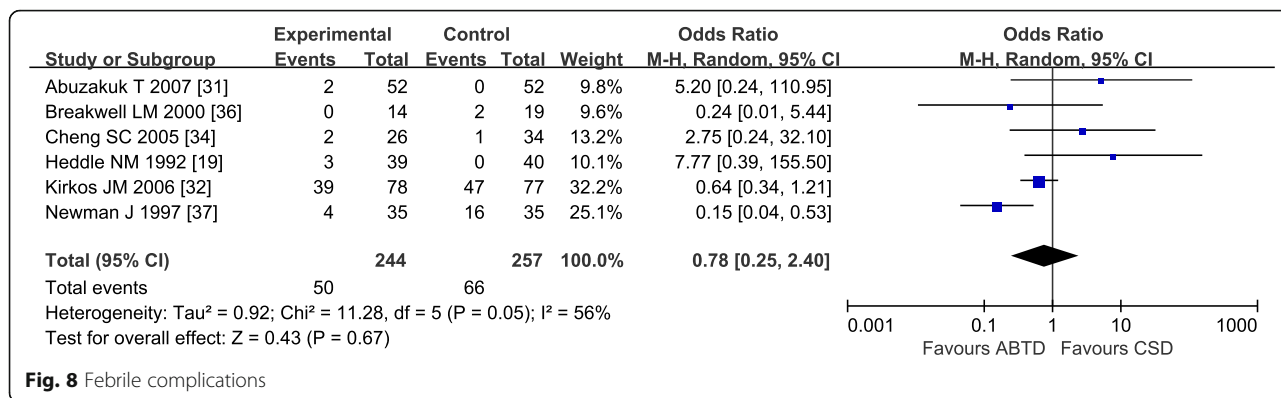Favours ABTD   Favours CSD

Fig. 7 Deep vein thrombosis

Fig. 8 Febrile complications

reported hemoglobin on the fifth day post-operation, one [18] reported hemoglobin on the eighth day post-operation, and the remaining two [37, 42] reported hemoglobin on the seventh day post-operation. Because the four studies [18, 31, 37, 42] showed moderate heterogeneity in the results (chi-square = 5.74, P = 0.13; I^2 = 48 %), a fixed effects model was used. The meta-analysis showed a significant beneficial effect of CSD compared with ABTD on post-operative hemoglobin on days 5–8 (WMD: 0.21 [–0.07, 0.48]; Z = 1.47, P = 0.14) (Fig. 9).

Drainage volume
Seven studies [18, 19, 31, 37–39, 41] reported post-operative drainage volume. These seven studies showed moderate heterogeneity in the results (chi-square = 9.03, P = 0.17; I^2 = 34 %); therefore, a fixed effects model was used. Pooling and analysis of the data of the 605 patients from the seven studies revealed no significant difference between the ABTD and CSD groups (WMD: –2.91 [–43.50, 37.68]; Z =0.14, P = 0.89) (Fig. 10).

Length of hospital stay
Three trials [18, 31, 37] compared ABTD with CSD in length of hospital stay. The three trials [18, 31, 37] showed substantial heterogeneity in the results (chi-square = 4.14, P = 0.13; I^2 = 52 %); therefore, a random effects model was used. The meta-analysis showed no significant difference in length of hospital stay between the ABTD and CSD groups (WMD: –0.96 [–2.09, 0.17]; Z = 1.67, P = 0.10)

(Fig. 11). Due to marked heterogeneity in length of hospital stay, sensitivity analysis was conducted by excluding one study [37] of lower quality, resulting in no significant heterogeneity detected (P = 0.32, I^2 = 0 %). The random effects model also showed no significant difference between the two groups in length of hospital stay (WMD: –0.52 [–1.30, 0.25]; Z = 1.33, P = 0.18).

Publication bias
The funnel plot of blood transfusion rate (Fig. 12) showed a markedly asymmetrical distribution of effect estimate, which indicated the presence of publication bias.

Discussion
The meta-analysis of 16 RCTs, including 1534 patients, suggested that ABTD is a safe system that yields a significantly reduced blood transfusion rate and fewer units of transfused blood per patient compared with CSD. We found no significant differences between the two drainage systems in wound complications, deep vein thrombosis, febrile complications, post-operative hemoglobin on days 5–8, drainage volume, or length of hospital stay.

TKA patients require post-operative allogenic blood transfusion, which was markedly reduced by using ABTD compared with CSD. Although allogenic transfusion remains the most popular method of compensating for blood loss in TKA patients, it can have potential deleterious effects, including transfusion-related infection, incompatibility-related transfusion reaction,
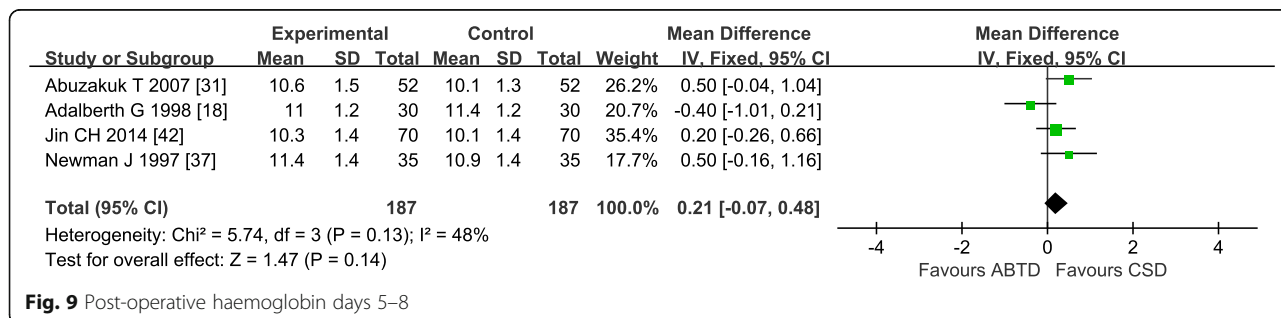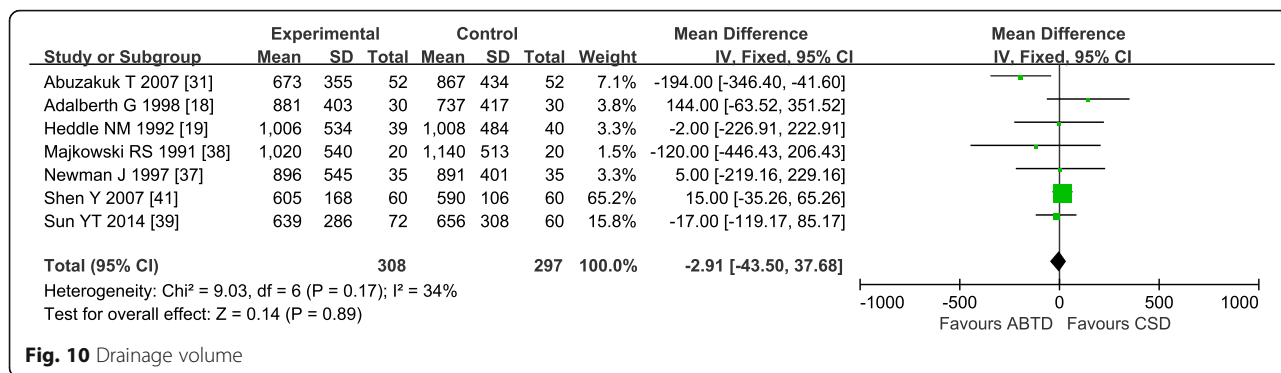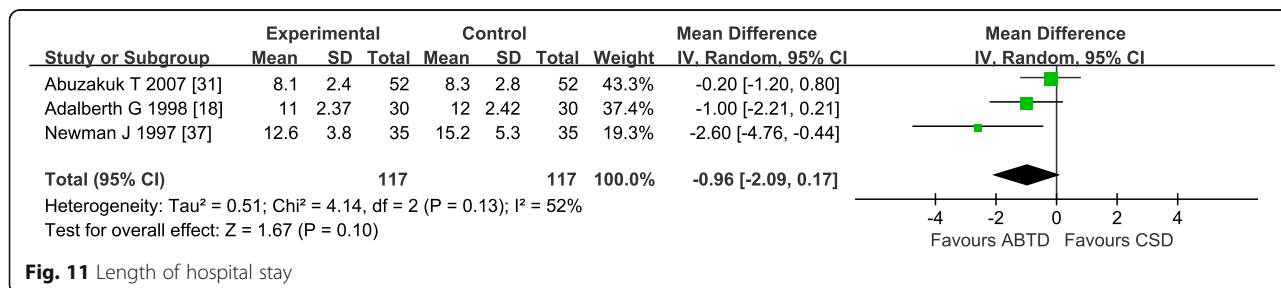

Fig. 9 Post-operative haemoglobin days 5–8

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Study or Subgroup	Experimental			Control			Weight	Mean Difference IV, Fixed, 95% CI	Mean Difference IV, Fixed, 95% CI
	Mean	SD	Total	Mean	SD	Total			
Abuzakuk T 2007 [31]	673	355	52	867	434	52	7.1%	-194.00 [-346.40, -41.60]	
Adalberth G 1998 [18]	881	403	30	737	417	30	3.8%	144.00 [-63.52, 351.52]	
Heddle NM 1992 [19]	1,006	534	39	1,008	484	40	3.3%	-2.00 [-226.91, 222.91]	
Majkowski RS 1991 [38]	1,020	540	20	1,140	513	20	1.5%	-120.00 [-446.43, 206.43]	
Newman J 1997 [37]	896	545	35	891	401	35	3.3%	5.00 [-219.16, 229.16]	
Shen Y 2007 [41]	605	168	60	590	106	60	65.2%	15.00 [-35.26, 65.26]	
Sun YT 2014 [39]	639	286	72	656	308	60	15.8%	-17.00 [-119.17, 85.17]	
Total (95% CI)			308			297	100.0%	-2.91 [-43.50, 37.68]	

Heterogeneity: Chi² = 9.03, df = 6 (P = 0.17); I² = 34%
Test for overall effect: Z = 0.14 (P = 0.89)

Favours ABTD Favours CSD

Fig. 10 Drainage volume

immune modulatory effects, and febrile complications [34]. These risks have led to use of autologous pre-donation blood, which also has drawbacks, e.g., difficulty of organizing patients for pre-donation and adherence to iron or erythropoietin therapy [43]. Studies have reported that nearly half of the autologous blood donated by patients for surgery is discarded [44, 45]. The use of autologous pre-donation blood is wasteful and costly [46]. Compared with the use of autologous pre-donation blood, ABTD has been found to be easier to perform, more cost-effective and able to lower the risks associated with allogenic blood use [47]. The present meta-analysis found that ABTD showed a significantly reduced blood transfusion rate and number of units transfused per patient; therefore, although the ABTD device is more expensive than CSD, a TKA patient using ABTD could spend 20 to 70 % less money on allogenic blood transfusion [30, 32, 34–36]. The procedures for setting up an ABTD system are similar to those for standard allogeneic blood transfusions [34] and require no additional medical personnel, but they do add staff time [31, 35]. The exact costs saved by using ABTD was not quantified in the present study because the unit cost of allogenic blood varies among regions.

Analysis of the extracted data on postoperative outcomes demonstrated that ABTD is safe and effective for TKA. There were no significant differences between ABTD and CSD in wound complications, deep vein thrombosis, and febrile complications. Kristiansson et al.

[48] found that hypercoagulability and high concentrations of IL-6 were present in drained blood. Some studies have reported that drained blood shows decreased platelet counts, pH levels, and clotting factor levels as well as increased fibrin degradation products [49, 50]. Hand et al. [51] identified low levels of methyl methacrylate monomers in filtered blood. Contra-indications to the use of unwashed shed blood have been formulated by the American Association of Blood Banks [52], who suggested that various cytokines are activated in drained blood and may be problematic for some patients if they increased to higher levels more than 6 h after bleeding [53]. In all of the studies included in the present meta-analysis, re-infusion was completed within 6 h post-operation. A lower rate of allogenic blood transfusion may help prevent febrile complications. Postoperative febrile complications were generally observed in the context of major orthopedic surgery, and it has been suggested that the rise in temperature is a response to the surgical procedure [54]. Some previous studies have also reported no difference between ABTD and CSD in the development febrile complications [55–57]. The absence of significant differences in wound complications, deep vein thrombosis, and febrile complications between ABTD and CSD indicate that ABTD is as safe as CSD.

Analysis of the pooled data revealed no significant difference in drainage volume, suggesting that ABTD is equally safe as CSD with respect to wound bleeding.

We found no significant differences between the two systems in post-operative hemoglobin on days 5–8. ABTD was found to be effective in reducing allogeneic
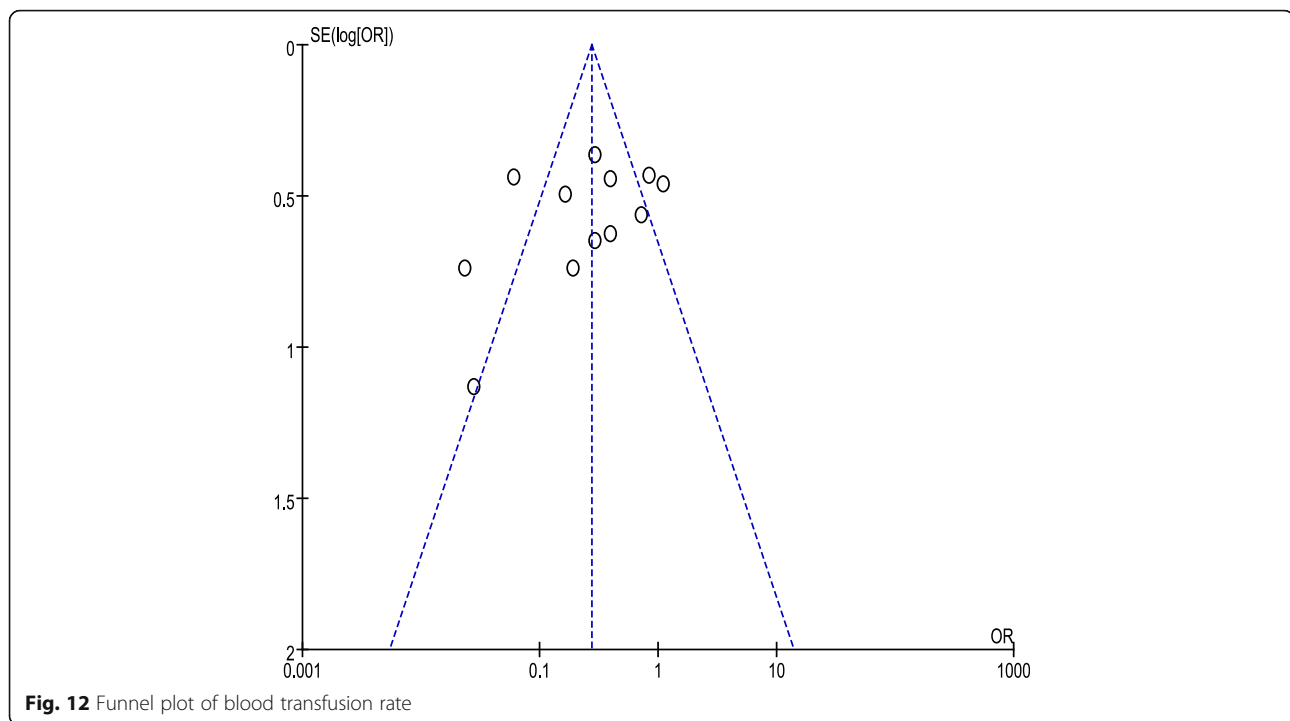
Study or Subgroup	Experimental			Control			Weight	Mean Difference IV, Random, 95% CI	Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total			
Abuzakuk T 2007 [31]	8.1	2.4	52	8.3	2.8	52	43.3%	-0.20 [-1.20, 0.80]	
Adalberth G 1998 [18]	11	2.37	30	12	2.42	30	37.4%	-1.00 [-2.21, 0.21]	
Newman J 1997 [37]	12.6	3.8	35	15.2	5.3	35	19.3%	-2.60 [-4.76, -0.44]	
Total (95% CI)			117			117	100.0%	-0.96 [-2.09, 0.17]	

Heterogeneity: Tau² = 0.51; Chi² = 4.14, df = 2 (P = 0.13); I² = 52%
Test for overall effect: Z = 1.67 (P = 0.10)

Favours ABTD Favours CSD

Fig. 11 Length of hospital stay

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Fig. 12 Funnel plot of blood transfusion rate

blood transfusions but not in achieving high postoperative hemoglobin levels. A high postoperative hemoglobin level has been reported to be associated with better rehabilitation outcomes after TKA [58]. The present findings suggest that ABTD was not useful in achieving high postoperative hemoglobin levels to enhance rehabilitation, similar to the findings of other studies [57, 59].

The present meta-analysis revealed no significant difference in length of hospital stay between ABTD and CSD. However, the previous meta-analysis [17] found a longer length of hospital stay in the CSD group. The data on length of hospital stay in Amin A et al. [29] were presented as means and ranges, and we were unable to obtain the original data by contacting the corresponding author. Therefore, we excluded these data [29], which were included in the previous meta-analysis [17]. Due to country and regional variation in medical insurance policies and social support facilitating discharge, the length of hospital stay could not be used in the present study as a measure of cost [36].

Two studies [36, 40] on bilateral TKA reported different outcomes that could not be synthesized. Due to this limited number of studies and insufficient description of the study methods, the outcomes could not be analyzed in a subgroup analysis.

To assess the impact of one study on the effect estimates, we performed sensitivity analysis by excluding one study with a high weight or of lower quality. The results regarding blood transfusion rate, febrile complications, and length of hospital stay were qualitatively

unchanged by this analysis. However, as a result of the sensitivity analysis, the original result regarding postoperative hemoglobin on days 5–8 was changed to favor CSD, and the heterogeneity decreased from 48 to 0 % when the study by Adalberth et al. [18] was excluded. Analysis of the four studies [18, 31, 37, 42] reporting on pre-operative hemoglobin revealed no significant difference between the two systems (Heterogeneity: chi-square = 3.09, $P = 0.38$; $I^2 = 3$ %; WMD: −0.07 [−0.33, 0.20]; $Z = 0.49$, $P = 0.62$). Some non-RCT studies [43, 60] have similarly found no significant difference in hemoglobin levels before and after TKA between the ABTD and CSD groups. Another study [31] found that ABTD could prevent a rapid decrease in hemoglobin level during the early postoperative period, although this benefit was no longer present by post-operative day 5. Because only three studies [18, 31, 37] included in this meta-analysis reported on post-operative hemoglobin, further studies are needed to evaluate the benefit of ABTD with respect to post-operative hemoglobin.

Limitations
This meta-analysis has limitations. We used the Jadad quality scale [26] and the Cochrane risk of bias tool [27] to assess the methodological quality of the included RCTs. According to the Jadad quality scale, the average score of the included studies was 1.4, and only two RCTs [18, 19] were of high quality. The Jadad score places more emphasis on reporting rather than performance, and its advantage is its simplicity and easy implementation.

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The Jadad score was used in this study because it makes it easy for readers to comprehend the quality of the included studies. Although a lack of adequate allocation concealment have been found in Jadad scores, this domain was assessed using criteria adopted from the Cochrane Handbook. The more important evaluation method used in this study is the Cochrane risk of bias tool.

The majority of the included RCTs were of moderate quality, and their sample sizes were comparatively small. In addition, it appears that the lack of random sequence generation increased the risk of bias.

Another limitation is that adequate information concerning each final outcome was not consistently provided among the 16 studies included. Furthermore, a prerequisite for the initial meta-analysis was the assumption of similarity between the two kinds of surgeries (SU-TKA and B-TKA), which enabled them to be evaluated together.

Fortunately, the results of the sensitivity analyses were similar to those of the original analyses. Another limitation of the present study is the heterogeneity among the included studies, which may reflect inter-study differences in analysis methodology, surgical method (SU-TKA vs. B-TKA), country and racial type. Future systematic reviews should assess different surgical methods, countries and racial types individually when sufficient high-quality RCT data become available. Surgeon experience in various TKA surgical approaches might also influence the results. Finally, as few of the included studies involving long-term follow-up, long-term outcomes could not be evaluated and require further study.

Conclusions

The present meta-analysis indicated that ABTD is more efficacious than CSD in reducing the blood transfusion rate and the number of units transfused per patient in TKA patients. The two types of drains appear to be equivalent in terms of wound complications, deep vein thrombosis, febrile complications, post-operative hemoglobin on days 5–8, drainage volume, and length of hospital stay. The results of this meta-analysis can help TKA surgeons make clinical decisions. The development of large-volume, well-designed RCTs and clinical trials with extensive follow-up will clarify the advantages and disadvantages of ABTD.

Additional file

Additional file 1: Search strategies. (DOCX 18 kb)

Abbreviations

ABTD: Autologous blood transfusion drainage; B-TKA: Bilateral total knee replacement; CBM: Chinese Biomedical Literature; CIs: Confidence intervals; CNKI: China National Knowledge Infrastructure; CSD: Conventional suction drainage; ITT: Intent-to-trea; ORs: Odds ratios; SU-TKA: Selective unilateral total knee replacement; TKA: Total knee arthroplasty; WMDs: Weighted mean differences

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article.

Authors' contributions

Conceived and designed the SRMA: JL. Performed the SRMA: JKP, KHH, HX. Analyzed the data: JKP, KHH, HX, MHL, DG, JL. Drafted the manuscript: JKP. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable.

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References

1. Torres-Claramunt R, Hinarejos P, Perez-Prieto D, Gil-Gonzalez S, Pelfort X, Leal J, Puig L. Sealing of the intramedullar femoral canal in a TKA does not reduce postoperative blood loss: A randomized prospective study. Knee. 2014;21(4):853–857.
2. Xie H, Pan JK, Hong KH, Guo D, Fang J, Yang WY, Liu J. Postoperative autotransfusion drain after total hip arthroplasty: A meta-analysis of randomized controlled trials. Sci Rep. 2016;(6):27461.
3. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. J Bone Joint Surg Br. 2004;86(4):561–5.
4. Keating EM, Meding JB, Faris PM, Ritter MA. Predictors of transfusion risk in elective knee surgery. Clin Orthop Relat Res. 1998;10(357):50–59.
5. Adie S, Naylor JM, Harris IA. Cryotherapy after total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. J Arthroplasty. 2010;25(5):709–15.
6. Hong KH, Pan JK, Yang WY, et al. Comparison between autologous blood transfusion drainage and closed-suction drainage/no drainage in total knee arthroplasty: a meta-analysis. BMC Musculoskelet Disord 2016;17:142.
7. Bidolegui F, Arce G, Lugones A, Pereira S, Vindver G. Tranexamic acid reduces blood loss and transfusion in patients undergoing total knee arthroplasty without tourniquet: a prospective randomized controlled trial. Open Orthop J. 2014;7(8):250–4.
8. Tai TW, Chang CW, Yang CY. The role of drainage after total knee arthroplasty[M]. INTECH Open Access Publisher. 2012;267–74.

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9. Drinkwater CJ, Neil MJ. Optimal timing of wound drain removal following total joint arthroplasty. J Arthroplasty. 1995;10(2):185–9.

10. Holt BT, Parks NL, Engh GA, Lawrence JM. Comparison of closed-suction drainage and no drainage after primary total knee arthroplasty. Orthopedics. 1997;20(12):1121–4. discussion 1124–5.

11. Martin A, Prenn M, Spiegel T, Sukopp C, von Strempel A. Relevance of wound drainage in total knee arthroplasty–a prospective comparative study. Z Orthop Ihre Grenzgeb. 2004;142(1):46–50.

12. Kim YH, Cho SH, Kim RS. Drainage versus nondrainage in simultaneous bilateral total knee arthroplasties. Clin Orthop Relat Res. 1998;2(347):188–93.

13. Gibbons CE, Solan MC, Ricketts DM, Patterson M. Cryotherapy compared with Robert Jones bandage after total knee replacement: a prospective randomized trial. Int Orthop. 2001;25(4):250–2.

14. Pavelescu D, Mirea L, Grintescu I. Combined perioperative use of tranexamic acid with a postoperative reinfusion/autotransfusion drainage system dramatically decrease the allogenic transfusion needs in total knee arthroplasty (TKA). Eur J Anaesthesiol 2014, 31((Pavelescu D.; Mirea L.; Grintescu I.) SCUB, Dept of Anaesthesiology and Intensive Care, Bucharest, Romania):103–4.

15. Kang DG, Khurana S, Baek JH, Park YS, Lee SH, Kim KI. Efficacy and safety using autotransfusion system with postoperative shed blood following total knee arthroplasty in haemophilia. Haemophilia. 2014;20(1):129–32.

16. Horstmann W, Kuipers B, Ohanis D, Slappendel R, Kollen B, Verheyen C. Autologous re-transfusion drain compared with no drain in total knee arthroplasty: a randomised controlled trial. Blood Transfus. 2014;12(Suppl 1):s176–s81.

17. Markar SR, Jones GG, Karthikesalingam A, Segaren N, Patel RV. Transfusion drains versus suction drains in total knee replacement: Meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2012;20(9):1766–72.

18. Adalberth G, Byström S, Kolstad K, Mallmin H, Milbrink J. Postoperative drainage of knee arthroplasty is not necessary: a randomized study of 90 patients. Acta Orthop Scand. 1998;69(5):475–8.

19. Heddle NM, Brox WT, Klama LN, Dickson LL, Levine MN. A randomized trial on the efficacy of an autologous blood drainage and transfusion device in patients undergoing elective knee arthroplasty. Transfusion. 1992;32(8):742–6.

20. Wu XY, Tang JL, Mao C, Yuan JQ, Qin Y, Chung VC. Systematic reviews and meta-analyses of traditional chinese medicine must search chinese databases to reduce language bias. Evid Based Complement Alternat Medicine. 2013;2013:812179.

21. Egger M, Zellweger-Zahner T, Schneider M, Junker C, Lengeler C, Antes G. Language bias in randomised controlled trials published in English and German. Lancet. 1997;350(9074):326–9.

22. Thomassen BJW, Hollander PHC, Kaptijn HH, Nelissen R, Pilot P. Autologous wound drains have no effect on allogeneic blood transfusions in primary total hip and knee replacement: A three-arm randomised trial. Bone Joint J. 2014,96-B(6):765–71.

23. Cip J, Widemschek M, Benesch T, Waibel R, Martin A.Does single use of an autologous transfusion system in TKA reduce the need for allogenic blood?: A prospective randomized trial general. Clin Orthop RelatRes 2013;471(4):1319–25.

24. Dobosz B, Dutka J, Dutka L, Maleta P. Clinical and cost effectiveness-related aspects of retransfusion in total hip and knee arthroplasty. Ortop Traumatol Rehabil. 2012;14(5):421–8.

25. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, Moher D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ. 2009;339:b2700.

26. Jadad AR, Moore RA, Carroll D, Jenkinson C, Reynolds DJ, Gavaghan DJ, McQuay HJ. Assessing the quality of reports of randomized clinical trials: is blinding necessary? Control Clin Trials. 1996;17(1):1–12.

27. Huggins J, Green S. Cochrane handbook for systematic reviews of interventions. New York: Cochrane Collaboration, John Wiley and Sons; 2008.

28. Elzik ME, Dirschl DR, Dahners LE. Correlation of transfusion volume to change in hematocrit. Am J Hematol. 2006;81(2):145–6.

29. Amin A, Watson A, Mangwani J, Nawabi DH, Nawabi D, Ahluwalia R, Loeffler M.A prospective randomised controlled trial of autologous retransfusion in total knee replacement. J Bone Joint Surg. 2008;90(4):451–4.

30. Zacharopoulos A, Apostolopoulos A, Kyriakidis A. The effectiveness of reinfusion after total knee replacement. A prospective randomised controlled study. Int Orthop. 2007;31(3):303–8.

31. Abuzakuk T, Senthil Kumar V, Shenava Y, Bulstrode C, Skinner JA, Cannon SR, Briggs TW. Autotransfusion drains in total knee replacement. Are they alternatives to homologous transfusion? Int Orthop. 2007;31(2):235–9.

32. Kirkos JM, Krystallis CT, Konstantinidis PA, Papavasiliou KA, Kyrkos MJ, Ikonomidis LG. Postoperative re-perfusion of drained blood in patients undergoing total knee arthroplasty: Is it effective and cost-efficient? Acta Orthop Belg. 2006;72(1):18–23.

33. Dramis A, Plewes J. Autologous blood transfusion after primary unilateral total knee replacement surgery. Acta Orthop Belg. 2006;72(1):15–7.

34. Cheng SC, Hung TS, Tse PY. Investigation of the use of drained blood reinfusion after total knee arthroplasty: a prospective randomised controlled study. In: J Orthop Surg (Hong Kong). 2005;13(2):120–4.

35. Thomas D, Wareham K, Cohen D, Hutchings H. Autologous blood transfusion in total knee replacement surgery. Br J Anaesth. 2001;86(5):669–73.

36. Breakwell LM, Getty CJM, Dobson P. The efficacy of autologous blood transfusion in bilateral total knee arthroplasty. Knee. 2000;7(3):145–7.

37. Newman J, Bowers M, Murphy J. The clinical advantages of autologous transfusion a randomised, controlled study after knee replacement. J Bone Joint Surg Br. 1997;79(4):630–2.

38. Majkowski RS, Currie IC, Newman JH.Postoperative collection and reinfusion of autologous blood in total knee arthroplasty. Ann R Coll Surg Engl. 1991; 73(6): 381–4.

39. Sun YT, Li JY, Liu Y. The applications and effect evaluation of autologous blood transfusion device in total knee replacement postoperative. Chinese Foreign Med Res. 2014;12(9):78–9.

40. Deng YJ, Lv G, Chu LT, Fang R, Liang ZQ, Xiang WY. Observation on the effect of three different methods on blood management during perioperation of double knee replacement. HeBei Medicine (China). 2015;21(1):97–100.

41. Shen Y, Zhang MX, Liu L, Chen YX, Li H. Observation and care of wound drainage after primary total knee arthroplasty. J Nurs. 2007;14(8):43–4.

42. Jin CH. Effect of autologous blood transfusion device in primary knee arthroplasty postoperative. Med Inform. 2014;27(9):191–2.

43. Lakshmanan P, Purushothaman B, Sharma A. Impact of reinfusion drains on hemoglobin level in total knee arthroplasty. Am J Orthop. 2010;39(2):70–4.

44. Sculco TP, Gallina J. Blood management experience: relationship between autologous blood donation and transfusion in orthopedic surgery. Orthopedics. 1999;22(1 Suppl):129–34.

45. Bierbaum BE, CALLAGHAN JJ, GALANTE JO, RUBASH HE, TOOMS RE, WELCH RB. An analysis of blood management in patients having a total Hip or knee arthroplasty. J Bone Joint Surg. 1999;81(1):2–10.

46. Etchason J, Petz L, Keeler E, Calhoun L, Kleinman S, Snider C, Fink A, Brook R. The cost effectiveness of preoperative autologous blood donations. N Engl J Med. 1995;332(11):719–24.

47. Woolson ST, Wall WW. Autologous blood transfusion after total knee arthroplasty: a randomized, prospective study comparing predonated and postoperative salvage blood. J Arthroplasty. 2003;18(3):243–9.

48. Kristiansson M, Soop M, Saraste L, Sundqvist KG, Suontaka AM, Blomback M. Cytokine and coagulation characteristics of retrieved blood after arthroplasty. Intensive Care Med. 1995;21(12):989–95.

49. Peter V, Radford M, Matthews M. Re-transfusion of autologous blood from wound drains: the means for reducing tranfusion requirements in total knee arthroplasty. Knee. 2001;8(4):321–3.

50. Dalén T, Broström L-Å, Engströrn KG. Autotransfusion after total knee arthroplasty: effects on blood cells, plasma chemistry and whole blood rheology. J Arthroplasty. 1997;12(5):517–25.

51. Hand C, Henderson M, Mace P, Sherif N, Newman J, Goldie D. Methyl methacrylate levels in unwashed salvage blood following unilateral total knee arthroplasty. J Arthroplasty. 1998;13(5):576–9.

52. American Association of Blood Banks. Guidance for standards for perioperative autologous blood collection and administration. 1st ed. Bethesda, Maryland; 2002.

53. Waters JH, Dyga RM, Yazer MH. Guidelines for blood recovery and reinfusion in surgery and trauma. Bethesda, MD: American Association of Blood Banks 2010.

54. Munoz M, Kuhlmorgen B, Ariza D, Haro E, Marroqui A, Ramirez G. Which patients are more likely to benefit from postoperative shed blood salvage after unilateral total knee replacement? An analysis of 581 consecutive procedures. Vox Sang. 2007;92(2):136–41.

55. Andersson I, Tylman M, Bengtson JP, Bengtsson A. Complement split products and pro-inflammatory cytokines in salvaged blood after hip and knee arthroplasty. Can J Anaesth. 2001;48(3):251–5.

56. Innerhofer P, Klingler A, Klimmer C, Fries D, Nussbaumer W. Risk for postoperative infection after transfusion of white blood cell-filtered allogeneic or autologous blood components in orthopedic patients undergoing primary arthroplasty. Transfusion. 2005;45(1):103–10.

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57. Haien Z, Yong J, Baoan M, Mingjun G, Qingyu F. Post-operative auto-transfusion in total hip or knee arthroplasty: a meta-analysis of randomized controlled trials. PLoS One. 2013;8(1):e55073.

58. Diamond PT, Conaway MR, Mody SH, Bhirangi K. Influence of hemoglobin levels on inpatient rehabilitation outcomes after total knee arthroplasty. J Arthroplasty. 2006;21(5):636–41.

59. Moonen AF, Knoors NT, van Os JJ, Verburg AD, Pilot P. Retransfusion of filtered shed blood in primary total hip and knee arthroplasty: a prospective randomized clinical trial. Transfusion. 2007;47(3):379–84.

60. Strumper D, Weber EW, Gielen-Wijffels S, Van Drumpt R, Bulstra S, Slappendel R, Durieux ME, Marcus MA. Clinical efficacy of postoperative autologous transfusion of filtered shed blood in hip and knee arthroplasty. Transfusion. 2004;44(11):1567–71.