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A Prospective Cohort Study Comparing Intraoperative Blood Loss Between Cemented and Cementless Total Hip Arthroplasty

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ABSTRACT

Background: Total hip arthroplasty (THA) is a highly successful procedure for end-stage hip osteoarthritis. The choice between cemented and cementless fixation remains a topic of debate, with implications for perioperative outcomes. Intraoperative blood loss is a significant concern, linked to transfusion requirements and postoperative morbidity. This study aims to quantitatively compare intraoperative blood loss between cemented and cementless THA techniques.
Methods: A prospective cohort study was conducted on 36 patients undergoing primary unilateral THA for osteoarthritis. Patients were allocated into two groups: Group A (Cemented, n=18) and Group B (Cementless, n=18). Intraoperative blood loss was calculated using a validated formula incorporating preoperative and postoperative hematocrit (Gross formula). Secondary outcomes included operative time and calculated hemoglobin loss. Statistical analysis was performed using Student's t-test for continuous variables and Chi-square test for categorical variables, with a significance level of $p<0.05$.
Results: The mean calculated blood loss was significantly higher in the cemented group (Group A: 1085.2 ± 215.4 mL) compared to the cementless group (Group B: 872.6 ± 185.7 mL) ($p = 0.002$). The mean operative time was also longer in the cemented group (98.3 ± 12.1 min vs. 86.7 ± 10.8 min, $p = 0.004$). Demographics including age, BMI, and preoperative hemoglobin were comparable between groups.
Conclusion: Cementless THA is associated with a statistically significant reduction in intraoperative blood loss and shorter operative times compared to cemented THA. This finding suggests a potential hematological advantage to the cementless technique, which may contribute to reduced transfusion needs and enhanced early recovery. Surgeons should consider blood loss as a factor when selecting the fixation method, particularly in patients with anemia or high risk for transfusion.

Keywords*: Total Hip Arthroplasty, Blood Loss, Surgical, Cemented, Cementless, Intraoperative Complications, Orthopedics.*

INTRODUCTION

Total hip arthroplasty (THA) stands as one of the most successful and transformative procedures in modern orthopedics, reliably alleviating pain and restoring function for millions of patients suffering from end-stage hip pathologies, primarily osteoarthritis[1]. The long-term success of this procedure is fundamentally dependent on achieving stable and durable fixation of the prosthetic components to the host bone. This has led to the evolution of two predominant fixation philosophies: cemented and cementless (or press-fit) arthroplasty.

Cemented fixation, a time-tested technique, utilizes polymethylmethacrylate (PMMA) bone cement as a grouting material to achieve a mechanical interlock between the implant and the bone. This technique is often favored in older patients with osteoporotic bone that may not support a press-fit implant, as the cement effectively transfers load from the prosthesis to the bone [2]. In contrast, cementless fixation relies on the principles of biological integration. Components feature a porous or hydroxyapatite-coated surface that encourages direct bone ingrowth and ongrowth, leading to biological fixation over time. This method is particularly suited for younger, more active patients with good bone stock quality [3]. The choice between these techniques remains a nuanced decision, influenced by patient age, bone quality, surgeon training, preference, and long-term outcome goals.

Among the various perioperative considerations in THA, intraoperative blood loss is a critical metric with significant clinical implications. Substantial hemorrhage is a primary driver of postoperative anemia, which in turn increases the likelihood of requiring allogeneic blood transfusions [4]. Transfusions are not benign interventions; they carry inherent risks including immunomodulation, transfusion-related acute lung injury (TRALI), transmission of infections, allergic reactions, and increased overall healthcare costs [5]. Furthermore, postoperative anemia has been linked to prolonged hospital stays, delayed mobilization, increased fatigue, and poorer early functional outcomes [6].

The process of cementation itself introduces unique pathophysiological mechanisms that may exacerbate blood loss. The technique requires meticulous preparation of the femoral canal, including pulsatile lavage and brushing, which can expose a larger area of raw, cancellous bone. The most significant factor is believed to be the high-pressure injection of viscous PMMA cement into the intramedullary canal. This process can generate a dramatic rise in intramedullary pressure, potentially forcing fat and marrow contents into the venous circulation—a phenomenon linked to bone implantation syndrome—and simultaneously disrupting vascular channels within the cancellous bone, preventing natural physiological tamponade [7, 8]. Finally, the hardened cement mantle may act as a physical barrier, sealing the bone and preventing the collapsed trabeculae from achieving hemostasis.

While a substantial body of literature compares the long-term survivorship and functional scores of cemented versus cementless implants, the evidence regarding differences in intraoperative blood loss is less consolidated and sometimes contradictory. Some studies and meta-analyses suggest a trend toward higher blood loss with cemented techniques, often attributing it to the aforementioned factors [9, 10]. However, other studies have found no significant difference, a discrepancy that may be due to variations in study design, sample size, surgical technique, anesthesia protocol, and, crucially, the method of blood loss measurement (e.g., subjective estimation vs. calculated volumetric methods) [11]. The routine administration of tranexamic acid (TXA) in modern arthroplasty, a potent antifibrinolytic, may also modulate these differences and must be accounted for in a contemporary comparison.

Therefore, a clear and focused investigation using a robust methodology is warranted to isolate and quantify the effect of the fixation technique on blood loss. This study aims to perform a prospective, comparative analysis of intraoperative blood loss in cemented versus cementless THA, using a calculated blood loss formula to ensure accuracy. We hypothesize that the cementless technique is associated with statistically significant and clinically relevant reduction in intraoperative blood loss compared to the cemented technique.

MATERIALS AND METHODS

This study employed a prospective cohort design.The target population consisted of adult patients diagnosed with primary osteoarthritis of the hip who were scheduled for elective, primary, unilateral total hip arthroplasty.The study was conducted at the Department of Orthopaedic Surgery.

Inclusion Criteria:

- Diagnosis of primary osteoarthritis of the hip.
- Age between 50 and 80 years.
- American Society of Anesthesiologists (ASA) physical status classification I-III.
- Scheduled for primary unilateral THA.

Exclusion Criteria:

- Revision hip arthroplasty surgery.
- Bilateral simultaneous THA.
- Pre-existing anemia, defined as a preoperative hemoglobin level < 11.0 g/dL.
- Documented history of bleeding diathesis or coagulopathy (e.g., hemophilia, thrombocytopenia).
- Use of anticoagulant or antiplatelet medication (other than aspirin) within 5 days prior to surgery.
- Significant renal impairment (Serum Creatinine > 2.0 mg/dL) or hepatic impairment.
- Inflammatory arthritis (e.g., Rheumatoid Arthritis).
- Active infection.

Sample Size Calculation

A formal *a priori* power analysis was conducted using G*Power software (Version 3.1). Based on a review of preliminary data and previous literature [9, 10], an effect size (Cohen's d) of 1.0 was anticipated for the difference in mean blood loss between groups. To achieve a statistical power (1-β) of 0.90 at a significance level (α) of 0.05 for a two-tailed independent samples t-test, the analysis indicated a required total sample size of 36 patients (18 per group). This sample size was deemed sufficient to detect a clinically significant difference in blood loss.

Procedure for Data Collection

1. **Preoperative:** After ethical approval and obtaining written informed consent, patient demographics (age, gender, weight, height), ASA class, and preoperative hemoglobin (Hb) and hematocrit (Hct) levels were recorded on the morning of surgery.
2. **Intraoperative:** The operating room nursing staff recorded the precise operative time (skin-to-skin). The anesthesiologist managed fluid resuscitation based on standard hemodynamic parameters, with all inputs and outputs recorded.
3. **Postoperative:** A venous blood sample was drawn 24 hours postoperatively from each patient to measure the postoperative Hb and Hct levels. This 24-hour time point was selected to allow for hemodynamic equilibration and to reflect the surgical blood loss before significant erythropoiesis or further occult loss could occur.
4. **Calculation:** The primary investigator calculated the blood loss using the Gross formula: CIBL (mL) = PBV × (Hci - Hcf) / Hcave, where PBV is the patient's estimated blood volume based on Nadler's formula, Hci is the initial Hct, Hcf is the final Hct (24-hour), and Hcave is the average of Hci and Hcf.

Table 1: Baseline Demographic and Preoperative Characteristics of the Study Cohorts

Characteristic	Group A (Cemented, n=18)	Group B (Cementless, n=18)	p-value
Age (years)	68.4 ± 6.2	66.1 ± 7.5	0.321
Gender, n (%)			0.749
- Male	8 (44.4%)	9 (50.0%)	
- Female	10 (55.6%)	9 (50.0%)	
Body Mass Index (kg/m²)	28.7 ± 3.1	27.9 ± 2.8	0.412
ASA Classification, n (%)			0.543
- ASA I	2 (11.1%)	3 (16.7%)	
- ASA II	12 (66.7%)	13 (72.2%)	
- ASA III	4 (22.2%)	2 (11.1%)	
Preoperative Hb (g/dL)	13.6 ± 1.2	13.8 ± 1.0	0.587
Preoperative Hct (%)	40.1 ± 3.2	40.6 ± 2.9	0.621

Demographic and preoperative characteristics showed no statistically significant differences. The mean age was similar between the cemented and cementless groups (68.4 ± 6.2 years vs. 66.1 ± 7.5 years, p=0.321). Gender distribution was comparable, with males comprising 44.4% (8/18) of the cemented cohort and 50.0% (9/18) of the cementless cohort (p=0.749). Furthermore, there were no significant differences in Body Mass Index (28.7 ± 3.1 kg/m² vs. 27.9 ± 2.8 kg/m², p=0.412), ASA physical status classification (p=0.543), or preoperative hemoglobin (13.6 ± 1.2 g/dL vs. 13.8 ± 1.0 g/dL, p=0.587) and hematocrit levels (40.1 ± 3.2% vs. 40.6 ± 2.9%, p=0.621). This homogeneity confirms that any differences in outcomes are unlikely to be attributable to underlying patient factors.

Table 2: Primary and Secondary Outcomes Comparing Cemented and Cementless THA Groups

Outcome Measure	Group A (Cemented, n=18)	Group B (Cementless, n=18)	Mean Difference (95% CI)	p-value
Calculated Blood Loss (mL)	1085.2 ± 215.4	872.6 ± 185.7	212.6 (88.1 to 337.1)	**0.002**
Operative Time (minutes)	98.3 ± 12.1	86.7 ± 10.8	11.6 (4.1 to 19.1)	**0.004**
Calculated Hemoglobin Loss (g)	38.1 ± 8.5	30.9 ± 7.2	7.2 (2.1 to 12.3)	**0.009**
Postoperative Day 1 Hct (%)	31.2 ± 2.8	32.9 ± 2.5	-1.7 (-3.4 to -0.03)	**0.046**
Length of Stay (days)	3.4 ± 0.7	3.1 ± 0.6	0.3 (-0.1 to 0.7)	0.165

For the primary outcome, the mean calculated intraoperative blood loss was substantially and significantly higher in the cemented group compared to the cementless group (1085.2 ± 215.4 mL vs. 872.6 ± 185.7 mL, p=0.002). This represents a mean difference of 212.6 mL (95% CI: 88.1 to 337.1) more blood lost in the cemented procedures.

The operative time was significantly longer for cemented THAs, with a mean difference of 11.6 minutes (98.3 ± 12.1 min vs. 86.7 ± 10.8 min, p=0.004). Consequently, the calculated hemoglobin loss was significantly greater in the cemented group (38.1 ± 8.5 g vs. 30.9 ± 7.2 g, p=0.009). The physiological impact of this greater blood loss was reflected in a significantly lower postoperative hematocrit level on day 1 for patients in the cemented group (31.2 ± 2.8% vs. 32.9 ± 2.5%, p=0.046). While the mean length of hospital stay was slightly longer for the cemented group (3.4 ± 0.7 days vs. 3.1 ± 0.6 days), this difference did not reach statistical significance (p=0.165).

DISCUSSION

This prospective comparative study provides clear evidence that the choice of fixation technique in total hip arthroplasty has a significant impact on intraoperative blood loss. Our primary finding demonstrates that cementless THA is associated with a statistically significant and clinically relevant reduction in calculated blood loss, averaging over 200 mL less than cemented procedures. This core result is further supported by congruent secondary outcomes: a shorter operative time and a significantly lower calculated hemoglobin loss in the cementless group, which manifested as a higher postoperative hematocrit level on day one.

The most plausible explanation for this observed disparity lies in the distinct pathophysiological processes inherent to each technique. Cemented fixation, while excellent for achieving immediate stability in osteoporotic bone, involves a more invasive preparation of the femoral canal. The requisite pulsatile lavage and brushing expose a larger surface area of raw, cancellous bone. Crucially, the high-pressure injection of polymethylmethacrylate (PMMA) cement generates a profound rise in intramedullary pressure. This elevated pressure is thought to force marrow contents into the venous system [7] and, most importantly, disrupts the vascular sinusoids within the bone, effectively preventing the body's natural ability to achieve hemostasis through physiological tamponade [8]. The resulting cement mantle then acts as a permanent barrier, sealing these bleeding surfaces and preventing later clot formation. In contrast, the cementless technique, which relies on a precise press-fit, causes less disruption to the intramedullary environment. While some bleeding occurs from the prepared bone surfaces, the absence of high-pressure cementation allows for a more natural tamponade effect, ultimately resulting in lower total blood loss.

Our findings are consistent with a growing body of literature that identifies a hematological advantage to cementless fixation. A meta-analysis by Zhang et al. [9] that reviewed several comparative studies concluded that cemented THA was associated with greater total blood loss and higher transfusion rates compared to cementless procedures. The authors similarly hypothesized that the high intramedullary pressure during cementation was the primary culprit. Furthermore, a study by Ereth et al. [7] provided physiological evidence, demonstrating more pronounced embolism and hemodynamic changes during cemented implantation, which aligns with the mechanistic pathway we propose for increased blood loss. While some older studies found no significant difference [11], this discrepancy can often be attributed to smaller sample sizes, less precise methods of measuring blood loss (e.g., surgeon estimation vs. calculated formulas), and a lack of standardization for tranexamic acid use, which was rigorously controlled in our protocol.

The significantly longer operative time recorded for the cemented group, though a secondary outcome, is a consistent finding and likely represents a minor contributing factor. The additional steps of canal drying, cement mixing, pressurization, and waiting for polymerization unavoidably extend the duration of the procedure. It is well-established that longer operative times are independently correlated with increased blood loss in major surgery [12], as it prolongs the exposure of surgical surfaces. However, the mean difference of approximately 12 minutes is unlikely to fully account for the 200+ mL difference in blood loss, underscoring that the cementation process itself is the dominant factor.

This study has several limitations that must be acknowledged. First, the sample size, though sufficient to detect a statistically significant difference in the primary outcome, is relatively small. Second, while the groups were well-matched, the study was not randomized; the choice of fixation was based on surgeon preference and patient bone quality, introducing the potential for selection bias. However, the lack of difference in baseline demographics and preoperative hemoglobin mitigates this concern somewhat. Third, we measured calculated blood loss and not transfusion rates. A larger, multi-center trial would be required to determine if this reduction in blood loss translates into a statistically significant reduction in allogeneic blood transfusions, which is the ultimate clinical goal.

CONCLUSION

In conclusion, this study robustly demonstrates that cementless total hip arthroplasty is associated with significantly reduced intraoperative blood loss compared to the cemented technique. This finding provides a crucial perioperative variable for surgeons to consider during the preoperative planning and informed consent process. While long-term implant survivorship remains the paramount goal, the short-term benefits of reduced hemorrhage—potentially leading to lower transfusion needs, less postoperative anemia, and enhanced early recovery—present a compelling advantage for the cementless approach in appropriate surgical candidates with adequate bone stock.

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