

# Blood loss and transfusion rate in short stem hip arthroplasty. A comparative study

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## Abstract

**Purpose** Little scientific evidence on blood loss and transfusion rates after short-stem hip arthroplasty exists. The hypothesis of this study was that the blood loss and transfusion rate is lower in short stems compared to straight stems.

**Methods** We compared 124 patients who underwent total hip arthroplasty (THA) using a short-stem design (group 1) and 141 patients using a straight-stem design (group 2). All patients were operated on by the same surgeon, and both groups were similar in age, gender, affected side, body mass index, and ASA score.

**Results** The calculated blood loss was 1139 ml in group 1 and 1358 ml in group 2 ( $p < 0.001$ ). The transfusion rate was 8% in group 1 and 15.6% in group 2 ( $p < 0.001$ ). There was no significant difference between groups 1 and 2 regarding complications and operation time ( $p > 0.05$ ).

**Conclusion** Compared to patients after straight stem THA, both blood loss and blood transfusion rates were lower in patients after short stem THA.

**Keywords** Blood loss · Hip arthroplasty · Short stem · Straight stem · Transfusion rate

## Introduction

Undoubtedly, total hip arthroplasty (THA) is one of the most successful surgeries of the past century in orthopaedic surgery. THA provides good long-term outcomes and high satisfaction rates in a great number of patients [1, 2]. Over the past few decades, a commonly used femoral component in THA has become the straight tapered titanium alloy stem with a rectangular cross-section. Despite good results, there are also some disadvantages, such as bone remodeling due to stress shielding and non-ideal load transformation [3, 4]. Additionally, straight designs often do not allow true minimally invasive implantation, causing some degree of muscle and soft tissue damage.

In the past few years, the use of femoral short-stems has been on the rise. Short-stem designs are assumed to have several advantages over straight stems. Due to the short length of the stem and a reduced lateral shoulder, more native bone is preserved, which is very important, especially in younger patients [4, 5]. Shorter stems facilitate implantation and can be gently implanted, without harming most soft tissue. The estimated lower tissue trauma also may reduce blood loss and transfusion rates.

The estimated blood loss after THA is reported to be up to 1800 ml [6–8], with transfusion rates up to 69% [9, 10]. Post-operative anemia can lead to hypertension, tachycardia, chest pain, fatigue, and even severe complications such as

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myocardial infarction [11, 12]. Blood transfusions after THA are common, but not without risks for the patient [13, 14]. Therefore, efforts should be made to reduce blood loss in THA, and keep the transfusion rate as low as possible, to avoid potentially serious complications for the patient and to help minimize healthcare system costs.

We therefore set out a study to compare blood loss and transfusion rates in THA using straight-stem and short-stem designs. We hypothesized that blood loss and transfusion rates are lower in patients after short-stem hip arthroplasty.

## Materials and methods

Institutional review board approval was obtained for this study. In this retrospective comparative study, we reviewed 124 patients who underwent THA using a short-stem design (group 1) and 141 patients using a straight-stem design (group 2). In all group 1 patients, a cement-less, short-stem (Optimys, Mathys, Bettlach, Switzerland) was implanted, and in all group 2 patients, a cement-less, straight-stem (Alloclassic Zweymüller, Zimmer GmbH, Winterthur, Switzerland) was used. For the acetabulum component, a cement-less press-fit cup (RM Pressfit Vitamys, Mathys, Bettlach, Switzerland) was used for patients in group 1, and a self-tapping screw cup (Alloclassic Variall shell, Zimmer GmbH, Winterthur, Switzerland) was used for patients in group 2.

For all patients in group 1, an anterolateral approach and for all patients in group 2 an lateral approach was used.

Patients in groups 1 and 2 were similar according to age, gender, affected side, body mass index, and ASA score. Patient data details for both groups are shown in Table 1.

All patients in groups 1 and 2 were operated on during the time period from 06/2013 to 06/2015 and from 01/2010 to 12/2011, respectively. Time periods for recruiting patients in groups 1 and 2 were chosen randomly.

All data for this study were obtained from a prospective gathered database.

Pre-operative planning for all hips was carried out based on analogue or digital X-ray templates. All surgeries were performed by one, highly experienced surgeon.

All patients had primary osteoarthritis and no previous surgeries of the affected hip.

Patients with coagulation disorder, liver or kidney disease or malignant tumors, previous surgeries of the affected hip and any other indications for THA, except primary arthritis, were excluded from this study.

No strategies to reduce blood loss, such as cell savers, or pharmacological agents were used. In all patients, in both groups, 1 intra articular suction drain was administered and removed on the first post-operative day. During surgery, monopolar cautery was used for haemostasis in all patients.

**Table 1** Demographic data of patients in both groups. f=female, m=male, r=right, l=left, BMI=Body-mass-index, ASA=American Society of Anesthesiologists Classification

	Short-stem	Straight-stem	<i>p</i> value
Gender (f/m)	81/43	92/49	0.98
Age	69.1	68.2	0.58
Side (l/r)	54/70	66/75	0.57
BMI	27.3	27.2	0.90
ASA I/II/III	21/86/17	33/94/14	0.32

Blood transfusions were administered in patients with haemoglobin levels less than 7 g/dL and haemodynamic symptoms such as hypotension, shortness of breath or fatigue that did not respond to fluid administration.

Low-molecular weight heparin (LMWH, 40 mg once daily) or Rivaroxaban (10 mg orally once daily) was used to prevent deep vein thrombosis. Pre-operatively, haemoglobin and haematocrit levels were obtained within one week before surgery for all patients. Post-operatively, haemoglobin and haematocrit values were obtained on the first post-operative day (day 1) and on the third post-operative day (day 3).

The blood volume was calculated using Moore's formula. Blood loss was calculated using haematocrit levels with the formula of Bourke [15]. Total blood transfusions were recorded for each patient.

## Statistical methods

Data consistency was checked and data were screened for outliers and normality by using quantile plots.

Crosstabulation tables with Fisher's Exact test or Pearson's test were used to analyze the crosstabulations.

A repeated ANOVA and paired and two-sided Student t-tests as post-hoc tests were used to compare Hb and HcT values among the different groups. A generalized model based on the Poisson distribution was used to compare the number of transfusions. All reported tests were two-sided, and *p*-values <0.05 were considered significant. All statistical analyses in this report were performed by use of STATISTICA 13 (Hill, T. & Lewicki, P. Statistics: Methods and Applications. StatSoft, Tulsa, OK).

## Results

The mean pre-operative haemoglobin levels did not significantly differ between groups 1 and 2 (14.1, 13.8, *p* = 0.11). The mean pre-operative haematocrit also did not differ significantly between group 1 and group 2 (42.1, 41.1 *p* = 0.16). In both groups, age, gender, side of extremity, body mass index, and ASA scores were similar and did not significantly differ (Table 1).

In group 1 and group 2, 19.4% (24/124) and 27.7% (39/141) of patients received Rivaroxaban, and 80.6% (100/124) and 72.3% (102/141) of patients received low molecular weight heparin (LMWH), as thrombosis prevention, respectively. The type of deep vein thrombosis prophylaxis did not significantly differ between the groups ( $p = 0.11$ ).

The post-operative haemoglobin and haematocrit on the first post-operative day (day 1) did not significantly differ between the groups. On the third post-operative day (day 3), the haematocrit and haemoglobin levels in group 2 were significantly lower ( $p < 0.001$ ) (Tables 2, 3 and Figs. 1, 2).

The calculated blood loss was 1139 ml in group 1 and 1358 ml in group 2 ( $p < 0.001$ ). The calculated blood loss for patients in group 1 treated with LMWH and Rivaroxaban did not differ significantly (1130 ml vs 1180 ml,  $p = 0.6325$ ). The calculated blood loss for patients in group 2 treated with LMWH and Rivaroxaban did not differ significantly (1371 ml vs 1325 ml,  $p = 0.6246$ ). Patients treated with LMWH in group 1 show significantly lower blood loss than patients in group 2 (1130 ml vs 1371 ml,  $p = 0.0002$ ). Blood loss in patients treated with Rivaroxaban in both groups did not differ significantly (1180 ml vs 1326 ml,  $p = 0.2982$ ). The calculated blood loss for patients in group 1 treated with LMWH is significantly lower than for patients in group 2 treated with Rivaroxaban (1130 ml vs 1325 ml,  $p = 0.0193$ ). The calculated blood loss for patients treated with Rivaroxaban in group 1 was significantly lower than patients treated with LMWH in group 2 (1180 ml vs 1371 ml,  $p = 0.2981$ ). Figure 3 show blood loss for both groups according to thrombosis prophylaxis.

The transfusion rate was 8% (10 patients) in group 1, and 15.6% (22 patients) in group 2 ( $p < 0.001$ ). In group 2, the mean number of transfused packs per patient of red cell transfusions was 2.2 (48/22), and in group 1, was 1.3 (13/10,  $p < 0.05$ ).

Compared to group 2, the mean transferred pack of red cell transfusions was significantly lower in group 1 (0.1, 0.34,  $p < 0.001$ ). Table 4 shows calculated blood loss and transfusions in detail.

There was no significant difference between groups 1 and 2, regarding complications ( $p = 0.532$ ). Mean operation time was 63 minutes (range, 45–91) in group 1 and 68 min (range, 49–102) in group 2 ( $p = 0.321$ ).

## Discussion

This study investigated the calculated blood loss and transfusion rate after THA, using a short-stem design compared to a straight-stem design. We found blood loss and transfusion rates significantly lower in the short-stem group.

THA is reported to lead to substantial blood loss, which often leads to blood transfusion [16, 17]. Due to the

**Table 2** Pre-operative and post-operative hematocrit (Hct) value. Values are given as mean SD  $\pm$

Hct (%)	Short-stem	Straight-stem	p
Pre-operative	41.9 $\pm$ 3.6	41.1 $\pm$ 3.6	0.17
Day 1	32.7 $\pm$ 4.1	32.8 $\pm$ 4.1	0.9
Day 3	36.3 $\pm$ 5.4	31.9 $\pm$ 5.4	<0.001

demographic changes that will occur over the next century, an increase in the total number of THAs can be expected; therefore, the total number of blood transfusions will also increase. National trends in blood transfusions in the US from 2000 to 2009 showed that the allogeneic blood transfusion rate increased, the homologous blood transfusion rate decreased, and the overall transfusion rate remained stable [18].

Although blood transfusions in orthopaedic surgery are a well-established method to treat peri- and post-operative anaemia, transfusions are not without risks for the patient, and they also include increased hospital costs and long-term morbidity and mortality [19]. Transfusion-related complications comprise systemic infection (HIV, hepatitis), and increased local and general infections, due to transfusion-triggered immunomodulation [20, 21]. Therefore, minimizing blood loss, which subsequently lowers the transfusion rate, is of fundamental importance to improve patient outcomes and to lower complication rates and costs for the health system.

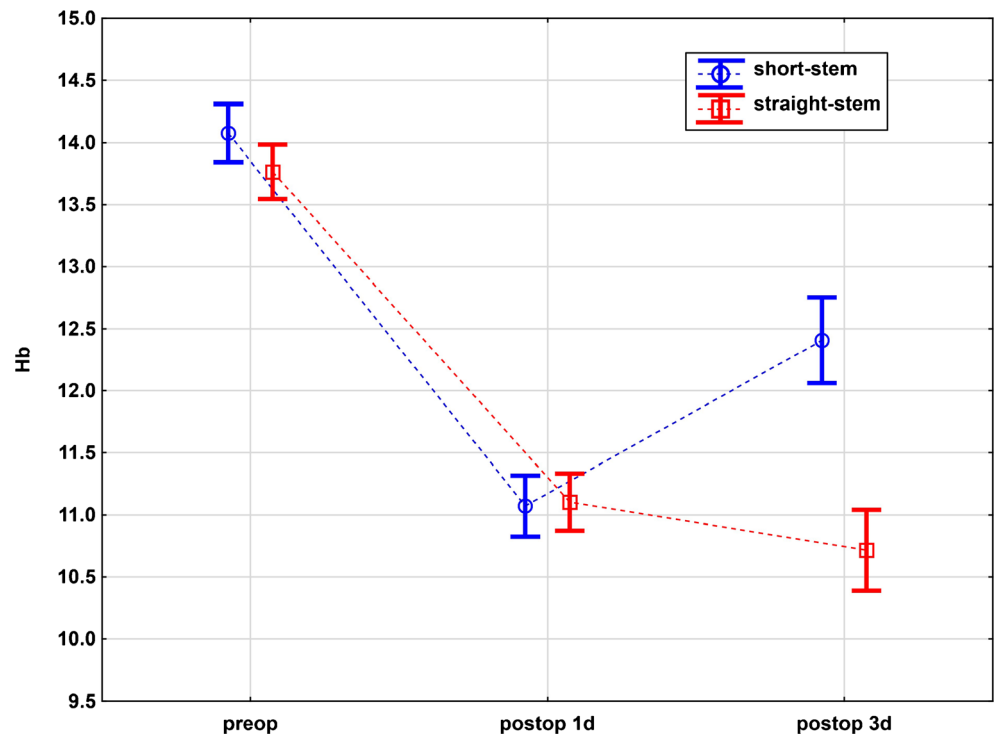
The transfusion rate in this study was 15.6% in group 2 (straight-stem) and 8% in group 1 (short-stem), which are both lower than in most previously published studies [9, 10, 22, 23]. There is a wide variation of reported transfusion rates after THA in the literature, ranging from 10 to 69% [9, 10, 22, 23]. In a prospective observational study of 114 THA, the allogeneic transfusion rate was 18% [22]. In a study by Wong et al. [24] the authors investigated 787 THA and found an allogeneic transfusion rate of 23%. However, 36 surgeons performed the surgeries, and no information about the implant and surgical technique are mentioned, which makes comparison to our results difficult.

In this study, the calculated blood loss was 1139 ml for group 1 and 1358 ml for group 2. Blood loss after THA is reported to be between approximately 600 and 1800 ml [6–8]. Post-operative haematocrit is reported to be lowest on the second or third post-operative day [25, 26]. However, in group 1,

**Table 3** Pre-operative and post-operative hemoglobin (Hb) value. Values are given as mean SD  $\pm$

Hb (mg/dL)	Short-stem	Straight-stem	p
Pre-operative	14.1 $\pm$ 1.3	13.8 $\pm$ 1.3	0.11
Day 1	11.1 $\pm$ 1.4	11.1 $\pm$ 1.4	0.87
Day 3	12.4 $\pm$ 1.9	10.7 $\pm$ 0.2	<0.001

**Fig. 1** The haemoglobin levels

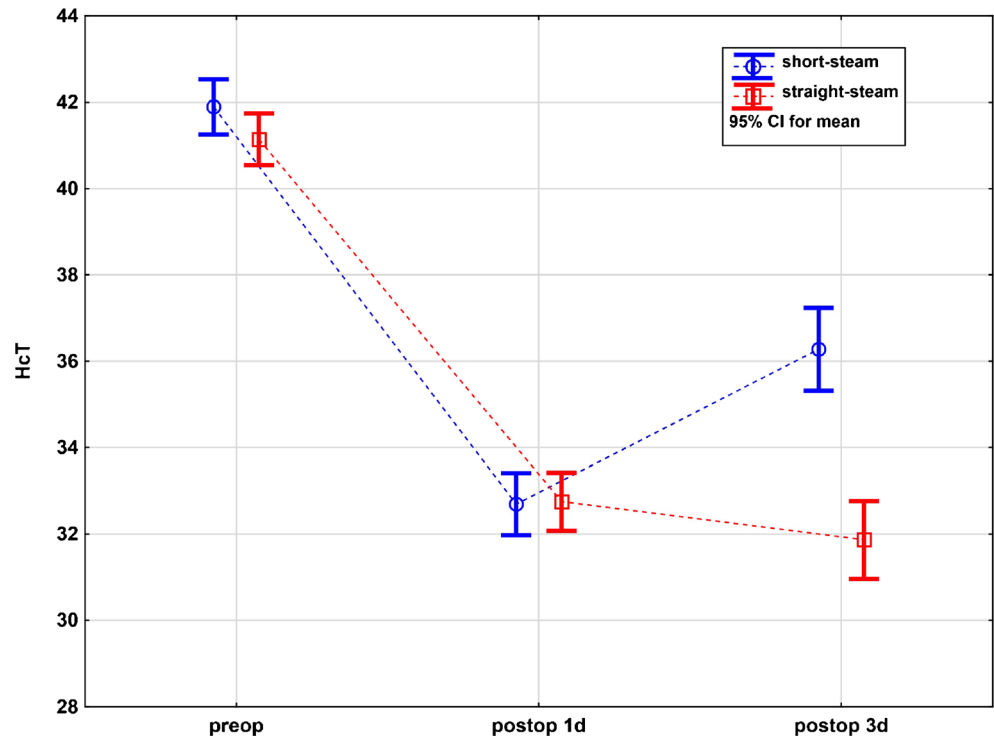


haemoglobin and haematocrit were higher on post-operative day three, than on day one. Additionally, between the groups, haemoglobin and haematocrit values were not significantly different on post-operative day one, but were significantly lower in group 2 on post-operative day 3.

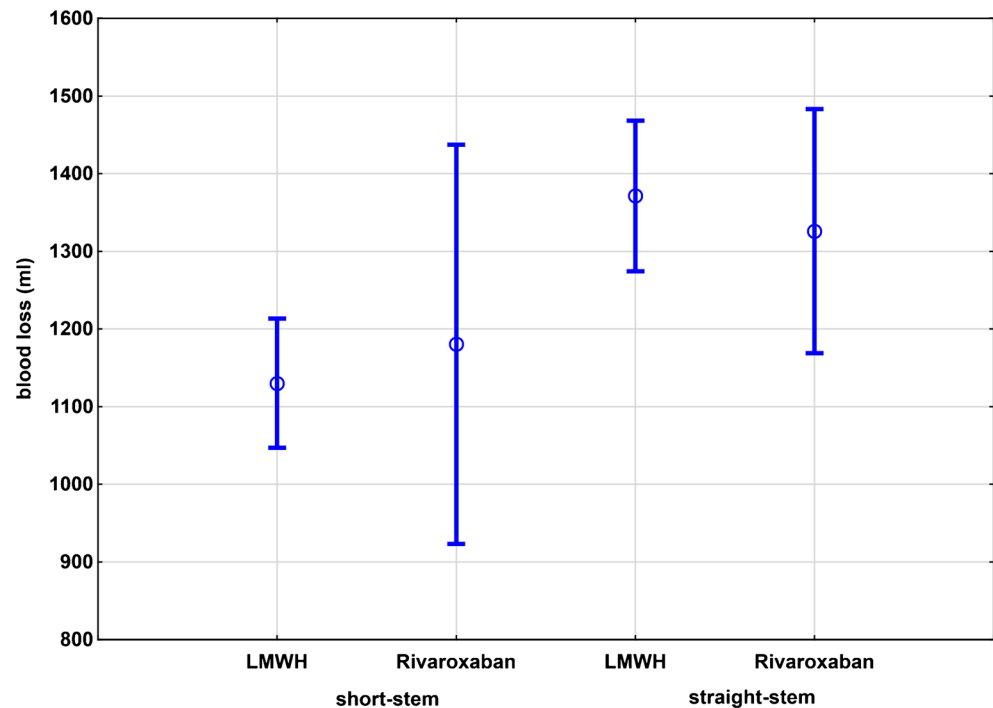
For us, this can be explained by a probably, incorrect-low measured haematocrit and haemoglobin value on post-operative day one for patients of group 1, due to the dilution effect, caused by intra-operative fluid administration.

**Fig. 2** The haematocrit levels.

Hct=hematocrit,  
preop=preoperative,  
postop=postoperative, d=day



**Fig. 3** Blood loss according to thrombosis prophylaxis. LMWH=Low molecular weight heparin



Data for blood loss after joint replacement in the literature are hardly comparable to each other due to the heterogeneity of patients and the many different equations used to calculate blood loss [27].

Amount of blood loss after joint replacement is determined by multiple factors, such as body mass index, indication for surgery, surgical approach, comorbidities, and anticoagulant agents. Reported risk factors for blood transfusion are female gender and lower pre-operative haemoglobin level [9, 24].

Several studies proved that blood loss and transfusion rates can be reduced by antifibrinolytic agents and hospitals' own pre-operative programs [28, 29].

The use of tranexamic acid (TXA), or aminocaproic acid have been shown to minimize blood loss in orthopaedic surgery. The most widely used is TXA, of which, systemic administration has been proven in many peer-reviewed studies to lower peri-operative and post-operative blood transfusion [30, 31]. In our institution, TXA has been routinely used since June 2015. Therefore, for this study, none of the patients received TXA in either of the groups.

Patients in both groups routinely received one intra-articular closed-suction drain. However, there is some evidence that closed-suction drains in THA increase blood transfusion [32]. Johansson et al. [33] found in a prospective, randomized controlled trial that wound compressions reduce wound discharge, and transfusion rates compared to drainage after THA. Therefore, not using drainage would have probably lowered blood loss and transfusion rates in both groups.

In a study by Chang-peng et al. [34], the authors showed that compared to standard incision in THA, there is some

evidence that mini-incision reduces blood loss. However, there is no clear definition of “minimally invasive,” and most would agree that soft tissue trauma is determined, not by length of incision but mainly by trauma to muscle tissue.

Undoubtedly, muscle and soft tissue damage during surgery is one of the major bleeding sources in THA. The curved and short femoral stem allows implantation without damaging almost any gluteal muscle, and without damaging the major trochanter. The stem can be brought in by sliding along the medial calcar of the preserved femoral neck. We think that in addition to muscle tissue, another major source of blood loss in cement-less THA is the bone. In standard straight stems, due to the straight stem design and the distal anchorage of the stem, some degree of major trochanter damage is unavoidable to obtain straight access to the intramedullary canal. Additionally, the femoral canal has to be prepared far more distally, which may also produce further blood loss. Therefore, we feel straight stems may unavoidably cause some more degree of muscle damage and bleeding.

**Table 4** Blood loss and transfusion rates. Values are given as mean SD  $\pm$

	Short-stem	Straight-stem	p
Calculated blood loss (ml)	1139 $\pm$ 459	1358 $\pm$ 490	<0.001
Transfusions (mean number of transfused packs per patient)	0.10 $\pm$ 0.4	0.34 $\pm$ 1.7	<0.001

The limitations of this study are its retrospective design and the small sample size of the groups and the different surgical approaches used for the two groups. Despite the threshold of 7 mg/dl for transfusion, clinical symptoms, such as tachycardia, hypotension, chest pain, fatigue, and the decision to transfuse a patient, may be influenced subjectively, and may bias the transfusion rate of the groups. Furthermore, the results of this study are only applicable for cement-less THA. On the other hand, all patients in both groups were operated on by the same, highly experienced surgeon, and patient groups were very similar, concerning demographic characteristics. In this study, no patient received tranexamic (TXA) acid and no cell savers were used. The routine use of TXA and cell savers may have led to lower overall blood loss in both groups. However, this did not affect comparison of the groups.

In summary, compared to patients after straight-stem THA, blood loss and blood transfusion rates were lower, and post-operative haemoglobin and haematocrit levels were higher, in patients after short-stem THA. Of course, the findings can be applicable only for cement-less THA and for the particular designs used in the study groups. As there is no significant difference in operation time and surgeon, we think that the lower estimated blood loss in the short-stem patients is mainly due to the minimized soft tissue trauma during surgery. The curved design and the short length of the shaft allow a gentler implantation without damaging the major trochanter and the gluteal muscle.

#### Compliance with ethical standards

**Conflict of interest** The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article. The authors declare, that they have no conflict of interest.

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#### References

- Lombardi AV, Berend KR, Mallory TH, Skeels MD, Adams JB (2009) Survivorship of 2000 tapered titanium porous plasma-sprayed femoral components. *Clin Orthop Relat Res* 467(1): 146–154. doi:10.1007/s11999-008-0568-x
- McLaughlin JR, Lee KR (2008) Total hip arthroplasty with an uncemented tapered femoral component. *J Bone Joint Surg Am* 90:1290–1296. doi:10.2106/JBJS.G.00771
- Otani T, Whiteside LA (1992) Failure of cementless fixation of the femoral component in total hip arthroplasty. *Orthop Clin North Am* 23:335–346
- Molli RG, Lombardi AV, Berend KR et al (2012) A short tapered stem reduces intraoperative complications in primary total hip arthroplasty. *Clin Orthop* 470:450–461. doi:10.1007/s11999-011-2068-7
- Santori FS, Santori N (2010) Mid-term results of a custom-made short proximal loading femoral component. *J Bone Joint Surg (Br)* 92:1231–1237. doi:10.1302/0301-620X.92B9.24605
- McSwiney MM, O'Farrell D, Joshi GP, McCarroll SM (1993) Blood transfusion in total hip arthroplasty: guidelines to eliminate overtransfusion. *Can J Anaesth* 40:222–226. doi:10.1007/BF03037034
- Kubota R, Nozawa M, Matsuda K et al (2009) Combined preoperative autologous blood donation and intra-operative cell salvage for hip surgery. *J Orthop Surg (Hong Kong)* 17:288–290
- Smith LK, Williams DH, Langkamer VG (2007) Post-operative blood salvage with autologous retransfusion in primary total hip replacement. *J Bone Joint Surg (Br)* 89:1092–1097. doi:10.1302/0301-620X.89B8.18736
- Rosencher N, Kerckamp HEM, Macheras G et al (2003) Orthopedic Surgery Transfusion Hemoglobin European Overview (OSTHEO) study: blood management in elective knee and hip arthroplasty in Europe. *Transfusion (Paris)* 43:459–469
- Alshryda S, Mason J, Sarda P et al (2013) Topical (intra-articular) tranexamic acid reduces blood loss and transfusion rates following total hip replacement: a randomized controlled trial (TRANX-H). *J Bone Joint Surg Am* 95:1969–1974. doi:10.2106/JBJS.L.00908
- Spence RK (1998) Anemia in the patient undergoing surgery and the transfusion decision. A review. *Clin Orthop* 19–29
- Miller RD, von Ehrenburg W (1995) Controversies in transfusion medicine: indications for autologous and allogeneic transfusion should be the same: con. *Transfusion (Paris)* 35:450–452
- Klein HG (1995) Allogeneic transfusion risks in the surgical patient. *Am J Surg* 170:21S–26S
- Schreiber GB, Busch MP, Kleinman SH, Korelitz JJ (1996) The risk of transfusion-transmitted viral infections. The retrovirus epidemiology donor study. *N Engl J Med* 334:1685–1690. doi:10.1056/NEJM199606273342601
- Bourke DL, Smith TC (1974) Estimating allowable hemodilution. *Anesthesiology* 41:609–612
- Haien Z, Yong J, Baoan M et al (2013) Post-operative auto-transfusion in total hip or knee arthroplasty: a meta-analysis of randomized controlled trials. *PLoS ONE* 8:e55073. doi:10.1371/journal.pone.0055073
- Morton J, Anastassopoulos KP, Patel ST et al (2010) Frequency and outcomes of blood products transfusion across procedures and clinical conditions warranting inpatient care: an analysis of the 2004 healthcare cost and utilization project nationwide inpatient sample database. *Am J Med Qual* 25:289–296. doi:10.1177/1062860610366159
- Yoshihara H, Yoneoka D (2014) National trends in the utilization of blood transfusions in total hip and knee arthroplasty. *J Arthroplasty* 29:1932–1937. doi:10.1016/j.arth.2014.04.029
- Pedersen AB, Mehnert F, Overgaard S, Johnsen SP (2009) Allogeneic blood transfusion and prognosis following total hip replacement: a population-based follow up study. *BMC Musculoskelet Disord* 10:167. doi:10.1186/1471-2474-10-167
- Ponnusamy KE, Kim TJ, Khanuja HS (2014) Perioperative blood transfusions in orthopaedic surgery. *J Bone Joint Surg Am* 96:1836–1844. doi:10.2106/JBJS.N.00128
- Levi N, Sandberg T (1998) Blood transfusion and postoperative wound infection in intracapsular femoral neck fractures. *Bull Hosp Joint Dis (New York)* 57:69–73

22. Carling MS, Jeppsson A, Eriksson BI, Brisby H (2015) Transfusions and blood loss in total hip and knee arthroplasty: a prospective observational study. *J Orthop Surg* 10:48. doi:[10.1186/s13018-015-0188-6](https://doi.org/10.1186/s13018-015-0188-6)
23. Borghi B, Casati A (2000) Incidence and risk factors for allogenic blood transfusion during major joint replacement using an integrated autotransfusion regimen. The Rizzoli Study Group on Orthopaedic Anaesthesia. *Eur J Anaesthesiol* 17:411–417
24. Wong S, Tang H, de Steiger R (2015) Blood management in total hip replacement: an analysis of factors associated with allogenic blood transfusion. *ANZ J Surg* 85:461–465. doi:[10.1111/ans.13048](https://doi.org/10.1111/ans.13048)
25. Sehat KR, Evans RL, Newman JH (2004) Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. *J Bone Joint Surg (Br)* 86:561–565
26. Sehat KR, Evans R, Newman JH (2000) How much blood is really lost in total knee arthroplasty? Correct blood loss management should take hidden loss into account. *Knee* 7:151–155
27. Gibon E, Courpied J-P, Hamadouche M (2013) Total joint replacement and blood loss: what is the best equation? *Int Orthop* 37:735–739. doi:[10.1007/s00264-013-1801-0](https://doi.org/10.1007/s00264-013-1801-0)
28. Wong CJ, Vandervoort MK, Vandervoort SL et al (2007) A cluster-randomized controlled trial of a blood conservation algorithm in patients undergoing total hip joint arthroplasty. *Transfusion (Paris)* 47:832–841. doi:[10.1111/j.1537-2995.2007.01197.x](https://doi.org/10.1111/j.1537-2995.2007.01197.x)
29. Alshryda S, Sukeik M, Sarda P et al (2014) A systematic review and meta-analysis of the topical administration of tranexamic acid in total hip and knee replacement. *Bone Joint J* 96-B:1005–1015. doi:[10.1302/0301-620X.96B8.33745](https://doi.org/10.1302/0301-620X.96B8.33745)
30. Rajesparan K, Biant LC, Ahmad M, Field RE (2009) The effect of an intravenous bolus of tranexamic acid on blood loss in total hip replacement. *J Bone Joint Surg (Br)* 91:776–783. doi:[10.1302/0301-620X.91B6.22393](https://doi.org/10.1302/0301-620X.91B6.22393)
31. Benoni G, Fredin H, Knebel R, Nilsson P (2001) Blood conservation with tranexamic acid in total hip arthroplasty: a randomized, double-blind study in 40 primary operations. *Acta Orthop Scand* 72:442–448. doi:[10.1080/000164701753532754](https://doi.org/10.1080/000164701753532754)
32. Zhou X, Li J, Xiong Y et al (2013) Do we really need closed-suction drainage in total hip arthroplasty? A meta-analysis. *Int Orthop* 37: 2109–2118. doi:[10.1007/s00264-013-2053-8](https://doi.org/10.1007/s00264-013-2053-8)
33. Johansson T, Engquist M, Pettersson L-G, Lisander B (2005) Blood loss after total hip replacement: a prospective randomized study between wound compression and drainage. *J Arthroplasty* 20: 967–971. doi:[10.1016/j.arth.2005.02.004](https://doi.org/10.1016/j.arth.2005.02.004)
34. Xu C-P, Li X, Song J-Q et al (2013) Mini-incision versus standard incision total hip arthroplasty regarding surgical outcomes: a systematic review and meta-analysis of randomized controlled trials. *PLoS ONE* 8:e80021. doi:[10.1371/journal.pone.0080021](https://doi.org/10.1371/journal.pone.0080021)