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# Blood loss and transfusion rates following total hip arthroplasty: a multivariate analysis

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**This study aimed to identify factors that independently predict increased rates of transfusion following total hip arthroplasty (THA) surgery. A retrospective analysis of all patients undergoing THA surgery over 12 months was performed. Electronic operative records were analysed to determine the following patient factors: American Society of Anesthesiologists (ASA) grade, body mass index (BMI), co-morbidities, indication for surgery, surgical technique, type of implant used, haematological markers, hospital length of stay (LOS) and complications. A total of 244 patients were included. There were 141 females (58%) and 103 males (42%). The median age was 65±12. The median pre-operative blood volume was 4500mls (IQR; 4000-5200). The median blood loss was 1069mls (IQR; 775-1390). The total number of patients requiring transfusion was 28 (11%), with a median of two units being transfused. Pre-operative haemoglobin ($p<0.001$) level, haematocrit ($p<0.001$) level and weight ($p=0.016$) were found to be predictive of transfusion requirement as well as ASA grade ($p=0.005$). Application of an intra-operative surgical drain was associated with higher rates of transfusion ($p<0.001$). Our study strengthens the evidence that pre-operative haemoglobin and haematocrit levels are valuable predictors of patients requiring transfusion. Additionally, ASA grade may be viewed as a helpful factor in predicting risk of transfusion. A strategy incorporating pre-operative optimisation of modifiable factors may reduce rates of transfusion requirement.**

**Keywords:** total hip arthroplasty; THR; THA; haemoglobin; blood loss; transfusion.

## INTRODUCTION

Total hip arthroplasty (THA) is one of the most common orthopaedic operations performed in the United Kingdom (UK) *(1, 2)*. With an ageing population and increasing levels of obesity, the demand for this procedure is expected to rise, placing a significant burden on the National Health Service (NHS) *(1, 3)*.

The estimated cost per THA is reported to be in excess of £6000, with each patient having an average

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stay in hospital of 5.6 days *(4, 5)*. The development of 'fast-track' or 'enhanced recovery' programs have aimed to reduce the time spent in hospital with promising results. Future targets involve day-case or outpatient arthroplasty, although this remains uncommon within the UK *(6)*.

Despite THA being considered a hugely successful intervention, there remains a degree of associated morbidity and mortality *(7)*. One important complication is blood loss, with the average peri-operative haemoglobin drop estimated to be 30 g/L *(8)*. The resulting anaemia has been identified as an independent risk factor of increased morbidity and mortality post-operatively *(9)*. This is partly due to the requirement of blood transfusion which carries its own complication risks such as sepsis, pneumonia, prolonged hospital stay and venous thromboembolism *(10)*. Additionally, blood transfusions have substantial cost implications and are associated with poorer functional outcomes *(8, 11)*.

The primary purpose of this research paper was to identify variables (haemoglobin, haematocrit, ASA grade, pre-operative anti-coagulation, length of surgery, BMI, surgical drain application) which may independently predict higher rates of blood transfusion.

## MATERIALS AND METHODS

Following institutional approval, the operative records of 279 patients undergoing primary THA at a single centre over a period of twelve months were retrospectively analysed. Patients undergoing revision or bilateral THA surgery were excluded from data selection. After removal of duplicate records or any records with insufficient data, 244 patients were included for further analysis. All procedures were performed with a posterior southern approach by a total of seven different surgeons. As no patients or members of public were involved in the design, or conduct, or reporting, or dissemination plans of our research, authors did not seek ethical approval for conduction of this study.

Data was obtained using the electronic patient record system, Cerner (Cerner corporation, North Kansas City, USA). Patient demographics were extracted alongside body mass index (BMI), American Society of Anaesthesiologist (ASA) grade, co-morbidities, surgical technique, haematological markers and length of stay. Patient records were reviewed for any complications. Complications were defined as any attendance to hospital that was unplanned and not part of routine follow-up. They were then further categorised into venous thromboembolism (confirmed or investigated), infection (surgical site infection, prosthetic joint infection, pneumonia, sepsis of unknown origin) or other (prosthesis dislocation, peri-prosthetic fracture, excessive pain).

Co-morbidities were further categorised into cardiovascular (including hypertension, previous myocardial infarction, atrial fibrillation, arrhythmia or congestive cardiac failure), respiratory (including asthma, chronic obstructive pulmonary disease, a history of lung tuberculosis or lung sarcoidosis), neuro-psychiatric (including stroke, schizophrenia, depression, Parkinson's disease) and immune system disorders. Diabetes mellitus was defined as having either tablet or insulin treatment, or a self-defined history of diabetes.

All patients underwent a standardized arthroplasty pathway including pre-operative patient education presentations from nursing staff, occupational therapy and physiotherapy. All patients underwent a pre-operative anaesthetic assessment with a member of the anaesthetic team. Operations were performed under general or spinal anaesthesia with standard antibiotic prophylaxis. No patients received intra or post-operative tranexamic acid. No patients required use of intra-operative blood salvage. As standard, multi-modal pain relief was offered as part of an enhanced recovery programme with admission to an elective orthopaedic ward.

Patients were managed using the local trust blood transfusion protocol. Haemoglobin levels were checked one day postoperatively. A level of less than 80 g/L resulted in blood transfusion. For patients with a history of cardiovascular disease, levels of 80-100g/L were deemed appropriate for transfusion. Blood loss estimation was calculated via the formula described by Gross and Nadler *(12, 13)* (Figure 1).

**Total blood loss = PBV x ($Hct_{pre}$ – $Hct_{post}$) / $Hct_{ave}$**

**PBV** = patient's blood volume

**$Hct_{pre}$** = preoperative haematocrit

**$Hct_{post}$** = lowest postoperative haematocrit during hospitalization

**$Hct_{ave}$** = mean of $hct_{pre}$ and $hct_{post}$

**PBV in men**[30] = 0.3669 x height$^3$ (m) + 0.03219 x weight (kg) + 0.6041

**PBV in women**[30] = 0.3561 x height$^3$ (m) + 0.03308 x weight (kg) + 0.1833

***Figure 1.*** — Calculation of blood loss.

IBM SPSS Statistics 25.0 software package (IBM Corp, Armonk, NY) was utilized for statistical analysis. Normality was tested using the Shapiro-Wilk test. Scale variable with normal distribution are presented based on Mean (±SD) and analyzed using Student-T test. Non-parametric variables and scale variables with Non-Gaussian distribution are presented as Median (IQR) and were tested using Mann-Whitney U-Test. Categorical variables are presented in numbers (%) and were tested using Fischer Exact Test. The p-value of 0.05 was deemed as statistically significant.

## RESULTS

A total number of 244 patients underwent THR during the study period. There were 141 females (58%) and 103 males (42%), with a median age of 65 years (±12). Patients had a median BMI of 28 kg/m2 (±4) and a median ASA grade of two (±0). General demographics of the patient cohort alongside their ASA grade are presented in Table I.

Mean pre-operative haemoglobin and haematocrit levels were 134.0g/L (±15.0) and 41.0% (±4), respectively. The median pre-operative blood volume was 4500ml (±700). Mean post-operative haemoglobin was 107.0 g/L (±16), with a median estimated blood volume loss of 1069ml (±350ml). The mean post-operative haematocrit was 32% (±5). The blood results are presented in. The overall rate of transfusion within our study population was 11% (28/244) with the majority of patients (57.1%) who required transfusion receiving two units of Red Blood Cells, as shown in Table II.

Further analysis compared patient related factors to post-operative transfusion requirement. Pre-operative haemoglobin and median blood volume prior to surgery were predictive of requirement of transfusion ($p<0.001$). Furthermore, pre-operative haematocrit (OR= 3.8, CI; 1.5-9.7), body weight/kg (OR=0.97, CI; 0.94-1) and application of drain (OR= 22.8, CI; 4-121) were found to be significant

Table I. — General characteristics of patient cohort

| Patient Characteristic | |
|---|---|
| Female / male (n) | 141, 103 |
| Age (years), Median (IQR) | 65 (53-74) |
| Weight (kg), Median (IQR) | 75 (66-88) |
| Height (cm), Median (IQR) | 166 (160-175) |
| BMI (kg/m$^2$), Median (IQR) | 27 (24-31) |
| ASA 1 N (%) | 45 (19) |
| ASA 2 N (%) | 144 (59) |
| ASA 3 N (%) | 51 (21) |
| ASA 4 N (%) | 3 (1) |
| BMI = Body Mass index, ASA = American Society of Anesthesiologists | |

Table II. — General characteristics of patient cohort

| | Value |
|---|---|
| Required transfusion, N (%) | 28 (11) |
| 1 Unit Transfused; N (%) | 11 (39.3) |
| 2 Unit Transfused; N (%) | 16 (57.1) |
| 3 Unit Transfused; N (%) | 0 (0) |
| 4 Unit Transfused; N (%) | 1 (3.6) |

factors in predicting the need for transfusion. 63.6% of patients who had a drain applied required blood post-operatively (Table III).

The ASA grade of patients was highlighted to be a significant factor (p=0.005). The similar medians (n=2) between the transfusion and non-transfusion group is due to the majority of patients being in this category (n=143). 100% of patients graded ASA 4 (n=3) required post-operative blood transfusion. 17.6% (n=9) of patients categorised as ASA 3 required transfusion compared to only 9.8% (n=14) of ASA 2 patients. The lowest rate of transfusion rates was seen amongst ASA 1 patients, with 4.3% (n=2).

There was no change in transfusion rates amongst patients who were on anti-coagulation medication prior to their operation (p=0.323). There was also no significant difference seen in the duration of operation between patients who required transfusion to those who did not. All THAs included in the study were performed by seven different orthopaedic consultants, with no identifiable difference between the operators in terms of transfusion rates. The overall average length of stay in hospital was four days. Patients requiring transfusion had a median stay of nine days (IQR 5-10). This was significantly longer than the non-transfusion group, who had a median stay of three days (IQR 2-5) (p<0.001).

There was no significant difference of complications between the groups (p=0.195). The most common complication in seen amongst both transfusion and non-transfusion patients was venous thromboembolism. As complications were defined

Table III. — Comparison of patient factors between transfusion and non-transfusion group

| Factors | Transfusion | Non-Transfusion | p-value |
|---|---|---|---|
| N (%) | 28 (11) | 216 (89) | - |
| Age (years), Median (IQR) | 71 (53-77) | 64 (53-74) | 0.211 |
| Weight (kg), Median (IQR) | 67 (61-82) | 77 (67-89) | 0.016 |
| Height (cm), Median (IQR) | 165 (158-169) | 167 (160-175) | 0.150 |
| BMI (kg/m$^2$), Median (IQR) | 25 (23-29) | 27 (24-31) | 0.062 |
| ASA Grade, Median (IQR) | 2 (2-3) | 2 (2-2) | 0.005 |
| Pre-operative anti-coagulation (%) | 8 (29) | 43 (20) | 0.323 |
| Pre-operative haematocrit (%), Median (IQR) | 37 (33-42) | 42 (39-44) | <0.001 |
| Pre-operative haemoglobin(g/L), Median (IQR) | 118 (106-133) | 137 (127-144) | <0.001 |
| Pre-operative blood volume (L), Median (IQR) | 4.2 (3.8-4.6) | 4.6 (4-5.3) | 0.022 |
| Duration of Surgery | 97 (74-132) | 81 (67-102) | 0.162 |
| Length of Stay (days), Median (IQR) | 9 (5-10) | 3 (3-5) | <0.001 |
| Complications (N), (%) | 5 (17) | 21 (10) | 0.195 |
| Drain application (N), (%) | 7 (25) | 4 (1.9) | <0.001 |
| Co-morbidities (N), (%) | 24 (86) | 157 (73) | 0.172 |
| Cardiovascular (N), (%) | 18 (64) | 101 (47) | 0.107 |
| Compromised Immune System (N), (%) | 17 (61) | 122 (57) | 0.840 |
| Neuro-Psychiatric Disorder (N), (%) | 3 (11) | 16 (7) | 0.46 |

BMI = Body Mass Index, ASA = American Society of Anesthesiologists

as any attendance to hospital that was unplanned, a number of subjects were investigated for venous thromboembolism with subsequent negative scans. Complications categorised as 'other' included peri-prosthetic fractures, admission to hospital for strong analgesia and prosthesis dislocation. A breakdown of the complications identified are presented in Table IV.

## DISCUSSION

The aim of this study was to identify factors which independently predict risk for higher rates of blood transfusion following THA. Our results suggest pre-operative haemoglobin and haematocrit levels, as well as ASA grade, can be viewed as significant predictive factors. Furthermore, the application of a surgical drain can be associated with higher levels of blood loss and subsequent need for transfusion.

THA is one of the most common surgical procedures where patients require allogenic blood transfusion. The rates of transfusion have been reported to range from 18% to 68% *(10)*. Encouragingly, in more recent years the implementation of blood management strategies has suggested this rate can be as low as 12.5% - which is in keeping with the rates seen amongst our patient cohort (11%) *(14)*. Authors from a German institute report even lower rates (3.9%) of blood transfusion amongst patients undergoing hip arthroplasty through utilisation of a minimally invasive approach *(15)*. This approach remains novel and is not yet widely practiced in the UK.

Our research adds to the strong evidence base that patients with low pre-operative haemoglobin and haematocrit levels have higher rates of blood transfusion *(15, 17)*. The post-arthroplasty transfusion protocol adhered to in our institute included patients receiving transfusion if a post-operative haemoglobin of less than 80 g/L. Alternatively, patients with a haemoglobin of 80 to 100 g/L were transfused if they were symptomatic or had a history of cardiovascular disease *(18)*. It is therefore important to identify methods in which these levels may be optimised and help reduce the complications associated with transfusion.

The difficulty in optimising haematocrit levels lies behind its aetiology - the abnormal levels are often due to underlying conditions which cannot be easily modified. Therefore, haematocrit levels may be viewed as a marker of risk, as opposed to a modifiable pre-operative factor *(19)*. Patients on anti-coagulation medication pre-operatively did not show higher rates of blood transfusion than those who were not. As all patients included were operated at our elective institute, a thorough pre-operative assessment was undertaken. Patients were identified at an early stage and subsequently any anticoagulation was appropriately reversed, or stopped, in ample time prior to procedure.

The most common cause of a low haemoglobin amongst patients undergoing surgery is iron deficiency, an easily modifiable factor *(20, 21)*. In the UK, the majority of patients undergoing elective THA in the NHS have a prolonged waiting period. The blood conserving strategy of iron supplementation may therefore be targeted at the

Table IV. — Comparison of complications between transfusion and non-transfusion group

| Complications | Transfusion | Non-Transfusion |
|---|---|---|
| N (%) | 5 (17) | 21 (10) |
| Confirmed VTE (N), (%) | 1 (20) | 3 (14) |
| Investigated for VTE (N), (%) | 2 (40) | 8 (38) |
| Surgical Site Infection (N), (%) | 1 (20) | 2 (10) |
| Pneumonia (N), (%) | 0 (0) | 1 (5) |
| Sepsis of Unknown Origin (N), (%) | 1 (20) | 0 (0) |
| Other (N), (%) | 0 (0) | 7 (33) |
| VTE = Venous Thromboembolism | | |

pre-operative stage. Current NICE guidance states all patients undergoing surgery must be considered for iron supplementation (oral or intravenous) *(18)*. NICE guidelines also stipulate that all patients undergoing arthroplasty require a full blood count, which includes haemoglobin and haematocrit levels *(22)*. This offers an opportunity for iron levels to be measured and optimised pre-operatively. Iron levels were not recorded in our patient cohort due to data being collected in the elective hospital setting where iron studies are not routinely performed. A strategy incorporating optimisation of iron levels pre-operatively in the community setting may prove to further reduce the rates of transfusion amongst our patient cohort.

Intra-operative blood management strategies include maintenance of body temperature, meticulous use of diathermy, reduction in operative time and administration of intravenous tranexamic acid *(23)*. Our institute focusses on a multidisciplinary effort between anaesthetists, surgeons and theatre staff to ensure patient operative time is kept to a minimum and appropriate body temperature is constantly maintained through use of warmed intravenous fluids and body warming devices where appropriate. The decision to administer tranexamic acid is taken on a case-to-case basis and left to clinician discretion. None of the patients included in our study were deemed to require intra or post-operative tranexamic acid.

The application of surgical drains remains a topic of debate amongst surgeons. They are often used in patients who have increased bleeding intra-operatively and were originally thought to reduce complications such as haematoma formation, post-operative swelling and development of infection *(24)*. Our data indicates that patients with a surgical drain applied during their procedure required significantly higher rates of transfusion than those who did not, in keeping with recent literature *(15)*. A meta-analysis showed a definite disadvantage for patients managed with a drain due to higher rates of blood transfusion requirement *(25)*. This highlights the importance of orthopaedic surgeons balancing the risks posed with post-operative haematoma formation or increased swelling versus that of post-operative blood transfusion, particularly as the proven benefits of drain usage remains controversial *(25)*. It is therefore important to consider all the risks, as well as benefits, associated with using a surgical drain in THA.

Although transfusion is often related to increased morbidity and mortality, it is difficult to establish causation. Often, these patients may be pre-disposed to poorer outcomes largely due to their pre-operative co-morbidities *(16)*. Conversely, in patients with cardiac disease and anaemia, transfusion has been shown to improve survival *(26)*. Other studies have shown no difference in mortality rates between patients, regardless of background, undergoing transfusion *(27)*. The ASA grade is a physical classification system that was developed for clinicians to categorise patient's physiological status based on their underlying co-morbidities. It allows for a simple yet effective method in which a patient's peri-operative risk can be predicted *(28)*. Our data corroborates previous findings amongst orthopaedic patients that ASA grade can be seen as a significant predictive factor of requiring post-operative transfusion *(29, 30)*. 93% of the patients receiving blood transfusion in this study were of ASA grade 2 or above. Although ASA grade is not an easily modifiable factor, it can be used alongside other variables to help predict the requirement of blood transfusion requirement. Although not yet thoroughly validated, a clinical prediction rule combining a number of variates has previously shown promising results *(30)*.

The strength of this study is in the detailed data collection allowing for identification of numerous variables. Limitations include the method of blood loss calculation based on pre and post-operative haematocrit levels *(12, 13)*. Although this is a validated method, there may be some level of over or underestimation of blood loss. A limitation can also be attributed to retrospective data collection - the study does not allow for randomisation or a control group. Furthermore, as this was a single centre study the findings may not be applicable to a wider demographic. Conversely, the advantages to this include uniform care and adherence to the same protocol for all subjects. Finally, a full cost analysis would be of benefit to evaluate cost of transfusions to elective units although this fell outside the remit of this paper.

## CONCLUSION

The results from our study show multiple factors predict risk of increased levels of blood loss during THA. We add to the evidence that a pre-operative haemoglobin and haematocrit levels are valuable in predicting an increased likelihood of requiring transfusion. Additionally, the ASA class of a patient can also be viewed a significant predictive factor. Further work targeted towards pre-operative optimisation of modifiable factors may help reduce rates of transfusion requirement.

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