The Efficacy of Bone Wax in Reduction of Perioperative Blood Loss in Total Hip Arthroplasty via Direct Anterior Approach

A Prospective Randomized Clinical Trial

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Background: Perioperative blood management in total hip arthroplasty (THA) has become a prime focus of research. Given the morbidity, delayed recovery, and prolonged hospital stay associated with postoperative anemia, various measures have been proposed to reduce perioperative blood loss (PBL). In this trial, we studied the efficacy of bone wax application on the distal cut surface of the femoral neck in reducing PBL during THA through the direct anterior approach.

Methods: In a randomized controlled clinical trial, 152 patients underwent THA through the direct anterior approach with use of bone wax (n = 75) or without bone wax (control) (n = 77). The study was triple-blinded. The primary outcomes were apparent PBL (blood in sponges and suction canister) and total PBL on postoperative days (PODs) 3 and 5 (as calculated with the Good and Nadler methods). Transfusion and complications were the secondary outcomes.

Results: No significant difference was found between the 2 groups in terms of age, sex, body mass index, American Society of Anesthesiologists score, etiology, preoperative hematologic/coagulation profile, anesthesia, intraoperative mean arterial pressure, or operative time. Apparent PBL, total PBL on POD3, and total PBL, in milliliters, on POD5 were significantly lower in the wax group, with median values of 200 (interquartile range [IQR]: 115 to 310) versus 370 (IQR: 195 to 513.7), 505.2 (IQR: 409.2 to 637.6) versus 747 (IQR: 494.6 to 955.4), and 536.7 (IQR: 430.9 to 689.3) versus 767.8 (IQR: 537.8 to 1,021.9) in the wax and control groups, respectively ($p < 0.001$). No significant differences in the rates of transfusion and complications were found.

Conclusions: Bone wax on the cut surface of femoral neck can significantly reduce PBL during THA through the direct anterior approach. Bone wax is accessible and inexpensive and can be considered a routine part of the surgical technique in THA through the direct anterior approach. This intervention has no impact on complication or transfusion rates.

Level of Evidence: Therapeutic Level I. See Instructions for Authors for a complete description of levels of evidence.

Total hip arthroplasty (THA) efficiently relieves pain and restores function in patients with hip osteoarthritis (OA)[1]. As a result of the aging of the population and the obesity epidemic, it has been estimated that the frequency of THA will increase by 400% from the 2000s to 2030[2,3]. The existing health-care economic crisis has highlighted the need for a more cost-containing perspective on THA, focusing more on optimizing perioperative measures such as patient education, perioperative blood loss (PBL) management, and rehabilitation[4-6]. Notably, outpatient THA was introduced in an attempt to address all of these issues concomitantly[7].

PBL has many detrimental effects on the outcomes of arthroplasty. Previous studies have demonstrated mean PBL values ranging from 450 to ~2,800 mL for THA through the direct anterior approach, causing up to a 3 g/dL serum hemoglobin (Hb) loss[8-12]. Postoperative anemia has been associated with an increased risk of wound complications, infection, venous thromboembolism, and poor recovery[13-15]. Transfusions also are associated with specific risks such as hemolytic

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reactions, transmission of infections, and coagulopathy[16]. Overall, these complications can lead to higher morbidity, longer hospital stays, and increased costs[13]. Although the extremely high rates of PBL and transfusion that were reported in older studies have not been reported in recent literature, minimizing PBL is still essential not only in the traditional inpatient setting but also in the setting of outpatient THA[4,17].

There are many strategies to reduce PBL, including preoperative correction of anemia[18] and coagulopathy[19], discontinuing antithrombotic drugs[20], neuraxial anesthesia[21], intraoperative blood pressure control[22], systemic hemostatic agents (tranexamic acid [TXA][23]), or local hemostatic agents[24]. Bone wax is the oldest known local hemostatic[25] agent and is composed mainly of beeswax and a softener such as petroleum jelly (e.g., Vaseline). Bone wax works by mechanically occluding the cut vessels or Haversian canals. Because it is inert, malleable, cohesive, practical, and cost-effective, it has been widely used[26,27].

The purpose of the present study was to assess the efficacy of bone wax in reducing PBL in THA through the direct anterior approach. The direct anterior approach involves cutting the femoral neck for femoral head removal, instead of dislocating the hip as is done in other approaches. As the acetabulum is usually approached first, there is continuous bleeding from the distal neck surface during head removal, acetabular reaming, cup placement, and posterior capsular release before broaching. We hypothesized that such blood loss is considerable and that temporary application of bone wax on the distal neck surface can significantly reduce it. This technique is not intended for surgeons who broach the femur first. To our knowledge, no similar original study exists in the literature, except for 1 paragraph in a technical report by Middleton et al.[28].

Materials and Methods

The comprehensive version of this section is available in the Appendix.

Design

This prospective randomized controlled clinical trial (RCT) was run in a high-volume academic tertiary referral center. The institutional review board approved the methodology and ethics (IR.TUMS.IKHC.REC.1399.032). It was registered in the Iranian Registry of Clinical Trials (IRCT20200305046700N1).

Patients

All patients participated voluntarily and signed the informed consent form. We enrolled 200 consecutive eligible patients from our hip subspecialty clinic from March 2020 to January 2022. Forty-eight of these patients were not included in the final analysis (Fig. 1).

Inclusion and Exclusion Criteria

The inclusion criteria were hip OA and indications for primary THA. The exclusion criteria were bleeding disorders, a history of venous/arterial thromboembolic events, high-risk medical comorbidities, use of antithrombotic drugs, impaired coagulation profile (an international normalized ratio [INR] of >1.1, an activated partial thromboplastin time [aPTT] of >1.4 seconds, a prothrombin time [PT] of >13.5 seconds, or a platelet count of <150,000/µL), the use of anesthesia other than spinal anesthesia, an intraoperative mean arterial pressure of >85 mm Hg, an intention not to participate in or continue with follow-up, and THA for the treatment of inflammatory arthritis, acute hip fracture, type-3 or 4 developmental dysplasia of the hip (DDH), and revision.

Intervention Groups

The intervention was the application of bone wax on the surface of the distal part of the femoral neck following osteotomy. The study included 2 groups: wax and control.

Randomization and Blinding

Each patient had a unique number in their case report form (CRF). We prepared the randomized allocation table with use of permuted block randomization and the random number generator function in Microsoft Excel 365. Subsequently, each patient was allocated to a group on the basis of the number generated in the table and their unique number.

Patients were blinded to their intervention group. The assessor researcher who collected the data and filled in the CRFs was also blinded. At the beginning of surgery, the circulator nurse opened a folded label attached to the patient's CRF, informed the surgeon of the intervention, and discarded the label. The surgeon, although aware of the groups, was not involved in data collection or analysis. The analyzer researcher also was blinded and analyzed the data based on A and B groups. After finishing the analysis, the groups were decoded. Therefore, this trial was triple-blinded.

Outcome Measures

The primary outcome was the efficacy of bone wax in reducing PBL. We measured both apparent PBL and total PBL.

Apparent PBL was measured by summing the blood content of the wet surgical sponges and suction canister. The former was calculated by subtracting the net dry weight of sponges from their wet weight and then dividing it by blood density (1.060 g/mL[29]). We used a high-accuracy (0.01-g) digital scale (K1-A Ming Heng; ATOM). The latter was calculated by subtracting the volume of irrigation serum from the final content of the canister. To improve accuracy, the greatest possible hemostasis (by electrocautery) and field suctioning was the rule. We calculated total PBL on postoperative days (PODs) 3 and 5 with use of the Good method[30], based on preoperative and postoperative serum Hb and estimated blood volume. Estimated blood volume was calculated using the Nadler formula[31].

The secondary outcomes were the need for blood transfusion (packed red blood cells [PRBCs]) and complications possibly related to the use of bone wax.

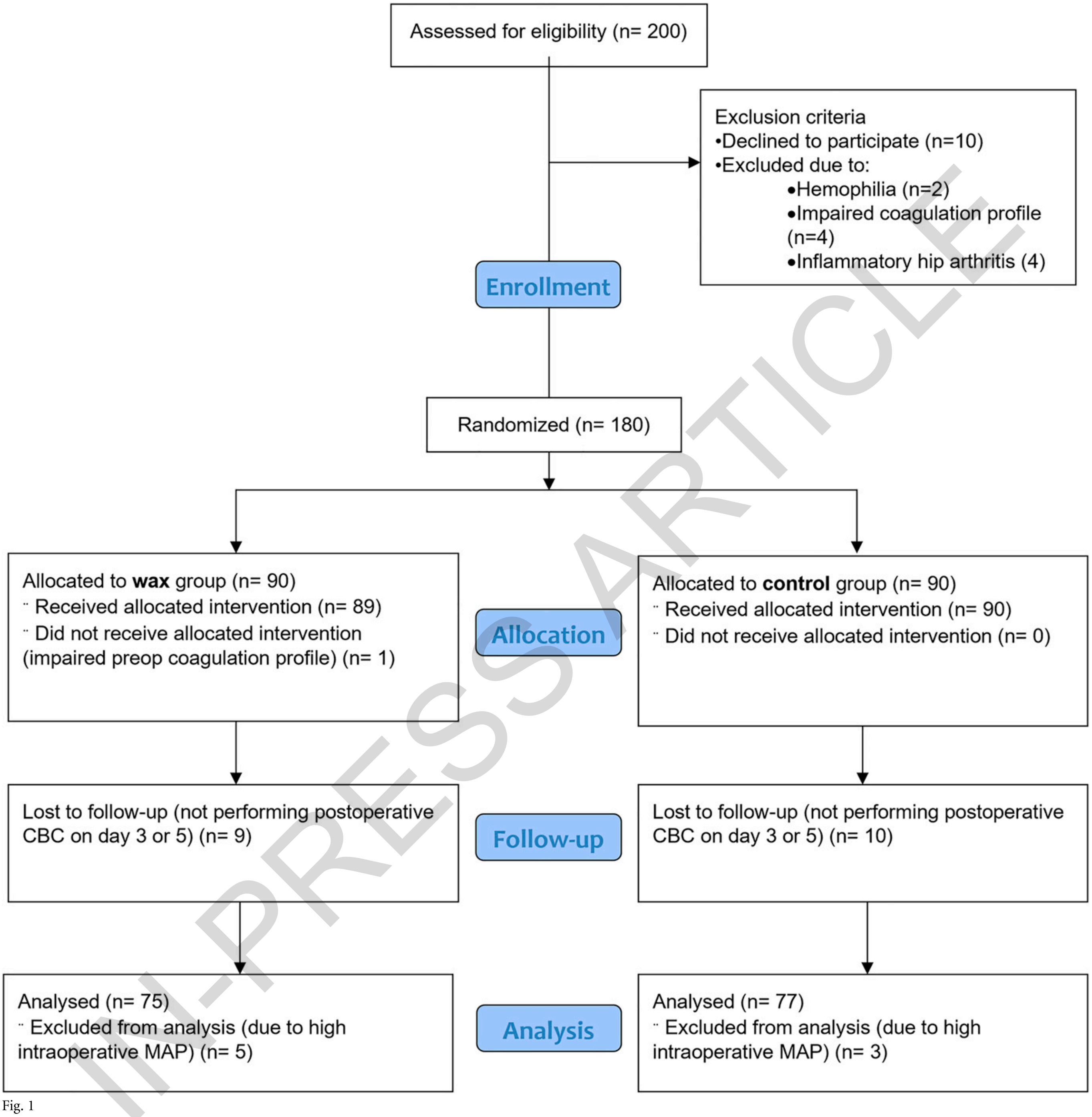

Fig. 1
CONSORT (Consolidated Standards of Reporting Trials) flow diagram. MAP = mean arterial pressure.

Preoperative and Postoperative Protocol

The patients were admitted 1 day before surgery. Base laboratory tests, including complete blood count (CBC), PT, aPTT, and INR, were done. The demographic, clinical, and laboratory data on the patients were recorded in their CRFs. After appropriate templating, THA was performed by the senior author, who is a high-volume hip surgeon. Thirty minutes before surgery, all of the patients received 10 mg/kg of intravenous TXA and cefazolin based on their body weight (1 g in <60 kg; 2 g in 60 to 80 kg; and 3 g in >80 kg). Spinal anesthesia was administered, with a target mean arterial pressure of <80 mm Hg during surgery.

For postoperative anticoagulant prophylaxis, aspirin (325 mg twice a day) was administered for 6 weeks according to American Academy of Orthopaedic Surgeons (AAOS) guidelines[32]. No antibiotic was administered. The patients walked with full weight-bearing on the evening after surgery. Postoperative transfusion indications were a serum Hb of <7 g/dL and symptomatic anemia. Patients were discharged on POD2 unless their medical conditions did not permit it (which occurred rarely). A CBC was done on POD3 and POD5 in the same laboratory. The patients returned for follow-up in 1 week, 1 month, and 3 months after the surgery. All postoperative complications were recorded in the CRF.

Surgical Technique

After standard preparation and draping, THA was performed through the direct anterior approach with use of the standard technique[33] on an ordinary operating table with the patient in the supine position. Following anterior capsulotomy, double osteotomy of the femoral neck was performed with use of a power saw. Immediately after removal of the neck fragment, an ample amount of bone wax (W31C; Ethicon) was applied to the distal cut surface only in the wax group. The wax remained in place during the subsequent head removal, acetabular reaming, cup impaction and fixation, and posterior capsular release for proximal femoral exposure. Immediately before broaching, the wax was completely removed and discarded. The stem was inserted, and stability was assessed. After complete hemostasis, the wound was irrigated and closed in a layered fashion. No drain was used. In this trial, we used uncemented stems (Fitmore, M/L Taper, and Wagner cone; Zimmer Biomet) and cups (Continuum and Trilogy; Zimmer Biomet).

Sample Size

As no similar study was found, we calculated the sample size on the basis of the results of the study by Moo et al. on the efficacy of bone wax in reducing blood loss 72 hours after total knee arthroplasty[34]. With a significance level of 0.05 ($\alpha = 0.95$), power of 0.9 ($\beta = 0.1$), and allocation ratio (k) of 1, the sample size ($n_1 = n_2$) was calculated so that if the difference between the mean 72-hour blood loss of 2 groups ($\Delta = \mu_1 - \mu_2 = 1183.5 - 987.9$) became greater than 196 mL, it would be significant. The minimum size of each group was 64. However, considering the possibility of excluded and lost cases, we enrolled 90 patients in each group.

Statistical Analysis

Continuous variables except PBL were presented as the mean and the standard deviation along with the range, and categorical variables were presented as the absolute and relative frequency. Normality was assessed with use of the Shapiro-Wilk test. An independent-samples t test was used to compare continuous variables, except for PBL. Because of non-normal distribution, PBL was compared with use of the Mann-Whitney U test and was presented as the median and interquartile range (IQR). Chi-square and Fisher exact tests were used for categorical variables. All statistical tests were performed with use of SPSS (version 26; IBM). The tests were 2-sided, and the level of significance was 0.05.

Source of Funding

This study did not receive any funding from external sources.

Results

Demographics

One hundred and fifty-two patients were analyzed in 2 groups: wax (n = 75) and control (n = 77). The female:male ratio was 50.7%:49.3%. The mean age was 47.7 ± 15.4 years (range, 17 to 83 years). The most common etiology was primary OA (42.1%), followed in order by osteonecrosis (30.3%), type-1 DDH (14.5%), previous femoral neck fracture (5.3%), type-2 DDH (5.3%), and Legg-Calvé-Perthes disease (2.6%). No significant difference was found between the 2 groups in terms of demographic and baseline hematologic variables (Tables I and II).

Primary Outcomes

Intraoperative mean arterial pressure was not significantly different between the 2 groups (95% confidence interval [CI] of difference, −1.37 to 1.69 mm Hg; p = 0.836). The mean operative time was 79.2 ± 13.2 minutes in the wax group and 76.9 ± 12.9 minutes in the control group; this difference also was not significant (95% CI = −6.53 to 1.84 minutes; p = 0.270) (Table III). The apparent PBL, total PBL on POD3, and total PBL on POD5 were significantly lower in the wax group, with corresponding median values, in milliliters, of 200 (IQR, 115 to 310) versus 370 (IQR, 195 to 513.7) (p < 0.001), 505.2 (IQR, 409.2 to 637.6) versus 747 (IQR, 494.6 to 955.4) (p < 0.001), and 536.7 (IQR, 430.9 to 689.3) versus 767.8 (IQR: 537.8 to 1,021.9) (p < 0.001) in the wax and control groups, respectively (Table III). Figure 2 shows the boxplots of the apparent and total PBL on POD3 for both groups. The mean postoperative Hb values, in g/dL, also remained significantly higher in the wax group than in the control group on POD3 (11.8 versus 11.3; 95% CI, −0.93 to −0.03; p = 0.037) and POD5 (11.7 versus 11.2; 95% CI, −0.94 to −0.05; p = 0.028), respectively. The Hb drops, in g/dL, on POD3 (95% CI, 0.38 to 0.80; p < 0.001) and POD5 (95% CI, 0.39 to 0.83; p < 0.001) were also significantly lower in the wax group. Moreover, the frequency of a postoperative:preoperative Hb ratio of <0.85 on POD5 was also significantly lower in the wax group than in the control group (22.7% versus 53.2%; p < 0.001) (Table III).

Table IV shows PBL values for the 2 groups according to different etiologies. Both apparent and total PBL were still significantly lower in the wax group among patients with osteonecrosis, DDH, and primary OA. However, patients with previous femoral neck fracture and Legg-Calvé-Perthes disease were not compared because of the small sizes of the groups.

Secondary Outcomes

Only 2 patients needed a transfusion. Both patients were in the control group, and both received 3 units of PRBCs in total; however, no significant difference was shown between the 2 groups (p = 0.497). The rate of complications also demonstrated

TABLE I Patient Demographics

	Wax (N = 75)	Control (N = 77)	P Value
Age* *(yr)*	46.9 ± 16.2 (17-83)	48.5 ± 14.7 (20-77)	0.515†
Weight* *(kg)*	70.7 ± 12.5 (46-105)	73.6 ± 12.2 (48-111)	0.141†
Height* *(cm)*	165.5 ± 8.9 (150-183)	168.2 ± 8.8 (150-186)	0.059†
Body mass index* *(kg/m²)*	25.9 ± 4.3 (18.3-37.3)	26.1 ± 4.5 (19.2-43.4)	0.725†
Sex *(no. of patients)*			0.104‡
Male	32 (42.7%)	43 (55.8%)	
Female	43 (57.3%)	34 (44.2%)	
American Society of Anesthesiologists score *(no. of patients)*			0.223‡
1	65 (86.7%)	61 (79.2%)	
2	10 (13.3%)	16 (20.8%)	
Etiology *(no. of patients)*			0.762§
Osteonecrosis	24 (32.0%)	22 (28.6%)	
DDH type 1	8 (10.7%)	14 (18.2%)	
DDH type 2	4 (5.3%)	4 (5.2%)	
Primary osteoarthritis	32 (42.7%)	32 (41.6%)	
Previous femoral neck fracture	4 (5.3%)	4 (5.2%)	
Legg-Calvé-Perthes disease	3 (4%)	1 (1.3%)	
Side *(no. of patients)*			0.991‡
Right	40 (53.3%)	41 (53.2%)	
Left	35 (46.7%)	36 (46.8%)	

*The values are given as the mean and the standard deviation, with the range in parentheses. †Independent-samples t test. ‡Chi-square test. §Fisher exact test.

no significant difference between the wax group (n = 1) and the control group (n = 3) after mean durations of follow-up of 11.6 ± 6.2 (range, 2 to 23 months) and 11.4 ± 6.9 months (range, 2 to 22 months), respectively (95% CI, −2.3 to −1.9 month; p = 0.620). In the wax group, the complication was a surgical site infection, which was treated with irrigation and debridement and antibiotics. In the control group, the complications included 2 surgical site infections and 1 instance of persistent wound drainage. One of the surgical site infections was treated with 2-stage revision. The other was treated with irrigation and debridement and antibiotics. The instance of persistent wound drainage was treated nonoperatively.

Our ancillary analysis (Table V) showed a significant difference between apparent and total PBL on POD3 and POD5, both overall and in each group; this finding was expected as hidden blood loss is not considered in measured PBL. However, total PBL on POD5 showed no significant differences from total PBL on POD3, overall or in the individual groups.

TABLE II Baseline Hematologic Profile of the Patients*

	Wax (N = 75)	Control (N = 77)	P Value†
Hemoglobin *(g/dL)*	13.5 ± 1.4 (10.2-16.6)	13.6 ± 1.3 (11.0-16.4)	0.613
Hematocrit *(%)*	40.5 ± 4.1 (31.1-49.8)	40.5 ± 3.9 (33.0-49.1)	0.962
Estimated blood volume *(mL)*	4,135.5 ± 565.7 (3,030.8-5,613.9)	4,314.5 ± 545.3 (3,095.2-5,606.1)	0.049
Prothrombin time *(s)*	12.2 ± 1.2 (10.2-15.3)	12.1 ± 1.1 (10.0-15.5)	0.657
International normalized ratio	1.02 ± 0.09 (0.85-1.28)	1.01 ± 0.09 (0.83-1.29)	0.788
Activated partial thromboplastin time *(s)*	28.5 ± 2.6 (22.4-35.4)	28.6 ± 2.7 (22.8-35.9)	0.669
Platelets* *(×1,000/µL)*	306.2 ± 62.8 (143.2-437.5)	289.4 ± 96.0 (155.7-423.3)	0.203

*The values are given as the mean and the standard deviation, with the range in parentheses. †Independent-samples t test.

TABLE III Primary and Secondary Outcome Measures*†

	Wax (N = 75)	Control (N = 77)	P Value
Mean arterial pressure *(mm Hg)*	75.0 ± 4.9 (67-87)	74.9 ± 4.7 (67-83.3)	0.836‡
Operative time *(min)*	79.2 ± 13.2 (51-110)	76.9 ± 12.9 (50-107)	0.270‡
Apparent PBL *(mL)*	200.0 (115.0-310.0)	370.0 (195.0-513.7)	<0.001§
Preop. Hb *(g/dL)*	13.5 ± 1.4 (10.2-16.6)	13.6 ± 1.3 (11.0-16.4)	0.613‡
Preop. Hct *(%)*	40.5 ± 4.1 (31.1-49.8)	40.5 ± 3.9 (33.0-49.1)	0.962‡
Hb day 3 *(g/dL)*	11.8 ± 1.3 (9.1-14.9)	11.3 ± 1.5 (7.5-15.0)	0.037‡
Hct day 3 *(%)*	35.8 ± 4.1 (28.1-45.6)	34.4 ± 4.5 (23.8-45.1)	0.042‡
Hb day 5 *(g/dL)*	11.7 ± 1.3 (9.0-14.8)	11.2 ± 1.5 (7.5-15.1)	0.028‡
Hct day 5 *(%)*	35.2 ± 4.0 (27.6-44.7)	33.7 ± 4.4 (23.7-45.8)	0.041‡
Hb drop day 3 *(g/dL)*	1.73 ± 0.54 (0.8-3.4)	2.3 ± 0.77 (1.1-4.2)	<0.001‡
Hb drop day 5 *(g/dL)*	1.82 ± 0.54 (0.9-3.6)	2.4 ± 0.81 (1.2-4.4)	<0.001‡
Postop.:preop. Hb ratio of <85% on day 5	17 (22.7%)	41 (53.2%)	<0.001#
Total PBL day 3 *(mL)*	505.2 (409.2-637.6)	747.0 (494.6-955.4)	<0.001§
Total PBL day 5 *(mL)*	536.7 (430.9-689.3)	767.8 (537.8-1,021.9)	<0.001§
No. of patients receiving PRBCs	0 (0%)	2 (2.6%)	0.497**
No. of complications	1 (1.3%)	3 (3.9%)	0.620**
Follow-up *(mo)*	11.6 ± 6.2 (2-23)	11.4 ± 6.9 (2-22)	0.845‡

*The values are given as the median and the interquartile range, the mean and the standard deviation (with the range in parentheses), or the number of patients (with the percentage in parentheses). †PBL = perioperative blood loss, Hb = hemoglobin, Hct = hematocrit, PBRCs = packed red blood cells. ‡Independent-samples t test. §Mann-Whitney U test. #Chi-square test. **Fisher exact test.

Discussion

Perioperative blood management (PBM) is a well-established concept in elective lower limb arthroplasties[35]. A host of preoperative, intraoperative, and postoperative strategies have been developed to minimize PBL[36]. Some centers have even used these strategies to define standard operating pathways for outpatient THA[4]. Recent studies have shown that the integrated use of these measures has resulted in a considerable decrease in PBL and transfusion rates following THA[37-39]. In a large-scale study of 69,350 THAs,

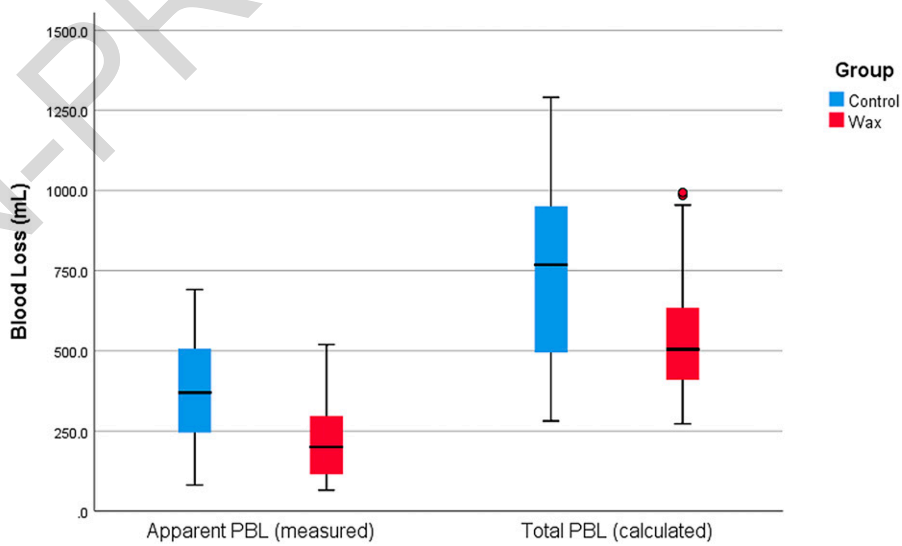

Fig. 2

Boxplots of apparent and total perioperative blood loss (PBL) in both groups on POD3. The top and bottom of a box indicates the IQR, the line within the box indicates the median, and the whiskers indicate the total range. Circles indicate outliers.

TABLE IV Apparent and Total Perioperative Blood Loss on Day 3 After Surgery Based on Etiology of Hip Osteoarthritis

Diagnosis	Group	Apparent PBL§ *(mL)*	P Value*	Total PBL§ *(mL)*	P Value*
Osteonecrosis	Wax (n = 24)	195.3 (118.5-328.8)	0.005	493.3 (392.5-632.4)	0.031
	Control (n = 22)	367.5 (138.9-521.0)		755.6 (464.0-877.7)	
DDH	Wax (n = 12)	146.3 (110.5-207.5)	0.004	468.9 (374.3-570.4)	0.002
	Control (n = 18)	372.5 (128.8-503.8)		789.2 (522.2-984.7)	
Primary osteoarthritis	Wax (n = 32)	212.6 (95.0-329.2)	0.001	543.4 (397.5-678.0)	0.001
	Control (n = 32)	366.0 (172.5-519.7)		776.5 (522.2-979.0)	
Previous femoral neck fracture	Wax (n = 4)	240.3 (136.0-324.8)	†	537.9 (364.3-648.7)	†
	Control (n = 4)	390.0 (260.0-550.8)		627.4 (497.9-987.1)	
Legg-Calvé-Perthes disease	Wax (n = 3)	322.0	†	594.43	†
	Control (n = 1)	282.5		547.49	

§The values are given as the median, with the IQR in parentheses. *Mann-Whitney U test. †Due to the small sample size and unreliability of the significance tests, p values were not reported for these strata.

transfusion rates decreased from 23% in 2007 to 4% in 2015[37]. As a prototype in PBM, TXA has reduced PBL by ~400 mL[38]. Despite these advances, no efforts should be spared to reduce PBL, which is of particular concern in patients undergoing outpatient THA, elderly patients, and patients with preoperative anemia[4,40-42].

In the present RCT, we showed the efficacy of a simple, inexpensive intervention, bone wax, in reducing PBL in patients undergoing THA through the direct anterior approach. Both apparent and total PBL were significantly reduced by wax application (Fig. 2, Table III). Both groups in the present study were similar in terms of demographic characteristics and other PBM measures, including preoperative hematologic/coagulation profile, spinal anesthesia, TXA dose, intraoperative mean arterial pressure, surgical approach, operative time, and postoperative protocol.

Blood loss following THA involves both time and cost for a patient to fully recover to the previous state. The lost Hb can take as long as 56 days to be fully restored because it results in iron deficiency anemia[43,44]. Each milliliter of blood loss depletes the body of 0.5 mg of iron[45]. Iron lost following a donation of 500 mL of blood has been reported to require >24 weeks to replete on a standard diet and in ideal conditions, which are not usually present after THA[46]. Treatment of postoperative anemia and iron deficiency has been recommended to prevent prolonged recovery, increased morbidity/mortality, and readmission[47].

The literature on costs associated with post-arthroplasty anemia is scarce. However, a cost-analysis study on postoperative shed-blood salvage showed a saving of $4.70 to $108.50 per patient for a mean reinfusion of 506 ± 212 mL of shed blood[48]. Another study indicated that the cost of perioperative anemia treatment was €13 to €128 per patient[49]. Our study showed that bone wax can significantly decrease the total PBL on POD3 (747 versus 505.2 mL) in patients managed with THA through the direct anterior approach. The median

TABLE V Comparison Between Apparent and Total Perioperative Blood Loss on Days 3 and 5 After Surgery*

	Wax (N = 75)	Control (N = 77)	Total (N = 152)
Apparent PBL *(mL)*	200.0 (115.0-310.0)	370.0 (195.0-513.7)	259.4 (124.1-388.7)
Total PBL day 3 *(mL)*	505.2 (409.2 637.6)	747.0 (494.6-955.4)	575.1 (446.1-817.9)
P value†	<0.001	<0.001	<0.001
Apparent PBL *(mL)*	200.0 (115.0-310.0)	370.0 (195.0-513.7)	259.4 (124.1-388.7)
Total PBL day 5 *(mL)*	536.7 (430.9-689.3)	767.8 (537.8-1,021.9)	601.2 (473.2-849.2)
P value†	<0.001	<0.001	<0.001
Total PBL day 3 *(mL)*	505.2 (409.2-637.6)	747.0 (494.6-955.4)	575.1 (446.1-817.9)
Total PBL day 5 *(mL)*	536.7 (430.9-689.3)	767.8 (537.8-1,021.9)	601.2 (473.2-849.2)
P value†	0.272	0.315	0.233

*The values are given as the median and the interquartile range. †Mann-Whitney U test.

difference of ~242 mL corresponds to loss of 121 mg of iron, which, if not treated with oral or intravenous iron, might take about 12 weeks to restore on a standard diet in ideal conditions. Such blood loss could have been prevented using 1 piece of bone wax with a cost not exceeding $3 to $4. However, a cost-effectiveness study is required for a more accurate analysis.

Post-THA anemia also might negatively affect functional outcomes. A study on 87 THAs in patients >65 years of age demonstrated a mean improvement of 8.57 and 2.9 in Short Form-36 (SF-36) and Functional Assessment of Cancer Therapy-Anemia (FACT-An) scores, respectively, at 2 months, for each 1 g/dL increase in Hb on POD8[50]. A similar study on 122 THAs in patients >65 years of age demonstrated a correlation between postoperative Hb and recovery in the 6-minute walking test[51]. Furthermore, a study of 82 THAs showed better recovery of hip muscle strength in patients with a postoperative:preoperative Hb ratio of >0.85 on POD10[52]. In our study, 22.7% of patients in the wax group had a postoperative:preoperative Hb ratio of <0.85 on POD5, compared with 53.2% of those in the control group; this difference was significant and might imply better recovery of hip muscles in the wax group.

Finally, postoperative anemia can be important in outpatient settings. Increasing hospital stays and readmission rates[53] are common concerns in outpatient THA centers. Therefore, studies have recommended employing as many PBM measures as possible to reduce postoperative anemia[17]. Although there are still no evidence-based criteria regarding postoperative anemia, some centers have required an intraoperative blood loss of <500 mL or Hb level of >9.7 g/dL for same-day discharge[54,55]. As bone wax could significantly reduce PBL for patients undergoing THA through the direct anterior approach, it might be an advantageous adjunct to PBM measures in outpatient THA.

This study had some limitations inherent to blood loss measurement. First, despite the intended precision, measuring the blood content of the suction canister and wet sponges is subject to underestimation: some blood might be absorbed on drapes or remain in the surgical field, the volume of irrigation serum might not be accurately reported, and sponges can also be soaked with fluids other than blood. Second, total PBL was calculated with use of formulae based on anthropometric and laboratory variables, which are also prone to some inaccuracy. Third, we believe that our study design is subject to a cluster bias, which should be noted when attempting to generalize the results. If THA is not performed under the same surgical circumstances and within the same operative time, the reported effect might not be as expected and PBL can also differ. Finally, we did not study any functional outcome measures in this trial.

In conclusion, bone wax on the distal cut surface of the femoral neck during THA through the direct anterior approach can significantly reduce PBL. It is practical, readily available, and inexpensive and could be considered as a routine part of the surgical technique in THA through the direct anterior approach.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/H196). ■

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