9-24-2022

Routine Use of Closed Suction Drains Following Revision Arthroplasty May Not be Necessary

Farideh Najafi
Thomas Jefferson University

Jonah M. Stein
Thomas Jefferson University

Nicholas V. Peterson
University of California Los Angeles

Michael Meghpara
Thomas Jefferson University

Matthew B. Sherman
Thomas Jefferson University

TITLE

Routine Use of Closed Suction Drains Following Revision Arthroplasty May Not be Necessary

AUTHORS

Farideh Najafi[1], MD

Jonah M Stein[1], BS

Nicholas V Peterson[2], MD

Michael Meghpara[1], MD, MBA

Matthew B Sherman[1], BS

Camilo Restrepo[1], MD

Javad Parvizi[1], MD, FRCS

AFFILIATIONS

[1]Department of Orthopaedic Surgery, Rothman Institute, Thomas Jefferson University, Philadelphia, PA.

[2]Department of Orthopaedic Surgery, University of California Los Angeles, Santa Monica, California.

ABSTRACT

Introduction: There are numerous studies demonstrating that closed suction drainage (CSD) usage after primary total joint arthroplasty (TJA) have little to no benefit. There is little data on the role of CSDs after revision-TJA. The purpose of our study was to evaluate whether there is any clinical advantage to CSD usage after revision-TJA.

Methods: This retrospective study evaluated the clinical records of 2,030 patients undergoing revision-TJA between 2007 and 2021. CSD was utilized in 472 patients and not used in 1,558 patients. Primary outcome was blood transfusion rate, and secondary outcomes included total blood loss (TBL), as determined by Gross formula, wound complications (hematoma, infection, and dehiscence), and length of hospital stay (LOS). Patients undergoing revision-TJA for oncologic reasons or those with incomplete data sets were excluded.

Results: There were no statistically significant differences in rates of allogeneic blood transfusion, TBL, and wound complications (hematoma, infection, and dehiscence) between the two groups ($p = 0.159$, 0.983, 0.192, 0.334, and 0.548, respectively). When adjusted for demographic and surgical confounders, there was no difference in transfusion and TBL rates between groups (Odds Ratio [OR] 1.04, 95% Confidence Interval [CI] 0.78 – 1.38, $p = 0.780$ and estimate -105.71 mL, 95% CI -333.96 – 122.55, $p = 0.364$ respectively). CSD cohort had a shorter LOS (4.30 vs. 5.82 days, $p < 0.001$).

Discussion: The current study revealed that routine use of CSD after revision-TJA does not provide additional clinical benefit. We acknowledge that there is a role for CSD-usage in a select group of patients.

INTRODUCTION

Closed suction drainage (CSD) has been widely used in orthopaedic procedures that include total hip arthroplasty (THA) and total knee arthroplasty (TKA). In theory, surgical drains decrease hematoma formation and accelerate wound healing by decreasing the tension on the wound, thus enhancing tissue perfusion. Prevention of hematoma formation may also influence the incidence of superficial and deep infections [1,2]. Surgical drains are also known to reduce post-operative ecchymosis and saturation of wound dressings [3–6].

There are some potential adverse effects of CSD such as increased blood loss that may result in a higher rate of allogeneic blood transfusion [7–10]. Furthermore, CSD may allow the ingress of bacteria to the surgical site by acting as a duct and potentially increase the rate of periprosthetic infections [11–13]. CSD may also make patient mobilization and early rehabilitation difficult, leading to a longer hospital stay [3]. Additional issues with CSD include misplacement and inadvertent suturing to the surrounding tissue with need for an additional surgery [14].

Although there are numerous studies that demonstrate CSD has little to no benefit after routine primary arthroplasty [3,7,15–20], there is little data on the role of CSD after revision arthroplasty. Because of the complex nature of revision arthroplasties that result in longer operative time [21–23], and a potential for generating a larger dead space, one may argue that CSDs are essential after revision TJA. The review of the literature revealed few studies on a small patient population undergoing revision THA or TKA [24–26]. These studies were unable to demonstrate a benefit for CSD usage after revision arthroplasty. Thus, based on the available data it is not known if there is a role for routine use of CSD in patients undergoing revision total joint arthroplasty (TJA).

The purpose of this study was to evaluate whether there is any clinical advantage to the use of CSD after revision THA and TKA. We hypothesized that routine use of CSD after revision TJA does not provide additional clinical benefit.

MATERIALS & METHODS

Study design and population

After an institutional review board (IRB) approval, we conducted a retrospective cohort study of patients undergoing revision TJA between March 2007 and November 2021. Eligible patients were older than 18 years, undergoing revision TJA, and had unilateral revision surgery. Patients' records were reviewed by three trained research fellows to extract relevant details including demographic characteristics, surgical variables, transfusion rate as the primary outcome, and other variables as the secondary outcomes (i.e. total blood loss (TBL), wound complications (including wound hematoma, infection, and dehiscence), operative time, and length of hospital stay). Entries were excluded if the patient underwent revision surgery because of oncologic reasons or post-op transfusion data was not recorded.

Study definitions

Revision arthroplasty was defined as operation for one of the following indications: mechanical, infection, fracture, dislocation/instability, and loosening, when one or more of the arthroplasty components were exchanged. Total blood loss was estimated using the calculation proposed by the Gross equation [27–29], **(See Table 1)**.

Statistical analyses

Data was broken down descriptively first to understand the distribution of the CSD and non-CSD groups. Continuous data is presented as mean (standard deviation) and categorical data is presented as cell count (%). Shapiro-Wilks and Kolmogorov-Smirnov tests were used to assess the normality of the continuous data. T-tests were used to calculate p-values for continuous data and Chi-Square tests were used to calculate p-values for categorical data. Following this, an unadjusted and adjusted logistic regression was analyzed using transfusion as the dependent outcome. Both regressions looked at the primary outcome of CSD vs. non-CSD with the second one adding in demographic and surgical co-variates (including age, BMI, sex, operated joint, tranexamic acid (TXA) use, tourniquet use, operative time, and surgical indications) to see how the primary variable acted. A similar approach used a linear regression with total blood loss as the dependent outcome. Additional regression analyses were also performed for wound complications (hematoma, infection, and dehiscence), operative time, and length of stay. Significance was

determined at p-value < 0.05. All statistical analyses were done using R Studio (Version 4.1.2, Vienna, Austria).

RESULTS

In total, 2,030 patients were identified for inclusion in the analysis of whom 472 patients received CSD and 1,558 patients did not receive CSD after revision THA and TKA. Demographic characteristics and surgical factors are summarized in **Table 2**. Patients in the non-CSD group had higher body mass index (BMI) (31.1 vs. 30.5 Kg/m^2, p = 0.043), had a greater proportion of female patients (56.2 vs. 45.3%, p =< 0.001), and there were significant differences for surgical indication (p = 0.005) as listed in **Table 2.**

The results of allogeneic blood transfusion rate, total blood loss, and other secondary outcomes are listed in **Table 3**. There was no difference in allogeneic blood transfusion rates (19.7 vs. 22.9%, p = 0.159), and TBL (1,170 vs. 1,173 mL, p = 0.983) between the cohorts, but the CSD cohort had a shorter length of hospital stay (4.30 vs. 5.82 days, p < 0.001). There were no statistically significant differences in rates of tourniquet use or wound complications including wound hematoma, infection, and dehiscence (p = 0.339, 0.192, 0.334, and 0.548, respectively).

Unadjusted logistic regression analysis showed no significant difference in rates of blood transfusion between the two cohorts (Odds ratio [OR] 0.83, 95% confidence interval [CI] 0.64 – 1.06, p = 0.142), (**See Supplementary Material, SM - Table 1)**. Adjusted analysis for transfusion is listed in **Table 4**. Higher rates of transfusion were associated with increasing age and operative time (OR 1.02, 95% CI 1.01 – 1.04, p < 0.001 and OR 1.01, 95% CI 1.00 – 1.01, p < 0.001, respectively). Lower rates of transfusion were associated with male sex and revision TKA (OR 0.74, 95% CI 0.59 – 0.94, p = 0.014 and OR 0.43, 95% CI 0.33 – 0.55, p < 0.001, respectively). When adjusted for demographic and surgical confounding variables, there was no statistically significant difference in rates of transfusion between groups (OR 1.04, 95% CI 0.78 – 1.38, p = 0.780).

Unadjusted linear regression analysis comparing rates of total blood loss in CSD to non-CSD cohorts revealed no significant difference (estimate -2.99 mL, 95% CI -233.55 – 227.57, p = 0.980), (**See Supplementary Material, SM - Table 2)**. Also, when adjusting for demographic and surgical confounding variables, the CSD cohort showed no difference in rates of blood loss between groups (estimate -105.71 mL, 95% CI -333.96 – 122.55, p = 0.364), (**See Table 5)**.

Furthermore, additional regression analyses were performed for wound complications (hematoma, infection, and dehiscence), operative time and length of stay, and included in the Supplementary Material. No significant differences were detected for wound complications.

Operative time was lower for the CSD group (-20.71 min, 95% CI -26.74 – -14.67, p =< 0.001), and this cohort revealed shorter length of hospital stay (-0.06 days, 95% CI -1.20 – -0.05, p = 0.033), **(See Supplementary Material, SM - Tables 3 to 10)**.

DISCUSSION

The analysis of our data revealed that routine use of CSD after revision TJA does not affect blood loss, the need for allogeneic blood transfusion, rate of hematoma formation, and other wound complications studied here. Currently, there is limited evidence demonstrating the utility of CSD in revision arthroplasty. It is possible that the more extensive soft tissue dissection and increased risk for bleeding in revision arthroplasty, may lead to a large dead space with more potential for blood accumulation. These factors may theoretically increase the need for transfusion and risk of infection [30–33]. CSD may ameliorate some of these risks by preventing hematoma formation and removing a nidus for infection.

Conversely, CSD after revision arthroplasty may provide more harm than benefit. Downsides include increased operative time, increased rate of post-surgical blood loss and need for transfusion [7,8], and a potential avenue for pathogens to enter the surgical site and lead to subsequent infection [11]. The use of CSD also leads to added costs, with one study estimating an additional $538 USD per THA and $455 USD per TKA [34]. Post-operative care is also more intensive when CSD is used, including an increased workload on healthcare personnel to manage the drain [17].

Since proponents and critics of CSD have conflicting arguments regarding bleeding, it is important to note that this study found no differences in post-operative blood loss and need for transfusion following revision arthroplasty at the time of discharge. Further, there were no differences in short-term clinical outcomes, including wound complications. These differences were maintained even during several adjusted regression analyses that allowed us to isolate potentially confounding factors in our results. The lack of difference in transfusion rates and other clinical outcomes of this study agree with the previously published data [3,5,11,35–38]. The large cohort in this study (>2,000) builds on the conclusions drawn from previous studies involving a smaller number of patients [24–26]. Based on these results, routine use of CSD during revision arthroplasty may not be justified.

There have been numerous changes in surgical practice that may have impacted the findings of this study. The regular use of tranexamic acid (TXA), hypotensive anesthesia and tendency towards minimally invasive surgery may have caused a reduction in blood loss, hematoma formation, and other wound-related issues. Also, certain outcomes of this study were contrary to our expectations, including decreased hospitalization days and operative time in the

CSD group. Interestingly, the rates of CSD use were more frequent in recent years. From our analysis, it was unclear as to what drove the increased utilization of CSD, or if there is a causal relationship between CSD and length of stay. Decreased operative times may also indicate increased efficiency, and shortened hospital stays may be a result of streamlined practices

The main strength of our study is its large patient population (more than 2000 patients). To our knowledge, this is the first study evaluating CSD usage among a large cohort of both revision hip and knee arthroplasties, using several outcomes including transfusion rate, total blood loss, wound complications (including hematoma, infection, and dehiscence), operative time, and length of hospital stay. Other studies on this topic include a much smaller number of patients (less than 100 patients), [24–26], and the larger series are not confined to revision arthroplasties or not fully reporting several outcomes [5,10].

The long period of study (spanning over 14-years) and large sample size in this study resulted in the diverse patient characteristics, variety of surgical indications, approaches, implants (such as cemented versus uncemented), and protocols (including tourniquet and TXA use), which could increase the generalizability of our results to a larger number of institutions and procedures. In addition, the results of this study are strengthened by a robust statistical analysis including both unadjusted and adjusted logistic regression assessing for demographic variables, surgical factors (TXA and tourniquet usage), and surgical indications as confounders.

However, there are several limitations to the present study. The retrospective and observational nature of this study inherently limit the conclusions that can be drawn from the analysis of the data. Due to long duration of this study, there are a number of changes to intraoperative techniques (such as TXA use), and post-operative management (including early mobilization and discharge), that could intrinsically confound our results. It is important to note that, although we have done robust multivariate analyses, there is still the possibility that other contemporary methods could potentially influence the findings and may have escaped the benefit of performing regression analyses.

Another limitation in our data set is the lack of information on the duration of drain usage and drain output. The low rate of complications including wound hematoma and dehiscence may also be too rare to reach statistical significance regarding the effect of CSD usage. In addition, heterogeneity regarding the definition of wound infections and the detection of hematomas may have caused underreporting of certain complications. The lack of early functional outcomes and

follow-up post discharge may have also prevented detection of differences between the two groups. Certain late-presenting outcomes such as functional range of motion, deep infection, and component loosening are critical to patient satisfaction and should be considered in future studies. Prospective studies with a focus on early functional outcomes and long-term follow-up would be useful to fully understand the utility of CSD in both revision hip and knee arthroplasties. However, designing such studies are challenging based on logistics, cost, and equipoise. There are some surgeons in our institution who would not be willing to randomize their patients into a prospective study related to the use of CSD, as they feel that the use of surgical drains increases the incidence of infection. In the absence of such study, we reviewed the clinical records of a relatively large number of patients undergoing revision arthroplasty over a 14-year period. The study demonstrated that routine use of CSD after revision arthroplasty does not provide additional clinical benefit. We of course acknowledge that there is a role for CSD usage in a select group of patients, and further research is needed to determine the best candidates and specific indications for CSD use in revision TJAs.

REFERENCES

[1] Alexander JW, Korelitz J, Alexander NS. Prevention of wound infections. A case for closed suction drainage to remove wound fluids deficient in opsonic proteins. Am J Surg 1976;132:59–63. https://doi.org/10.1016/0002-9610(76)90291-9.

[2] Waugh TR, Stinchfield FE. Suction drainage of orthopaedic wounds. J Bone Joint Surg Am 1961;43-A:939–46.

[3] Sharma GM, Palekar G, Tanna DD. Use of closed suction drain after primary total knee arthroplasty – an overrated practice. SICOT-J 2016;2:39. https://doi.org/10.1051/sicotj/2016034.

[4] Koyano G, Jinno T, Koga D, Hoshino C, Muneta T, Okawa A. Is closed suction drainage effective in early recovery of hip joint function? Comparative evaluation in one-stage bilateral total hip arthroplasty. J Arthroplasty 2015;30:74–8. https://doi.org/10.1016/j.arth.2014.08.007.

[5] Zhou X, Li J, Xiong Y, Jiang L, Li W, Wu L. Do we really need closed-suction drainage in total hip arthroplasty? A meta-analysis. International Orthopaedics (SICOT) 2013;37:2109–18. https://doi.org/10.1007/s00264-013-2053-8.

[6] Holt BT, Parks NL, Engh GA, Lawrence JM. Comparison of closed-suction drainage and no drainage after primary total knee arthroplasty. Orthopedics 1997;20:1121–4; discussion 1124-1125.

[7] Park C-W, Lim S-J, Yoo I, Lee Y, Won J-Y, Park Y-S. Effects of disusing closed suction drainage in simultaneous bilateral total hip arthroplasty: A retrospective cohort study. PLoS ONE 2021;16:e0247845. https://doi.org/10.1371/journal.pone.0247845.

[8] Kelly EG, Cashman JP, Imran FH, Conroy R, O'Byrne J. Systematic review and meta-analysis of closed suction drainage versus non-drainage in primary hip arthroplasty. Surg Technol Int 2014;24:295–301.

[9] Walmsley PJ, Kelly MB, Hill RMF, Brenkel I. A prospective, randomised, controlled trial of the use of drains in total hip arthroplasty. J Bone Joint Surg Br 2005;87:1397–401. https://doi.org/10.1302/0301-620X.87B10.16221.

[10] Parker MJ, Roberts CP, Hay D. Closed suction drainage for hip and knee arthroplasty. A meta-analysis. J Bone Joint Surg Am 2004;86:1146–52. https://doi.org/10.2106/00004623-200406000-00005.

[11] Mengal B, Aebi J, Rodriguez A, Lemaire R. [A prospective randomized study of wound drainage versus non-drainage in primary total hip or knee arthroplasty]. Rev Chir Orthop Reparatrice Appar Mot 2001;87:29–39.

[12] Sørensen AI, Sørensen TS. Bacterial growth on suction drain tips. Prospective study of 489 clean orthopedic operations. Acta Orthop Scand 1991;62:451–4. https://doi.org/10.3109/17453679108996642.

[13] Magee C, Rodeheaver GT, Golden GT, Fox J, Edgerton MT, Edlich RF. Potentiation of wound infection by surgical drains. Am J Surg 1976;131:547–9. https://doi.org/10.1016/0002-9610(76)90007-6.

[14] Cobb JP. Why use drains? J Bone Joint Surg Br 1990;72:993–5. https://doi.org/10.1302/0301-620X.72B6.2246304.

[15] Jennings JM, Loyd BJ, Miner TM, Yang CC, Stevens-Lapsley J, Dennis DA. A prospective randomized trial examining the use of a closed suction drain shows no influence on strength or function in primary total knee arthroplasty. The Bone & Joint Journal 2019;101-B:84–90. https://doi.org/10.1302/0301-620X.101B7.BJJ-2018-1420.R1.

[16] Wang D, Xu J, Zeng W, Zhou K, Xie T, Chen Z, et al. Closed Suction Drainage Is Not Associated with Faster Recovery after Total Knee Arthroplasty: A Prospective Randomized Controlled Study of 80 Patients. Orthop Surg 2016;8:226–33. https://doi.org/10.1111/os.12247.

[17] Quinn M, Bowe A, Galvin R, Dawson P, O'Byrne J. The use of postoperative suction drainage in total knee arthroplasty: a systematic review. International Orthopaedics (SICOT) 2015;39:653–8. https://doi.org/10.1007/s00264-014-2455-2.

[18] Cheung G, Carmont MR, Bing AJF, Kuiper J-H, Alcock RJ, Graham NM. No drain, autologous transfusion drain or suction drain? A randomised prospective study in total hip replacement surgery of 168 patients. Acta Orthop Belg 2010;76:619–27.

[19] Dora C, von Campe A, Mengiardi B, Koch P, Vienne P. Simplified wound care and earlier wound recovery without closed suction drainage in elective total hip arthroplasty. A prospective randomized trial in 100 operations. Arch Orthop Trauma Surg 2007;127:919–23. https://doi.org/10.1007/s00402-006-0260-0.

[20] González Della Valle A, Slullitel G, Vestri R, Comba F, Buttaro M, Piccaluga F. No need for routine closed suction drainage in elective arthroplasty of the hip: a prospective

randomized trial in 104 operations. Acta Orthop Scand 2004;75:30–3. https://doi.org/10.1080/00016470410001708050.

[21] Jafari SM, Coyle C, Mortazavi SMJ, Sharkey PF, Parvizi J. Revision Hip Arthroplasty: Infection is the Most Common Cause of Failure. Clin Orthop Relat Res 2010;468:2046–51. https://doi.org/10.1007/s11999-010-1251-6.

[22] Sodhi N, Piuzzi NS, Khlopas A, Newman JM, Kryzak TJ, Stearns KL, et al. Are We Appropriately Compensated by Relative Value Units for Primary vs Revision Total Hip Arthroplasty? The Journal of Arthroplasty 2018;33:340–4. https://doi.org/10.1016/j.arth.2017.09.019.

[23] Lavernia CJ, Drakeford MK, Tsao AK, Gittelsohn A, Krackow KA, Hungerford DS. Revision and primary hip and knee arthroplasty. A cost analysis. Clin Orthop Relat Res 1995:136–41.

[24] Abolghasemian M, Huether TW, Soever LJ, Drexler M, MacDonald MP, Backstein DJ. The Use of a Closed-Suction Drain in Revision Knee Arthroplasty May Not Be Necessary. The Journal of Arthroplasty 2016;31:1544–8. https://doi.org/10.1016/j.arth.2015.08.041.

[25] Bartosz P, Grzelecki D, Chaberek S, Para M, Marczyński W, Białecki J. A prospective randomized study, use of closed suction drainage after revision hip arthroplasty may lead to excessive blood loss. Sci Rep 2022;12:881. https://doi.org/10.1038/s41598-022-05023-2.

[26] Fichman SG, Mäkinen TJ, Lozano B, Rahman WA, Safir O, Gross AE, et al. Closed suction drainage has no benefits in revision total hip arthroplasty: a randomized controlled trial. Int Orthop 2016;40:453–7. https://doi.org/10.1007/s00264-015-2960-y.

[27] Nadler SB, Hidalgo JH, Bloch T. Prediction of blood volume in normal human adults. Surgery 1962;51:224–32.

[28] Gross JB. Estimating allowable blood loss: corrected for dilution. Anesthesiology 1983;58:277–80. https://doi.org/10.1097/00000542-198303000-00016.

[29] 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;86:561–5.

[30] Mortazavi SMJ, Schwartzenberger J, Austin MS, Purtill JJ, Parvizi J. Revision total knee arthroplasty infection: incidence and predictors. Clin Orthop Relat Res 2010;468:2052–9. https://doi.org/10.1007/s11999-010-1308-6.

[31] Barrack RL. Economics of revision total hip arthroplasty. Clin Orthop Relat Res 1995:209–14.

[32] Crowe JF, Sculco TP, Kahn B. Revision total hip arthroplasty: hospital cost and reimbursement analysis. Clin Orthop Relat Res 2003:175–82. https://doi.org/10.1097/01.blo.0000072469.32680.b6.

[33] Barrack RL, Sawhney J, Hsu J, Cofield RH. Cost analysis of revision total hip arthroplasty. A 5-year followup study. Clin Orthop Relat Res 1999:175–8. https://doi.org/10.1097/00003086-199912000-00018.

[34] Bjerke-Kroll BT, Sculco PK, McLawhorn AS, Christ AB, Gladnick BP, Mayman DJ. The increased total cost associated with post-operative drains in total hip and knee arthroplasty. J Arthroplasty 2014;29:895–9. https://doi.org/10.1016/j.arth.2013.10.027.

[35] Fagotti L, Ejnisman L, Miyahara H de S, Gurgel H de MC, Croci AT, Vicente JRN. Use of closed suction drainage after primary total hip arthroplasty: a prospective randomized controlled trial. Rev Bras Ortop 2018;53:236–43. https://doi.org/10.1016/j.rboe.2018.01.001.

[36] Suarez JC, McNamara CA, Barksdale LC, Calvo C, Szubski CR, Patel PD. Closed Suction Drainage Has No Benefits in Anterior Hip Arthroplasty: A Prospective, Randomized Trial. The Journal of Arthroplasty 2016;31:1954–8. https://doi.org/10.1016/j.arth.2016.02.048.

[37] Matsuda K, Nakamura S, Wakimoto N, Kobayashi M, Matsushita T. Drainage does not increase anemia after cementless total hip arthroplasty. Clin Orthop Relat Res 2007;458:101–5. https://doi.org/10.1097/BLO.0b013e31802ea45f.

[38] Sundaram RO, Parkinson RW. Closed suction drains do not increase the blood transfusion rates in patients undergoing total knee arthroplasty. Int Orthop 2007;31:613–6. https://doi.org/10.1007/s00264-006-0232-6.

Table 1. Gross equation [27–29].

Gross equation	***Index***
TBL= PBV × (Hctpre− Hctpost)/Hctave PBV = $k_1 \times H^3 + k_2 \times W + k_3$	For males: k_1=0.3669, k_2=0.03219, and k_3=0.6041 For females: k_1=0.3561, k_2=0.03308, and k_3=0.1833

TBL (mL)=Total blood loss; PBV = Predicted blood volume (mL); Hctpre =The hematocrit values before surgery; Hctpost=The hematocrit values at day 3 after surgery; Hctave =The average of the Hctpre and Hctpost; H (m)=Height; W (kg)=Weight.

*If an allogeneic transfusion is performed, the volume transfused is added when calculating total blood loss.

Table 2. Demographic and surgical factors for all revision total joint arthroplasty patients.

Demographic and surgical factors	***Non-CSD cohort (N=1558)***	***CSD cohort (N=472)***	***p-value***
Age in years (range)	65.3 (25.0 – 94.0)	65.1 (34.0 – 91.0)	0.724
BMI in Kg/m2 (range)	31.1 (16.2 – 63.5)	30.5 (17.9 – 49.3)	**0.043**
Sex			**<0.001**
Women (%)	875 (56.2%)	214 (45.3%)	
Men (%)	683 (43.8%)	258 (54.7%)	
Surgical indication			**0.005**
Mechanical (%)	568 (36.5%)	189 (40.0%)	
Infection (%)	400 (25.7%)	111 (23.5%)	
Fracture (%)	67 (4.30%)	12 (2.54%)	
Dislocation/Instability (%)	52 (3.34%)	27 (5.72%)	
Loosening (%)	15 (0.96%)	11 (2.33%)	
Other (%)	456 (29.3%)	122 (25.8%)	
Operated joint			0.104
Hip (%)	926 (59.4%)	260 (55.1%)	
Knee (%)	632 (40.6%)	212 (44.9%)	
Operative time in minutes (range)	143 (28.0 – 498.0)	125 (43.0 – 498.0)	**<0.001**
TXA use			**<0.001**
No (%)	1212 (77.8%)	191 (40.5%)	
Yes (%)	346 (22.2%)	281 (59.5%)	
Tourniquet use			0.339
No (%)	971 (62.3%)	282 (59.7%)	
Yes (%)	587 (37.7%)	190 (40.3%)	

CSD=Closed suction drainage; BMI=Body mass index; Kg/m^2=Kilogram/square meter; TXA=Tranexamic acid.

Table 3. Primary and secondary outcomes.

Outcomes	*Non-CSD cohort (N=1558)*	*CSD cohort (N=472)*	*p-value*
Transfusion			0.159
No (%)	1201 (77.1%)	379 (80.3%)	
Yes (%)	357 (22.9%)	93 (19.7%)	
TBL in mL (range)	1173 (-1140 – 7070)	1170 (1237.8 – 4715.5)	0.983
LOS in days (range)	5.82 (0 – 98.00)	4.30 (0.65 – 49.00)	**<0.001**
Wound Hematoma			0.192
No (%)	1540 (98.8%)	470 (99.6%)	
Yes (%)	18 (1.16%)	2 (0.42%)	
Wound Infection			0.334
No (%)	1436 (92.2%)	442 (93.6%)	
Yes (%)	122 (7.8%)	30 (6.4%)	
Wound Dehiscence			0.548
No (%)	1556 (99.9%)	471 (99.8%)	
Yes (%)	2 (0.1%)	1 (0.2%)	

CSD=Closed suction drainage; TBL=Total blood loss; LOS= Length of hospital stay.

Table 4. Logistic regression looking at blood transfusion as the primary outcome, adjusting for demographic and surgical variables.

Variable	*Estimate*	*OR (95% CI)*	*p-value*
CSD cohort	0.04	1.04 (0.78 – 1.38)	0.780
Age	0.02	1.02 (1.01 – 1.04)	**<0.001**
BMI	-0.004	1.00 (0.98 – 1.01)	0.696
Men	-0.30	0.74 (0.59 – 0.94)	**0.014**
Knee	-0.84	0.43 (0.33 – 0.55)	**<0.001**
Operative time	0.01	1.01 (1.00 – 1.01)	**<0.001**

OR=Odds ratio; CI=Confidence interval; CSD=Closed suction drainage; BMI=Body mass index.

Table 5. Linear regression looking at total blood loss as the primary outcome, adjusting for demographic and surgical variables.

Variable	***Estimate***	***95% CI***	***p-value***
CSD cohort	-105.71	-333.96 – 122.55	0.364
Age	-1.49	-7.15 – 4.18	0.607
BMI	24.45	14.89 – 34.02	**<0.001**
Men	509.37	371.84 – 646.91	**<0.001**
Knee	-355.07	-758.32 – 48.18	0.085
TXA use	77.29	-144.41 – 298.99	0.495
Tourniquet use	49.81	-360.21 – 459.82	0.812

CI=Confidence interval; CSD=Closed suction drainage; BMI=Body mass index; TXA=Tranexamic acid.

Supplementary Material

SM - Table 1. Unadjusted logistic regression analysis with transfusion as the dependent outcome.

Variable	*Estimate*	*OR (95% CI)*	*p-value*
CSD cohort	-0.20	0.83 (0.64 – 1.06)	0.142

OR=Odds ratio; CI=Confidence interval; CSD=Closed suction drainage.

SM - Table 2. Unadjusted linear regression analysis with total blood loss as dependent outcome.

Variable	*Estimate*	*95% CI*	*p-value*
CSD cohort	-2.99	-233.55 – 227.57	0.980

CI=Confidence interval; CSD=Closed suction drainage.

SM - Table 3. Unadjusted analysis with wound hematoma as the dependent outcome.

Variable	*Estimate*	*OR (95% CI)*	*p-value*
CSD cohort	-1.01	0.36 (0.06 – 1.27)	0.176

OR=Odds ratio; CI=Confidence interval; CSD=Closed suction drainage.

SM - Table 4. Unadjusted analysis with wound infection as the dependent outcome.

Variable	*Estimate*	*OR (95% CI)*	*p-value*
CSD cohort	-0.22	0.80 (0.52 – 1.19)	0.287

OR=Odds ratio; CI=Confidence interval; CSD=Closed suction drainage.

SM - Table 5. Regression analysis looking at wound infection as the primary outcome, adjusting for demographic and surgical variables.

Variable	*Estimate*	*OR (95% CI)*	*p-value*
CSD cohort	-0.16	0.85 (0.55 – 1.30)	0.476
Age	0.01	1.01 (0.99 – 1.03)	0.212
BMI	0.03	1.03 (1.001 – 1.05)	**0.038**
Men	0.20	1.22 (0.86 – 1.72)	0.265
Knee	-0.09	0.91 (0.63 – 1.30)	0.607
Operative time	0.00	1.004 (1.001 – 1.01)	**0.008**
Surgical indication			
Mechanical	Reference		
Infection	1.35	3.86 (2.51 – 6.06)	**<0.001**
Fracture	0.45	1.57 (0.52 – 3.88)	0.367
Dislocation/Instability	0.71	2.03 (0.74 – 4.76)	0.131
Loosening	0.58	1.79 (0.28 – 6.57)	0.447
Other	0.34	1.41 (0.85 – 2.34)	0.183

OR=Odds ratio; CI=Confidence interval; CSD=Closed suction drainage; BMI=Body mass index.

SM - Table 6. Unadjusted analysis with wound dehiscence as the dependent outcome.

Variable	*Estimate*	*OR (95% CI)*	*p-value*
CSD cohort	0.50	1.65 (0.08 – 17.28)	0.682

OR=Odds ratio; CI=Confidence interval; CSD=Closed suction drainage.

SM - Table 7. Unadjusted analysis with operative time as the dependent outcome.

Variable	*Estimate*	*95% CI*	*p-value*
CSD cohort	-18.13	-23.73 – -12.52	**<0.001**

CI=Confidence interval; CSD=Closed suction drainage.

SM - Table 8. Regression analysis looking at operative time as the primary outcome, adjusting for demographic and surgical variables.

Variable	*Estimate*	*95% CI*	*p-value*
CSD cohort	-20.71	-26.74 – -14.67	**<0.001**
Age	-0.04	-0.26 – 0.18	0.729
BMI	0.56	0.18 – 0.95	**0.004**
Men	3.75	-1.06 – 8.56	0.127
Knee	-4.59	-18.13 – 8.95	0.506
TXA use	7.17	1.67– 12.66	**0.011**
Tourniquet use	-10.77	-24.43 – 2.90	0.123
Surgical indication			
Mechanical	Reference		
Infection	0.45	-5.66 – 6.56	0.885
Fracture	0.67	-11.97 – 13.29	0.918
Dislocation/Instability	-8.13	-20.79 – 4.52	0.208
Loosening	29.29	8.15 – 50.43	**0.007**
Other	-2.02	-7.90 – 3.86	0.501

CI=Confidence interval; CSD=Closed suction drainage; BMI=Body mass index; TXA=Tranexamic acid.

SM - Table 9. Unadjusted analysis with the length of hospital stay as the dependent outcome.

Variable	*Estimate*	*95% CI*	*p-value*
CSD cohort	-1.51	-2.08 – -0.94	**<0.001**

CI=Confidence interval; CSD=Closed suction drainage.

SM - Table 10. Regression analysis looking at the length of hospital stay as the primary outcome, adjusting for demographic and surgical variables.

Variable	*Estimate*	*95% CI*	*p-value*
CSD cohort	-0.63	-1.20 - -0.05	**0.033**
Age	0.04	0.02 - 0.06	**<0.001**
BMI	0.04	0.01 - 0.08	**0.022**
Men	-0.46	-0.92 - -0.01	**0.048**
Knee	-1.03	-2.32 - 0.26	0.118
TXA use	-1.67	-2.20 - -1.15	**<0.001**
Tourniquet use	-0.27	-1.57 - 1.04	0.689
Surgical indication			
Mechanical	Reference		
Infection	4.19	3.61 – 4.78	**<0.001**
Fracture	4.59	3.40 – 5.79	**<0.001**
Dislocation/Instability	3.17	1.97 – 4.38	**<0.001**
Loosening	1.69	-0.31 – 3.69	0.097
Other	1.67	1.11 – 2.23	**<0.001**

CI=Confidence interval; CSD=Closed suction drainage; BMI=Body mass index; TXA=Tranexamic acid.