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Comparison of Direct Lateral (Hardinge) and Direct Superior Approaches in Total Hip Arthroplasty – Effects on Perioperative Blood Loss and Transfusion Risk

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ABSTRACT

Background. Total hip arthroplasty (THA) can be performed through several approaches, including the direct superior (DSA) and direct lateral (Hardinge) approach. Perioperative blood loss and transfusion requirements remain key determinants of postoperative recovery and complications. This retrospective cohort study aimed to quantitatively compare perioperative blood loss and transfusion rates between DSA and Hardinge approaches in primary THA.

Material and methods. 215 consecutive adults who underwent primary unilateral THA (106 DSA, 109 Hardinge) were analysed. Perioperative blood loss (PBL) was estimated using Nadler's formula for blood volume and Gross's method based on perioperative haematocrit values from the preoperative day to postoperative day 2. Demographic variables and perioperative laboratory parameters were collected. Univariable and multivariable logistic regression assessed whether the Hardinge approach was associated with transfusion, adjusting for age, sex, and body mass index (BMI).

Results. Mean PBL was lower with DSA than with Hardinge (1.153 L [SD 0.489] vs 1.323 L [SD 0.506]; P =.013). Overall, 17 patients (7.9%) required transfusion (3.8% DSA vs 11.9% Hardinge; P =.041). In multivariable analysis, the Hardinge approach remained associated with higher odds of transfusion (adjusted odds ratio, 3.63; 95% confidence interval, 1.19–13.7; P =.034), whereas age, sex and BMI were not statistically significant predictors. The model showed modest discrimination (AUC, 0.74) and acceptable calibration.

Conclusions. DSA was associated with lower PBL and a reduced likelihood of red blood cell transfusion in primary THA. These findings support the use of minimally invasive approaches such as DSA to minimise blood loss–related morbidity.

Introduction

Total hip arthroplasty (THA) is among the most commonly performed orthopaedic procedures worldwide, with a wide range of surgical approaches used depending on surgeon preference and experience. As early as 2012, it was reported that the annual number of THA procedures performed worldwide had surpassed one million. [1], with an expected upward trend. In the United States, the annual number of these procedures is projected to rise to 572,000 by 2030 [2,3].

Surgical approaches for THA are conventionally categorised into two main groups: classic and minimally invasive. Among the historically oldest classic approaches, the posterior approach, popularised by Moore in the 1950s, appears to be widely adopted globally, followed by the direct lateral approach, as described by Hardinge in 198 [4–6]. The Hardinge approach involves splitting the fascia lata at the interval between the tensor fasciae latae and gluteus maximus, followed by splitting of the gluteus medius tendon and muscle fibres while preserving a cuff for subsequent repair. The procedure is completed by splitting the fibres of the gluteus minimus and performing a capsulotomy or, as preferred by some surgeons to facilitate hip dislocation, a capsulectomy.

In recent years, minimally invasive approaches (MIA) have gained traction in the orthopaedic community, offering faster postoperative recovery and minimising soft-tissue damage, with the Direct Anterior Approach (DAA) perhaps the most popular. The Direct Superior Approach (DSA) is a minimally invasive approach derived from the posterolateral approach [7] and has been used by an increasing number of surgeons. DSA preserves the iliotibial band, obturator externus, and quadratus femoris muscles. By performing a posterior repair that includes the piriformis, conjoined tendon, and joint capsule, the risk of dislocation is reduced compared with the traditional posterior approach [8]. The Hardinge approach offers advantages such as excellent visualisation of the surgical field and a low incidence of dislocation [9–11]. In contrast, the DSA is associated with reduced blood loss, decreased postoperative pain, and a shorter incision length compared with the posterolateral approach [12].

Despite numerous studies comparing various surgical approaches to the hip joint, no single technique has yet demonstrated a clear superiority that would establish it as the 'gold standard.' The literature frequently emphasises that one of the most critical factors in selecting the optimal approach is the surgeon's preference and experience [13,14]. Therefore, the selection of surgical approaches for training future orthopaedic surgeons should be guided by the differences in outcomes associated with each technique and their clinical implications. One of the most significant complications of hip arthroplasty is perioperative blood loss (PBL), which directly affects the frequency of transfusions and their associated complications, ultimately impacting overall treatment outcomes [15].

This study aims to quantitatively compare PBL in patients undergoing THA via two different surgical approaches – Hardinge and DSA – and to evaluate the impact of the chosen technique on the frequency of perioperative blood transfusions.

Materials and methods

Data were retrospectively collected from 223 patients consecutively treated at a single high-volume clinical centre (Wiktor Dega Clinical Hospital, Poznan) between 2024 and 2025, with 110 patients undergoing surgery via the DSA and 113 via the Hardinge approach. Inclusion criteria were adult patients (≥18 years), diagnosed with primary osteoarthritis or avascular necrosis of the femoral head, undergoing primary unilateral THA with either the DSA or the Hardinge approach in an elective setting, treated at our institution during the study period, with standard intra-articular administration of tranexamic acid in accordance with the hospital's standard protocol, approved by the local bioethics committee and complete perioperative laboratory data (preoperative and early postoperative hemoglobin (Hgb), hematocrit (Hct) and red blood cell (RBC) counts) available for the calculation of perioperative blood loss and assessment of red blood cell transfusions. In all patients included in the study, anaesthesia was provided using a peripheral nerve block supplemented with intravenous propofol sedation, and

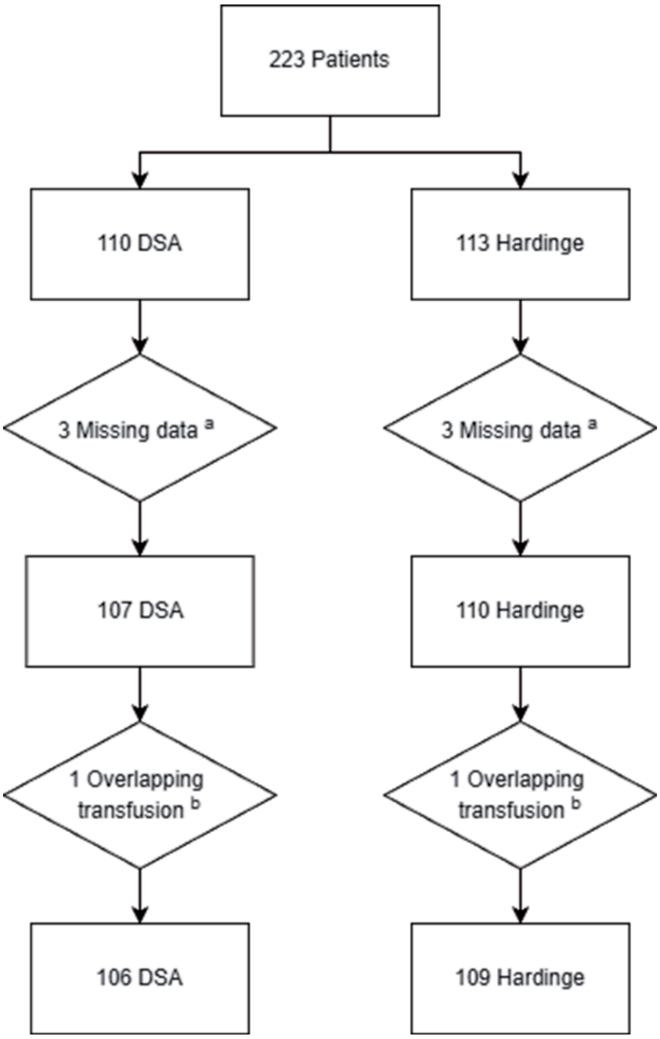

Figure 1. Flowchart of exclusion criteria. a-missing or incomplete data, including absent or uncertain records of perioperative blood transfusions, missing results from blood counts, or laboratory tests performed outside the required time intervals, which could compromise reliable calculations and comparisons; b – blood transfusions during the period overlapping with laboratory assessments (immediately postoperatively or on the first postoperative day).

the anaesthesia team maintained hemodynamic stability and normothermia throughout the procedure, actively preventing intraoperative hypotension and hypothermia. All wounds were routinely closed with resorbable sutures, and the skin was closed with staplers. No drains were used in all patients. Patients with hematologic conditions affecting blood coagulation, such as von Willebrand disease or Haemophilia, were excluded from the study. In addition, no patients undergoing THA for proximal femoral fractures or tumours were included.

10 experienced consultants performed the procedures: 5 used the DSA, and 5 used the Hardinge approach (each surgeon had performed at least 100 procedures using the respective surgical approach before the study period). The choice of surgical approach was based on the surgeon's preference and experience. Collected data included demographic variables (age, sex, height, weight). They routinely obtained perioperative peripheral blood parameters – Hct, RBC, and hgb concentration – measured on the day before surgery, the day after surgery, and two days postoperatively. Perioperative blood transfusion information was also recorded. Patients who required transfusions during the period corresponding to the laboratory assessments, as well as those with incomplete data, were excluded, as shown in **Figure 1**. Excluding patients who required transfusion immediately postoperatively or on the first postoperative day prevented the influence of transfused red blood cell mass on hematocrit values, thereby avoiding underestimation of calculated PBL.

All patients received thromboprophylaxis in accordance with the standard hospital protocol (adopted from national guidelines), consisting of low-molecular-weight heparin administered at a dose of 40 mg (4000 IU) on the day before surgery (approx. 12 hours before the surgery), 12 hours postoperatively, and once daily in the evening for the subsequent 30 days, starting on the first postoperative day. Patients on chronic anticoagulation with Vitamin K Antagonist (VKAs) or (New Oral Anticoagulant) NOACs were instructed to switch to low-molecular-weight heparin approximately 4–5 days (VKAs) or 72h (NOACs) before surgery, with dosing and frequency individually adjusted. Nevertheless, this subgroup also received anticoagulation according to the same protocol as patients not taking long-term anticoagulants during the period from the preoperative day to 2 days after surgery, corresponding to the timeframe during which the laboratory tests used in the present study were performed. The exception to this rule was administration of prophylactic doses of aspirin (up to 150 mg daily) for coronary risk. These patients were allowed to take the drug up to 48h before surgery. The final study cohort comprised 106 patients in the DSA group and 109 patients in the Hardinge group.

Gross's method was chosen to calculate Perioperative Blood Loss (PBL) [16]:

$$PBL\ [L] = BV \times \frac{\mathrm{Hct}(0) - \mathrm{Hct}(\mathrm{f})}{\mathrm{Hct}(\mathrm{av})}$$

where Hct (0) = preoperative hematocrit; Hct(f) = minimum available hematocrit; Hct (av) = mean of Hct (0) and Hct(f)

Application of this formula necessitated a prior estimation of the patient's total blood volume (BV), which was calculated using the Nadler formula [17] (height – H [m], weight – W [kg]):

- for men:

$$BV\ [L] = (0.3669\ x\ H^3) + (0.03219\ x\ W) + 0{,}6041$$

- for women:

$$BV\ [L] = (0.3561\ x\ H^3) + (0.03308\ x\ W) + 0.1833$$

Calculations were performed for all 215 patients enrolled in the study. To standardise the data and facilitate subsequent comparisons, all results were converted to a common unit (L) and rounded to three decimal places.

The statistical analyses were conducted using PQStat Software 2023 (v1.8.6; Poznan, Poland), with a significance threshold of α = 0.05. The Shapiro-Wilk test was employed to assess the normality of PBL data. Consequently, comparisons between the two groups were performed using the Mann-Whitney U test. Descriptive analyses of demographic variables were also conducted: normality was assessed using the Shapiro-Wilk test, followed by the chi-square test for sex, the Mann-Whitney U test for age and body mass index (BMI), and the Student's t-test for weight and height. Given the normal distribution of peripheral blood count parameters, group comparisons for these variables were performed using the Student's t-test.

Subsequently, the data were stratified into two groups based on the requirement for perioperative transfusion: patients who required transfusion ('transfusion group') and those who did not ('non-transfusion group'). Transfusion criteria included patients with laboratory-confirmed haemoglobin concentrations below 9 g/dL accompanied by clinical signs of anaemia (shortness of breath, dizziness, or increased heart rate), or below 8 g/dL regardless of clinical presentation. Fisher's test was used to evaluate the effect of surgical approach on the need for red blood cell transfusion, given the small size of one of the groups. Additional analyses of demographic and perioperative variables were conducted within the transfusion and non-transfusion groups: Fisher's test was applied for sex, the Mann-Whitney U test for non-normally distributed variables (age, height), and the Student's t-test for normally distributed variables (weight, perioperative blood loss, and blood volume).

First, a univariable logistic regression model was fitted to explore whether the Hardinge approach was a risk factor for red blood cell transfusion. Subsequently, a multivariable logistic regression model including age, sex and BMI were fitted to evaluate whether the Hardinge approach remained an independent risk factor after adjustment for these potential demographic confounders, and to determine whether age, sex and BMI themselves had a statistically significant impact on transfusion risk. Model performance was assessed by quantifying discrimination with the area under the receiver operating characteristic curve (AUC) and its 95% confidence interval and evaluating calibration with the Hosmer-Lemeshow goodness-of-fit test.

This study was reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. The completed STROBE checklist is provided as Supplementary Material.

Results

A summary of the baseline characteristics of patients included in the study is presented in **Table 1**. There were no statistically significant differences in demographic variables such as sex, weight, height or BMI. However, patients in the Hardinge cohort were, on average, 3 years older than those in the DSA cohort, and this difference was statistically significant.

There were no statistically significant differences in preoperative Hct, Hgb or RBC, nor in 2-day postoperative Hct and RBC. However, the 2-day postoperative Hgb was significantly lower in patients who underwent the Hardinge approach. It is also noteworthy that statistically significant differences were observed between the groups for all three parameters on the first postoperative day (**Figure 2**).

The Shapiro-Wilk test revealed a normal distribution in the DSA group ($p = 0.1989$) and a non-normal distribution in the Hardinge group ($p = 0.0009$). The mean calculated PBL in the group of patients operated with the DSA approach was 1.153 L (SD: 0.489 L; min. 0.131 L, max. 2.362 L),

Table 1. Summary of patients' basic demographic data. For clarity of presentation, given the nonparametric distribution of some of the data, the results (excluding sex) are presented as medians with corresponding minimum–maximum ranges: Median (minimum-maximum). BMI – Body Mass Index.

	All (n = 215)	DSA Group (n = 106)	Hardinge Group (n = 109)	p-value
Sex (n%)	Male – 99 (46%) Female – 116 (54%)	Male – 50 (47%) Female – 56 (53%)	Male – 49 (45%) Female – 60 (55%)	p = 0.8501
Age (years)	67 (31–93)	65 (31–93)	68 (32–91)	p = 0.0465
Weight (kg)	82 (44–143)	82,5 (49–131)	81 (44–143)	p = 0.0859
Height (m)	1.68 (1.45–2.02)	1.68 (1.45–1.92)	1.68 (1.46–2.02)	p = 0.4228
BMI	28.84 (16.36–44.95)	28.68 (19.49–44.95)	29.05 (16.36–42.92)	p = 0.7924

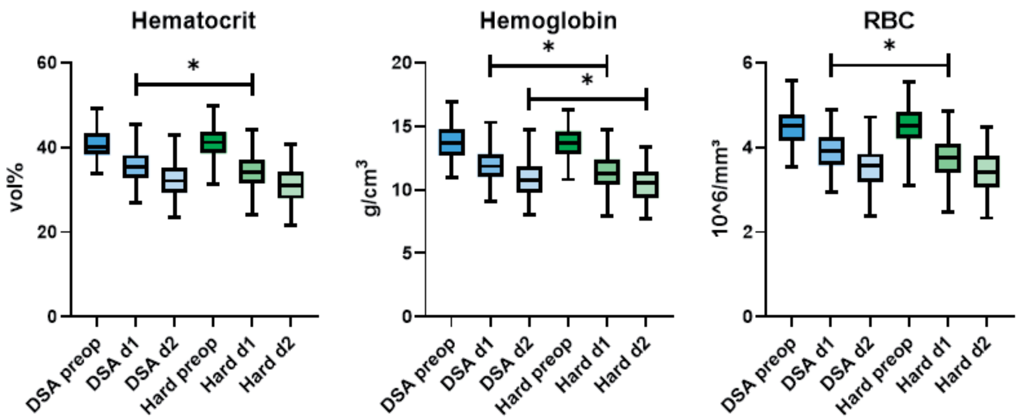

Figure 2. Boxplot summarization of the peripheral blood count results. * - statistically significant difference (as follows: Hct d1 p = 0,0147; Hgb d1 p = 0,0009; Hgb d2 p = 0,0152; Rbc d1 p = 0,0140). "DSA" – DSA group; "Hard" – Hardinge group; "preop" – preoperative day, " d1" – 1-day postoperative, "d2" – 2-day postoperative. RBC – Red Blood Cells count.

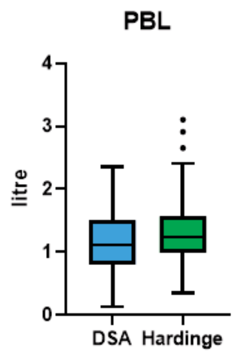

Figure 3. Boxplot comparison of DSA group and Hardinge group PBL values.

Table 2. Single variable analysis for transfusion and non-transfusion groups. For clarity of presentation, given the nonparametric distribution of some of the data, the results (excluding approach and sex) are presented as medians with corresponding minimum–maximum ranges: Median (minimum-maximum). PBL – Perioperative Blood Loss, BV – Blood Volume, DSA – Direct Superior Approach.

	All (n = 215)	Transfusion Group (n = 17)	Non-transfusion Group (n = 198)	p-value
Approach	DSA – 106 (49%) Hardinge – 109 (51%)	DSA – 4 (24%) Hardinge – 13 (76%)	DSA – 102 (52%) Hardinge – 96 (48%)	p = 0.0408
Age (years)	67 (31–93)	68 (32–86)	67 (31–93)	p = 0.8933
Sex	Male – 99 (46%) Female – 116 (54%)	Male – 4 (24%) Female – 13 (76%)	Male – 95 (48%) Female – 103 (52%)	p = 0.0744
Weight (kg)	82 (44–143)	67 (52–111)	82 (44–143)	p = 0.1322
Height (m)	1.68 (1.45–2.02)	1.64 (1.51–2.02)	1.68 (1.45–1.92)	p = 0.1783
PBL (L)	1.202 (0.131–3.106)	1.743 (0.818–3.106)	1.183 (0.131–2.655)	p = 0.0014
BV (L)	4.807 (3.129–7.568)	3.963 (3.129–7.201)	4.845 (3.188–7.568)	p = 0.1514

Table 3. Univariate and multivariate logistic regression results. OR, odds ratio; CI Confidence Interval, BMI – Body Mass Index. The model showed modest discrimination, with an AUC of 0.74 (95% CI 0.60–0.88), and acceptable calibration on the Hosmer–Lemeshow test (χ^2 = 8.65, df = 8; p = 0.37).

Variable	OR	95% CI	p
Unviariate analysis			
Hardinge approach	3.45	1.18–12.6	0.0354
Multivariate analysis			
Hardinge approach	3.63*	1.19–13.7	0.034
Age	0.984*	0.94–1.03	0.465
Sex (Females)	3.11*	0.99–11.9	0.0674
BMI	0.928*	0.83–1.02	0.148

* Adjusted OR's

while in the group of patients operated with the Hardinge approach, the mean was 1.323 L (SD 0.506; min. 0.355, max. 3.106). A statistically significant difference between these two groups was found (Mann-Whitney, p = 0.0134) (**Figure 3**).

Of the 215 patients in the study, 17 required perioperative blood transfusions (4 from the DSA approach and 13 from the Hardinge group). Most of these patients required administration of 1–2 units of red blood cell concentrate on the second postoperative day. Fisher's analysis showed that, in the Hardinge group, treatment with blood components was significantly more frequent than in the DSA Group (p = 0.0408). **Table 2** presents the results of the analysis of additional variables in the cohort of patients in the transfusion and non-transfusion groups.

In the multivariable logistic regression model including age, sex, BMI and surgical approach, the Hardinge approach remained associated with higher odds of red blood cell transfusion compared with the DSA approach (adjusted OR 3.63, 95% CI 1.19–13.69; p = 0.034) (**Table 3**). Age and BMI were not significantly associated with transfusion, while female sex showed only a non-significant trend towards higher odds.

Discussion

This study examined differences in perioperative blood loss volumes among patients undergoing THA via the DSA and Hardinge approaches. The use of less-invasive DSA was associated with significantly lower perioperative blood loss in patients undergoing THA compared with those undergoing the Hardinge approach. The study also evaluated the relationship between surgical approach and perioperative transfusion frequency, demonstrating that patients undergoing the Hardinge approach were significantly more likely to require red blood cell transfusion. A logistic regression model adjusted for demographic factors (age, sex, BMI) indicated that selection of a more invasive approach increases the risk of requiring transfusion during the perioperative period.

Most available methods for mathematical estimation of PBL rely on prior estimates of the patient's total blood volume (BV). Therefore, the Nadler method [17] was selected for the calculations, as it is one of the most commonly used approaches in this type of research, including studies in arthroplasty and other fields of orthopaedic surgery [18–21]. PBL was estimated using the method described by Gross[16], based on the difference between preoperative and postoperative haematocrit values and noted for its simplicity, which facilitates its application in routine clinical practice. In the present study, PBL was defined as the total blood volume lost over a three-day period, encompassing the day of surgery and the first two postoperative days. Because perioperative blood loss (PBL) encompasses the preoperative, intraoperative, and postoperative periods, only non-traumatic cases were included to minimise potential confounding related to injury mechanism and trauma severity. Obada et al. [22] reported that although overall outcomes were comparable between patients undergoing total hip arthroplasty for osteoarthritis and those treated for femoral neck fracture, surgical blood loss differed significantly between groups. Inclusion of trauma cases might therefore have influenced the observed PBL values.

At the end of the surgical procedure, intra-articular tranexamic acid was administered to all patients, regardless of the surgical approach. The authors acknowledge that intra-articular injection of tranexamic acid is not widely used; it has been used at their institution since 2017 as standard of care and was therefore explicitly described in the Materials and Methods section. Moreover, a recent meta-analysis of randomised controlled trials showed that both intra-articular and intravenous tranexamic acid effectively reduce perioperative blood loss and complication rates after THA without statistically significant differences [23]. Consequently, its administration and potential effects on haemostasis were not considered to have influenced the comparative PBL outcomes; intra-articular application could potentially increase the risk of infection.

Statistical analysis revealed a significant difference in PBL between patients undergoing surgery via the Hardinge approach and those treated with the DSA. It is important to note that, although the difference in PBL between groups reached statistical significance, the absolute difference in mean values, approximately 170 mL, seems modest. While this magnitude of difference might have a limited impact on postoperative recovery for younger, fit patients, it should be considered for older patients and those with multiple comorbidities. In an indirect comparison from a network meta-analysis comparing Super-Path with other approaches, blood loss was greater in patients undergoing the direct lateral approach than in those undergoing Super-Path; however, the difference was smaller, around 126 mL [24]. Another meta-analysis comparing Super-Path with conventional approaches in patients undergoing hemiarthroplasty also showed a smaller difference (approximately 104 mL). However, the authors emphasised the benefits of minimally invasive approaches in older patients[25]. Overall, while the absolute difference in blood loss is moderate in our study, it exceeds that reported in several previous comparisons and may be clinically relevant in vulnerable patient populations.

Notably, three outliers were observed in the Hardinge group (**Figure 1**). Upon identifying the patients corresponding to these values and performing a thorough review of their cases, they were retained in the analysis because the measurements were reliable. Each of these three patients exhibited the largest decreases in haematocrit between the day of surgery and postoperative day two, with two of them requiring perioperative blood transfusion. To minimise the influence of hydration status on haematocrit values, all patients had daily fluid balance monitored and received hydration in accordance with the standard hospital protocol. Additionally, a standard deviation of approximately 0.5 L was observed in both groups, indicating substantial inter-patient variability in PBL even within the same surgical approach.

A review of the literature revealed no studies directly comparing PBL between the Hardinge and DSA. However, several studies have reported lower PBL with other minimally invasive approaches than with the Hardinge approach. A meta-analysis comparing the minimally invasive anterolateral and lateral transgluteal approaches found higher blood loss in the anterolateral group [26]. Similarly, a recent meta-analysis comparing the direct superior approach (DSA) with the posterior approach demonstrated increased blood loss and higher transfusion rates in the posterior group [27]. In contrast, another meta-analysis found no significant differences in haemoglobin levels, blood loss, or transfusion rates between the DSA and posterior approaches [28]. Given the absence of direct comparisons between the Hardinge and DSA approaches, our study addresses an important gap in the literature. The inconsistent findings among previous meta-analyses highlight the influence of methodological heterogeneity and suggest that conclusions regarding blood loss should be interpreted within the context of specific surgical techniques and institutional protocols.

This study has several limitations. Although it assessed the impact of surgical approach on PBL, other potentially influential factors – such as total operative duration, the duration of the procedure excluding the time required for the surgical approach, hospital stay, and chronic medications (e.g. prophylactic doses of acetylsalicylic acid in coronary risk) – were not considered. Despite all procedures being performed by experienced surgeons, the relatively small sample size precluded adjustment for inter-surgeon variability in perioperative blood loss (PBL) and transfusion rates. This limitation underscores the need for further studies with larger cohorts to evaluate surgeon-specific experience as a potential determinant of PBL and transfusion risk. Patients in the Hardinge group were older than those in the DSA group (p = 0.0465), which may have influenced the comparative PBL findings and cannot be entirely excluded as a source of residual confounding. However, no significant age difference was observed between the transfusion and non-transfusion groups, suggesting that age was unlikely to have materially affected the assessment of transfusion risk according to surgical approach. Furthermore, for patients with haemoglobin concentrations of 8–9 g/dL, transfusion was guided by the clinician's individual judgement of the patient's clinical condition, potentially affecting transfusion rates in both the DSA and Hardinge groups. Additionally, only PBL was evaluated, while other important complications of THA, including infection and prosthesis dislocation, were not examined. Given the number of patients included in this study, data on the need for transfusion has limited clinical significance, underscoring the need for further, preferably multicentre, studies to confirm or refute these findings. This was a retrospective, single-centre study from a high-volume institution with standardised perioperative protocols and surgeons experienced in the respective approach. Therefore, the observed differences in PBL and transfusion risk may not fully generalise to centres with different perioperative blood-management strategies (e.g., tranexamic acid dosing/routes, transfusion thresholds), surgeon experience, case-mix, or implant choices. In particular, the non-random allocation of approach and the inability to fully adjust for surgeon-level effects limit extrapolation of effect sizes to other settings; however, the direction of effect is likely most applicable to similar elective primary unilateral THA populations.

Conclusions

Application of a minimally invasive surgical approach, such as the direct superior approach (DSA), is associated with significantly lower perioperative blood loss and, consequently, a reduced likelihood of requiring blood transfusions. This represents a notable clinical advantage of the technique in minimising complications during hospitalisation for patients undergoing total hip arthroplasty.

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Author Contributions

Conceptualization, B.G., P.C.; Methodology, B.G, A.B., M.Z.; Investigation, B.G., M.Z.; Resources, Ł.Ł., P.C.; Data curation, B.G., M.Z.; Formal analysis, B.G., A.B., F.B.; writing—original draft preparation, B.G., A.B., M.Z., Z.B.; writing—review and editing, B.G., A.B., M.Z., F.B., Z.B, Ł.Ł., P.C.; Visualization, B.G., A.B., F.B., Ł.Ł.; Supervision, Ł.Ł., P.C.; Project administration, B.G.; All authors have read and agreed to the published version of the manuscript.

Abbreviations

THA – Total Hip Arthroplasty
DSA – Direct Superior Approach
MIA – Minimally Invasive Approach
PBL – Perioperative Blood Loss
DAA – Direct Anterior Approach
BMI – Body Mass Index
VKA – Vitamin K Antagonist
NOAC – New Oral Anticoagulant
RBC – Red Blood Cell Count
Hct – Haematocrit
Hgb – Haemoglobin

Conflict of interest statement

The authors declare no conflict of interest.

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