Postoperative hemoglobin level in patients with femoral neck fracture

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Objectives: The aim of this study was to analyze the changes of hemoglobin levels in patients undergoing fixation for femoral neck fracture.

Methods: Perioperative hemoglobin levels of patients who underwent either dynamic hip screw (DHS) fixation (n=74; mean age: 80 years) or hip hemiarthroplasty (n=104; mean age: 84 years) for femoral neck fracture was monitored.

Results: There was a statistically and clinically significant mean drop of 31.1 g/L between the preoperative (D0) and postoperative Day 5 Hb levels (p<0.001), with significant reductions from D0 to Day 1 and Day 1 to Day 2 (p<0.001). At each postoperative measurement, DHS patients had lower hemoglobin values over hemiarthroplasty patients (p=0.046).

Conclusion: The decrease in hemoglobin in the first 24-hour postoperative period (D0 to Day 1) is an underestimation of the ultimate lowest value in hemoglobin found at Day 2. Relying on the Day 1 hemoglobin level could be detrimental to patient care. We propose a method of predicting patients likely to be transfused and recommend a protocol for patients undergoing femoral neck fracture surgery to standardize postoperative hemoglobin monitoring.

Keywords: Fracture; hemoglobin; neck of femur; postoperative.

Level of Evidence: Level II, Therapeutic Study.

Postoperative hemoglobin analysis for orthopedic patients expected to have lost significant volumes of blood during surgery is part of good medical practice. Therefore, it is often routine care to measure hemoglobin levels on postoperative Day 1 (D1 [within 24 hours of surgery; subsequent 24-hour periods are defined as D2, D3, etc.]). However, the timing of subsequent analyses is not well defined within the literature.

Surgery for fractured neck of femur (NOF) is one of the most common orthopedic procedures performed in hospitals worldwide today.¹,² Generally occurring in an older age group,³ fractured NOF is associated with high morbidity (approximately 50%⁴) and mortality (33%⁵) at 1 year postoperatively. National Institute for Health and Care Excellence guidelines recommend that surgery for fractured NOF occur between 24 and 48 hours after admission, following medical optimization and multidisciplinary input, based upon the National Hip Fracture Database, which suggests a 36-hour operative window.⁶
Low pre- and postoperative hemoglobin are recognized factors which affect length of stay, transfusion risk, morbidity, and mortality.[7–16] However, as of 2014, review of peer-reviewed literature revealed that no recommendations exist regarding an optimum perioperative hemoglobin level. In addition, there are currently no recommendations of the timeframe within which postoperative hemoglobin should be obtained in the UK.[17] A study at our institution revealed inconsistent postoperative blood sampling practice of hip fracture patients, with some patients having daily blood sampling as default.

An evidence-based protocol could optimize this patient group’s recovery and reduce cost for the National Health Service. Therefore, we investigated pre- and postoperative hemoglobin to establish a perioperative hemoglobin analysis regime for patients undergoing routine fixation of fractured NOF, with the aim of efficaciously assessing for anemia.

**Patients and methods**

A prospective study of all NOF fractures surgically managed over an 18-month period was conducted at our institution. The Research and Ethics Committee, UK approved the study and associated protocols. A total of 390 patients were admitted for surgical management of fractured NOF during this study period. A total of 178 patients (74 dynamic hip screw for intertrochanteric fractures [DHS] and 104 hemiarthroplasties for NOF fractures, both monopolar and bipolar) were eligible for analysis after application of exclusion criteria described in Table 1.

Certain assumptions were made for the purposes of this study. The same technique was used for monopolar and bipolar hemiarthroplasty surgery; only the implant used for each of the 2 techniques differed. It is therefore reasonable to combine their data. Additionally, hemoglobin values during the perioperative period are a recognized measure of blood volume and/or blood loss. ‘Blood loss’ may therefore be used to describe our results. All patients received the same low-molecular-weight heparin anticoagulation regimen unless contraindicated. Drains were not routinely inserted.

Hemoglobin levels were measured preoperatively (D0) and on at least 2 consecutive postoperative days for 68% of patients included in this study, with all remaining patients having their hemoglobin levels monitored on at least 2 nonconsecutive postoperative days. No protocol was in place to instruct clinicians when to monitor hemoglobin levels. The decrease in hemoglobin was calculated by subtracting the hemoglobin level on the studied postoperative day from the preoperative level.

A repeated measures general estimating equation (GEE) model was employed for any omitted hemoglobin values with day (D) used as the factor to assess for the overall trend in hemoglobin levels over time (Figure 1). Pair-wise comparisons between days were assessed and significances adjusted using Quasi-Bonferroni correction for multiple testing by applying a lower critical value of 0.01 (1% significance level) for pair-wise p values. Adjusted means were comparable between time points despite variance in numbers of non-missing outcome measures due to use of the GEE model.

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**Table 1.** Exclusion criteria.

| Exclusion Criteria                                      |
|--------------------------------------------------------|
| 1. Patients with associated injuries.                  |
| 2. Patient age ≤50 years.                               |
| 3. Surgical repair other than dynamic hip screw/hemiarthroplasty. |
| 4. >72 hour time to surgery.                            |
| 5. <2 Postoperative hemoglobin readings during admission.|
| 6. Patients requiring perioperative transfusion.        |

**Fig. 1.** (a) Scatter plot of hemoglobin values with locally weighted scatterplot smoothing best-fit curve. (b) Average hemoglobin values with 95% confidence intervals.
DHS and hemiarthroplasty patients were compared for hemoglobin values over time. In addition, hemoglobin levels were compared between patients undergoing prompt surgery (surgery commenced within 36 hours of admission) with patients who had delayed surgery for a non-medical cause (between 36 and 72 hours following admission). The GEE models investigated differences between surgical procedures (fitted with factors of numbers of days since admission, type of surgical procedure, and interaction) and influence of delay to surgery (fitted with factors of numbers of days since admission, type of surgical procedure, and surgery delay). Additionally, hemoglobin blood loss to D2 was assessed using analysis of covariance (ANCOVA). The analyses of D2 hemoglobin values included predictors for D0 hemoglobin, type of surgical procedure, and surgery delay. Changes in hemoglobin from D0 to D2 were calculated from the adjusted means from the ANCOVA model.

Overall analysis used a conventional two-sided 5% significance level, and pair-wise comparisons were adjusted for multiple comparisons using a two-sided 1% significance level. All analyses were produced using SPSS software (version 20.0, SPSS Inc., Chicago, IL, USA).

### Results

Mean age of the patient cohort was 83 years (DHS: 80.5 years; hemiarthroplasty: 84.4 years; range: 58–98 years; standard deviation [SD]: 10 years), and preoperative hemoglobin was 126.3 g/L (range: 93–168 g/L; SD: 12.9 g/L).

There were significant reductions in hemoglobin over time (p<0.001); specifically, the drop in hemoglobin values between the preoperative period and the lowest adjusted mean value (on D5) was 31.1 g/L.

#### Table 2. Changes in Hb in the perioperative period from Day 0 until Day 5.

| Day       | n-value | Hb adjusted mean (g/L) | 95% CI (g/L) |
|-----------|---------|------------------------|--------------|
| Day 0 (preop) | 178     | 126.3                  | 124.4, 128.2 |
| Day 1     | 166     | 101.5                  | 99.6, 103.5  |
| Day 2     | 114     | 97.1                   | 95.0, 99.3   |
| Day 3     | 69      | 95.8                   | 93.5, 98.1   |
| Day 4     | 76      | 95.9                   | 93.8, 98.1   |
| Day 5     | 49      | 95.2                   | 92.8, 97.6   |

GEE: General estimating equation; Hb: Hemoglobin.

#### Table 3. Changes in Hb in the perioperative period by type of surgical repair.

| Surgery type grouping | Day       | n-value | Hb adjusted mean (g/L) | 95% CI (g/L) |
|-----------------------|-----------|---------|------------------------|--------------|
| Dynamic hip screw     | Day 0 (Preop) | 74     | 125.0                  | 121.9, 128.1 |
|                       | Day 1     | 68      | 99.5                   | 96.4, 102.6  |
|                       | Day 2     | 49      | 93.9                   | 90.6, 97.2   |
|                       | Day 3     | 32      | 93.9                   | 90.3, 97.5   |
|                       | Day 4     | 28      | 94.0                   | 90.1, 97.8   |
|                       | Day 5     | 23      | 93.3                   | 89.9, 96.7   |
| Hemiartthroplasty     | Day 0 (Preop) | 104    | 127.3                  | 124.9, 129.6 |
|                       | Day 1     | 98      | 102.9                  | 100.4, 105.4 |
|                       | Day 2     | 65      | 99.6                   | 96.7, 102.4  |
|                       | Day 3     | 37      | 96.9                   | 94.1, 99.8   |
|                       | Day 4     | 48      | 97.3                   | 94.7, 99.8   |
|                       | Day 5     | 26      | 96.7                   | 93.4, 99.9   |

GEE: General estimating equation; Hb: Hemoglobin.
(p<0.001) was noted between D1 and D2 (97.1 g/L) postoperatively. However, there were no statistically significant changes between D2 and D3 (p=0.131), from D3 to D4 (p=0.881), or from D4 to D5 (p=0.483) (Table 2).

Comparison between types of surgical procedures showed statistically significant differences in hemoglobin (p=0.046) over all postoperative measurement points. DHS patients consistently had lower average hemoglobin values than hemiarthroplasty patients (Table 3). The average change from D0 to D5 was 31.7 g/L for DHS patients and 30.6 g/L for hemiarthroplasty patients.

For both DHS and hemiarthroplasty, the drop was greatest on the first 2 days postoperatively, after adjusting for D0 values and surgical delay (Table 4). DHS patients had 4.6 g/L greater mean hemoglobin reduction compared to hemiarthroplasty patients (p=0.043, 95% confidence interval [CI] 9.12, 0.15 g/L), with the hemoglobin values experiencing the greatest decrease from D0 to D1. The trend of hemoglobin changes over time showed no statistically significant differences between either forms of surgery (interaction p value=0.414). Therefore, although the decrease in hemoglobin was

| Surgery type grouping | Day      | n-value | Hb Adjusted Mean (g/L) | 95% CI (g/L) |
|-----------------------|----------|---------|------------------------|--------------|
| DHS                   | Day 0 (Preop) | 54       | 124.0                  | 120.9, 127.1 |
|                       | Day 1     | 50       | 99.2                   | 96.1, 102.3  |
|                       | Day 2     | 35       | 94.8                   | 91.6, 98.1   |
|                       | Day 3     | 20       | 93.5                   | 90.2, 96.8   |
|                       | Day 4     | 20       | 93.6                   | 90.2, 97.0   |
|                       | Day 5     | 17       | 93.0                   | 89.7, 96.3   |
|                       | Day 0 (Preop) | 20       | 125.5                  | 122.1, 128.9 |
|                       | Day 1     | 18       | 100.7                  | 97.4, 104.0  |
|                       | Day 2     | 14       | 96.3                   | 92.8, 99.8   |
|                       | Day 3     | 12       | 95.0                   | 91.2, 98.7   |
|                       | Day 4     | 8        | 95.1                   | 91.4, 98.7   |
|                       | Day 5     | 6        | 94.5                   | 90.7, 98.3   |
| Hemiarthroplasty      | Day 0 (Preop) | 71       | 127.2                  | 124.7, 129.7 |
|                       | Day 1     | 66       | 102.4                  | 99.8, 105.0  |
|                       | Day 2     | 45       | 98.0                   | 95.3, 100.8  |
|                       | Day 3     | 26       | 96.7                   | 93.9, 99.4   |
|                       | Day 4     | 29       | 96.8                   | 94.2, 99.4   |
|                       | Day 5     | 20       | 96.2                   | 93.3, 99.0   |
|                       | Day 0 (Preop) | 33       | 128.7                  | 125.5, 131.8 |
|                       | Day 1     | 32       | 103.8                  | 100.7, 107.0 |
|                       | Day 2     | 20       | 99.5                   | 96.2, 102.7  |
|                       | Day 3     | 11       | 98.1                   | 94.6, 101.7  |
|                       | Day 4     | 19       | 98.3                   | 95.1, 101.5  |
|                       | Day 5     | 6        | 97.6                   | 94.0, 101.3  |

DHS: Dynamic hip screw; GEE: General estimating equation; Hb: Hemoglobin.

Table 4. Analysis of changes in Hb levels from D0 to D2. Statistically significant changes in Hb using the ANCOVA model are observed between D0 and D2 after adjusting for D0 Hb levels, type of surgery and surgical delay.

Table 5. Analysis of changes in Hb levels in the perioperative period. No statistically significant changes in Hb were observed when comparing prompt surgery with 36–72 hour delay, after adjusting for day of Hb levels and type of surgical repair.

DHS: Dynamic hip screw; GEE: General estimating equation; Hb: Hemoglobin.
greater from D0 for DHS, the pattern of change was similar between types of surgery.

There were no statistically significant differences in hemoglobin levels for surgical delay (p=0.389) (Table 5) after adjusting for number of days since admission and type of surgery (Figure 2). The decrease in hemoglobin from D0 values was greatest until D2; hence, further detailed analysis was conducted for this time period.

Discussion

Although expeditious surgery for patients with hip fractures has benefits for patient recovery and return to function, there is no improvement in postoperative hemoglobin values. Patients who undergo DHS fixation lose more blood overall (unequivocally within the first 2 days postoperatively), a finding which is not affected by prompt surgery. If surgery occurs within 72 hours of the first hemoglobin reading, then repeating this preoperatively is unnecessary.

The results show a mean hemoglobin decrease of 31.1 g/L for all patients in the first 5 days postoperatively. Interestingly, the present study showed that the drop in hemoglobin continues until D5; however, reductions between consecutive days were only significant until D2. Hence, we recommend D2 for the most timely analysis and subsequent management of postoperative hemoglobin. Our analysis in bleeding kinetics within acute fractured NOF patients parallels findings of a French study by Irisson et al., who investigated the fall in hemoglobin in elective lower limb arthroplasty. Irisson et al. demonstrated that while the most significant blood loss occurred between the end of surgery and D1, the fall in hemoglobin ceased by D3. It is reasonable to assume that the observed decrease in hemoglobin is caused by factors including bleeding from the wound site, bleeding into soft tissues, loss in drains, and the dilutional effect of postoperative fluids. Furthermore, complex pathological processes such as decreased erythropoiesis secondary to a large inflammatory response from surgery and decreased intestinal absorption and mobilization of iron also contribute to postoperative hemoglobin drop.

Based on the findings from this study, surgeons should be aware that patients’ preoperative hemoglobin should be able to withstand a minimum drop of 31.1 g/L. When considering the upper and lower limits of the 95% CIs of D0 and D2, respectively, a preoperative hemoglobin of 40 g/L above the institution’s transfusion trigger value (TTV) is recommended to allow for the predicted drop in hemoglobin and to avoid transfusion. This level can be achieved by preoperative transfusion and/or iron replacement (with or without erythropoietin), with decisions made on a case-by-case basis. Further justification for the surgical prerequisite stems from previous studies, which suggest that a low D0 hemoglobin increases the necessity of transfusion (and its associated risks), in addition to increased morbidity and mortality. Halm et al. showed that patients with higher preoperative hemoglobin had a shorter length of stay, lower morbidity, and lower readmission within 60 days of discharge. Gruson et al. followed 395 patients over the age of 65 and similarly found that hospital length of stay and mortality at 6 and 12 months postoperatively were higher for patients with preoperative anemia. In fact, it was shown that patients were twice as likely to die in hospital compared with non-anemic patients (odds ratio 2.0, p=0.3). This trend is supported by a study by Ho et al., who found that preoperative hemoglobin of less than 110 g/L was associated with increased mortality at 12 months postoperatively. Importantly, the Nottingham Hip Fracture Score, one of the most commonly used and reliable predictors of mortality post-hip fracture fixation surgery, specifically includes preoperative hemoglobin in its mortality predicting score due to the high association with mortality.

This study demonstrated that the hemoglobin value taken on postoperative D2 represents the largest drop in a patient’s circulating hemoglobin, with statistical and
clinical significance. We conclude that D1 postoperative hemoglobin values may provide false reassurance to clinicians monitoring patients who have undergone a fractured NOF procedure. The evidence shows that the hemoglobin value might be above the TTV on D1 but may fall below TTV due to the continued and significant fall in hemoglobin. In effect, a hemoglobin value measured on D1 might provide false assurance to the clinician and will have fallen further at D2. Within the study cohort of 178, 14 patients (7.9%) who had a ‘falsely high’ hemoglobin value were detected at D1, which subsequently fell further at D2 to below the TTV value. However, 7.9% is a fairly conservative estimation, considering that these 14 patients were within the 102 patients who had both D1 and D2 blood samples taken.

Considering specific values, the data show that the average statistically significant fall in hemoglobin between D1 and D2 was from 101.5 g/L (95% CI 99.6, 103.5 g/L) to 97.1 g/L (95% CI 95.0, 99.3 g/L) for all fixations of NOF fractures. This decrease traverses the value of 100 g/L, which is typically the threshold for anemia.[22] Though this threshold has been historically relevant for transfusions,[23] with increased awareness of risks associated with transfusion, more restrictive transfusion policies are now favored. Despite this, patients with symptomatic anemia with hemoglobin less than 100 g/L are still recommended to undergo a transfusion.[24]

Additionally, it may be concluded that the average patient undergoing NOF fracture fixation becomes anemic on D2 and not on D1. This adds further weight to the idea of routinely testing patients on postoperative D2 and not D1. If D2 hemoglobin level is more sensitive for anemia, affected patients can be reliably identified, and appropriate measures to restore their hemoglobin to acceptable levels can be commenced. This is important because anemic patients are more likely to require a transfusion if their hemoglobin is not properly managed.[25,26]

Of chief importance to the orthopedic surgeon should be the limitations anemic patients might have when working with rehabilitation services. Young et al. described that patients experiencing anemia-related lethargy may have a reduced functional status, resulting in increased time to discharge and a potentially higher postoperative infection rate.[27] Lawrence et al. showed that higher postoperative hemoglobin levels were associated with increased functional status as measured by walking distance.[28] Dunne et al. found that patients who were anemic postoperatively (defined by hematocrit less than 36) had increased mortality, incidence of pneumonia, and length of hospital stay.[29] A hemoglobin level of less than 100 g/L has been shown to be associated with increased likelihood of wound infection rates in vascular surgery,[30] a trend which has also been confirmed in total joint arthroplasty.[31] Early intervention in treating low hemoglobin was shown to reduce postoperative transfusion frequency and number of units, as well as postoperative infection rates in orthopedic patients.[19,32] Collectively, this research adds significant justification to the argument for timely hemoglobin monitoring in order to predict, detect, and treat anemia promptly.[7–16]

Jointly, the resource and subsequent financial burden of hip fracture surgery is significant. The estimated cost of collecting, transporting, and processing a single full blood count sample is £6.[33] Individually, while this may appear to be an insignificant sum, when considering the number of patients undergoing hip fracture surgery (currently approximately 70,000 per year and projected to increase to 101,000 by 2020) in the context of an aging population, the financial burden runs into thousands of pounds per annum per center and is set to increase.[34] Moreover, after consideration of the risks associated with the practice of phlebotomy—including but not limited to bruising/hematoma, phlebitis/bacteremia, and needle stick injuries—a greater evidence base should be employed to make decisions regarding postoperative blood testing. Therefore, a protocol for efficacious blood sampling would reduce the number of samples required for hemoglobin analysis, in turn reducing the risk to patient and practitioner.

Evidence has shown that certain groups require daily monitoring of hemoglobin levels. Carson et al. found that surgical patients with cardiovascular disease had a greater incidence of morbidity and mortality if they had a hemoglobin level of 100 g/L or less.[35] With regards to chronic disease in the elderly population, patients with chronic renal impairment have been shown to have an increased incidence of transfusion in the perioperative period;[36] thus, this group should also be given special consideration. With regards to this study, patients receiving some form of anticoagulation therapy were excluded due to the fact that this subgroup intrinsically has significant comorbidities and should therefore be monitored on an individual basis. Finally, anticoagu-

Table 6. Defining factors for ‘at risk’ patient.

| ‘At risk’ groups: |
|------------------|
| 1. Patients with preoperative hemoglobin level of <32 g/L above the center’s transfusion trigger value. |
| 2. Patients taking any form of anticoagulation therapy. |
| 3. Patients with underlying chronic renal or cardiac disease. |
lation therapy has been shown to facilitate blood loss,[37] so levels of hemoglobin should be monitored with greater attention, beginning from postoperative D1.

These aforementioned ‘at risk’ patient groups (as defined in Table 6) require closer observation due to greater variance in physiology (such as patients with renal or cardiovascular disease) and coagulation (patients receiving anticoagulation therapy).

Conflicts of Interest: No conflicts declared.

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