Prevalence of anaemia before major joint arthroplasty and the potential impact of preoperative investigation and correction on perioperative blood transfusions

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Background. Preoperative investigation and treatment of anaemia is recommended before orthopaedic surgery. We measured the prevalence of anaemia among admissions presenting for elective major joint arthroplasty (MJA), assessed their transfusion requirements, and investigated factors associated with perioperative blood transfusion.

Methods. All admissions to a dedicated elective orthopaedic hospital during 2000–2001 were studied. The patients’ database was merged with the haematology and transfusion databases. Population estimates for different types of anaemia and their blood transfusion requirements were generated using local reference ranges (males, 130 g litre⁻¹; females, 115 g litre⁻¹).

Results. One thousand three hundred and twenty-two admissions were included; haematology data were complete for 1142 (544 primary hip, 490 primary knee, 77 revision hip, 31 revision knee). About 19.6% were anaemic [7.1% haemoglobin (Hb) <110 g litre⁻¹; 1.6% Hb <100 g litre⁻¹]. Overall, 21.3% of admissions were transfused (mean 0.58 units per case: 95% CI 0.50–0.61). For anaemic admissions, 42.0% were transfused (mean 1.11 units per case: 95% CI 0.90–1.32). Mean red cell use for admissions with normocytic normochromic anaemia (12.7% of admissions) and hypochromic anaemia (4.6%) was 1.04 (95% CI 0.78–1.31) and 1.14 (95% CI 0.71–1.57) units per admission, respectively. Factors strongly associated independently with transfusion were preoperative haemoglobin ≤110 g litre⁻¹ (odds ratio: 13.92 (95% CI 7.77–24.9)) and revision hip surgery (OR: 17.80 (9.59–33.02)).

Conclusions. The prevalence of preoperative anaemia among admissions undergoing elective MJA is approximately 20%. Patients most likely to avoid transfusions with preoperative intervention are those with low haemoglobin undergoing revision hip surgery.

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Major orthopaedic surgery uses a significant proportion of blood stocks.1 Red cell transfusions are necessary because of perioperative blood loss, and are more likely to be required if patients are anaemic before operation.2 3 It is often suggested that anaemic patients should be identified and investigated before surgery, and where possible the anaemia corrected. Although this has the potential to reduce perioperative red cell transfusions, few studies have evaluated the likely impact of preoperative interventions on blood use. This issue is currently relevant for a number of reasons. First, surgical and anaesthetic techniques have decreased blood loss compared with previously published work; secondly, the use of restrictive transfusion triggers after operation has been widely adopted since the publication of evidence-based guidelines;2 4 and thirdly, blood is becoming increasingly scarce and expensive due to
decreasing donation rates and increased production costs. In addition, current pressure to minimize waiting times and shorten hospital stays mean that delaying surgery in order to perform preoperative investigations and interventions to treat anaemia should be based on evidence of clinical effectiveness. There is a potential conflict between the need to improve efficiency of patient flow and the guidance of the Department of Health Document ‘Better Blood Transfusion’, which encourages preoperative identification and correction of anaemia before surgery.\(^5\)\(^6\)

There are no recent published studies describing the epidemiology of anaemia in admissions presenting for elective major orthopaedic surgery or its importance as a risk factor for perioperative transfusion. The primary aim of this study was to determine the prevalence and characteristics of preoperative anaemia in admissions undergoing elective major joint arthroplasty (MJA), namely primary and revision hip and knee arthroplasty. Secondary aims were to investigate factors associated with increased transfusion risk in this patient group and the relationship between preoperative anaemia and overall blood use for this type of surgery.

Methods

The study was carried out in the form of a retrospective audit. We obtained guidance from the local regional ethics committee that ethical review was not required. Guidelines from the Data Protection Act were followed and data were anonymized after linkage was done.

Patients and setting

We used data for all admissions that were operated on at a specialized Scottish orthopaedic hospital [The Princess Margaret Rose Hospital (PMR), Edinburgh], which performed only elective orthopaedic procedures, between 1 August 2000 and 31 July 2001. During this period, 16 surgeons practiced in the hospital. There was no universally agreed transfusion protocol in place during the period reviewed, and details of transfusion triggers used by individual clinical teams were not available. Intraoperative cell salvage was not used during the period analysed; preoperative erythropoietin + autologous pre-donation were not routine practice and were never used during the study period. No patients received autologous blood transfusion; all transfusions were donated allogeneic red blood cells.

Data sources and management

We used data recorded during routine patient management from the hospital’s computerized information systems. Three data sets were accessed; each data set was obtained in Excel files and data sets were imported to Microsoft Access (Access 2000, version 9) for linkage.

Data set 1: patients’ data set from Patient Administration System database

Admissions’ identifiers were obtained, namely surname, forename, sex, date of birth, age, hospital ID, date of hospital admission, date of hospital discharge, and operation code.

Data set 2: hospital haematology laboratory data

The extract from the laboratory database contained the following haematological results: haemoglobin (Hb) values, mean cell volume (MCV), mean cell haemoglobin (MCH), and the sample request date on patients’ samples submitted from the PMR hospital between 1 July 2000 and 31 July 2001 (1 month before study period to end of study period).

Data set 3: blood bank data

From the blood bank database, we obtained all transfusion records for all admissions that had any request forms originating from PMR between 1 July 2000 and 31 August 2001. The extract from the blood transfusion database for each patient were: sample request date, group and save (G&S), units cross-matched, number of red blood units cell issued, and number of red cell units returned.

After extraction of the data from the three databases, a linkage was undertaken.

Patients Administration System data set linkage with the haematology data set

All blood sample records were considered and those with identical forename surname, gender, and date of birth (4 fields) to an admission record were identified and designated as linked (complete match). Blood sample records with identical 3, 2, or 1 field (partial matches) were considered sequentially and checked manually. Particular attention was paid to non-matching hospital numbers, which were known to be inconsistently used. Partial matches were only included in the study data set if considered valid after manual checking. As a final sense check, the sample request date was used to exclude those blood samples obtained before or after the relevant study period. After the linkage process was completed, some admissions had more than one haematological record. For the purpose of the study, the pre-admission haematological record was defined as the sample request date within 1 month before the hospital admission date. If there was more than one result, the one closest to the admission date was used in the analysis. The rest of the haematological records were subsequently deleted. The final linked data set was used to generate the estimates of anaemia prevalence and to determine the characteristics of the anaemia observed.

Linkage with the blood bank database

The study data set was subsequently linked to the transfusion data set. For this linkage, we included only the
records that showed complete matches and ignored all other records. After linking the blood transfusion data set, some admissions had more than one transfusion record. Events related to the study were defined as: (i) the records of G&S requests submitted within 1 month before admission and during hospital stay (the period between hospital admission and discharge dates); (ii) Red Cell Units Assigned (RCUA); and (iii) Red Cell Units Transfused (RCUT) were defined as records created by the Blood Bank within 1 week before hospital admission and during the hospital stay. Red cells transfused were derived from those assigned but not returned during the period from 1 week before hospital admission to hospital discharge after the procedure.

**Analysis**

We calculated the proportion (95% confidence intervals) of admissions that were anaemic, defined as a haemoglobin concentration (Hb) less than reference range before surgery. We also calculated the proportion with Hb<110 and <100 g litre\(^{-1}\) as indices of more severe anaemia. We classified anaemia types based on MCV and MCH into: (i) normochromic normocytic types (primary aetiology likely to be ‘anaemia of chronic disease’); (ii) hypochromic anaemia (MCH<27; potentially responsive to preoperative iron); and (iii) other types of anaemia.

For admissions with successful linkage to the transfusion database, we described the distribution of red cell unit use in relation to anaemia groups (median, quartiles; range), and generated population estimates of blood use (mean, 95% confidence interval). For the subgroups that received red cell transfusions, we calculated the median (1st, 3rd quartile; range) of units received.

**Overall red cell use in relation to preoperative haemoglobin concentration**

For different preoperative haemoglobin concentration ranges, we plotted the mean red cell use per patient and the proportion of patients transfused in each preoperative haemoglobin group.

**Factors associated with perioperative red cell transfusion**

We used available data to explore variables associated with the chance of perioperative transfusion using forward stepwise binary logistic regression. The variables examined were gender (categoric), age (continuous), preoperative haemoglobin value (as categoric variables with three groups: ≤110, 111–130, and 131–150 g litre\(^{-1}\)), and procedure (as categoric variable with four groups: primary knee, revision knee, primary hip, and revision hip). The outcome was exposure to perioperative blood transfusion (binary outcome). Variables were entered into the model if \(P\leq0.05\) on univariable analysis and excluded on multivariable analysis if \(P\geq0.1\). SPSS version 14 was used for analysis.

**Results**

**Characteristics of the cohort**

Between 1 August 2000 and 31 July 2001, 3417 admissions were recorded in the Patients Administration System. Of these, 1322 (38.6%) admissions underwent MJA. The mean (range) age for these admissions was 68 (15–91) yr. After linkage, 1142 (86.4%) of these admissions had preadmission haematology results (Fig. 1). The procedures performed in these cases were primary hip (544), primary knee (490), revision hip (77), and revision knee (31).

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**Proportion of total blood use in relation to preoperative haemoglobin concentration**

We explored the overall use of blood by anaemic patients by plotting the proportion of the total red cells used by the study cohort by patients in each preoperative haemoglobin group.

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**Fig 1** Flow diagram showing the derivation of the study data set.
**Anaemic admissions**

About 19.6% (210/1142) admissions were anaemic compared with local population reference ranges (males $<130$ g litre$^{-1}$; females $<115$ g litre$^{-1}$) and linked to the transfusion data. The proportion of admissions with various degrees and types of anaemia is shown in Table 1. A comparison of admissions for which linkage was and was not obtained is shown in Table 2. This indicated a low probability of selection bias from the non-linked admissions. All estimates of blood use for anaemic patient groups are based on the 210 linked records.

**Blood transfusion requirements**

Linkage to transfusion data was successful for 1059 (92.7%) of admissions with haematology data. Overall, the proportion of admissions transfused was 225 (21.3%). For the entire cohort, mean transfusion requirement was 0.58 (95% CI: 0.50–0.66) red cell units per case.

Overall, 88/210 (42%) of anaemic admissions were transfused (number of red cell units assigned less than number returned), with a total of 106 transfusion episodes. Overall mean red cell use for anaemic admissions was 1.11 (95% CI: 0.90–1.32) red cell units per patient episode. A breakdown describing transfusion according to procedure type, together with the number of red cell units used for the transfused cases, is shown in Table 3. Transfusion was more common among anaemic patients undergoing hip surgery, especially revision hip procedures.

**Table 1** Prevalence of different types of anaemia for all anaemic admissions that underwent MJA with available preoperative haemoglobin (Hb), MCV, and MCH ($n=210$)

<table>
<thead>
<tr>
<th>Type of anaemia</th>
<th>Number</th>
<th>Proportion (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb $&lt;110$</td>
<td>76</td>
<td>36.2% (6.9–7.3)</td>
</tr>
<tr>
<td>Hb $&lt;100$</td>
<td>13</td>
<td>8.1% (1.5–1.7)</td>
</tr>
<tr>
<td>Normocytic normochromic</td>
<td>135</td>
<td>64.3% (12.0–13.4)</td>
</tr>
<tr>
<td>Hypochromic varieties</td>
<td>49</td>
<td>23.3% (4.3–4.9)</td>
</tr>
<tr>
<td>Other types of anaemia</td>
<td>26</td>
<td>12.4% (2.3–2.5)</td>
</tr>
</tbody>
</table>

**Table 2** Characteristics of anaemic admissions ($n=224$) that were successfully linked and those not linked to the transfusion data set. There were no significant differences between the groups. LOS, length of hospital stay; Rhip, revision hip surgery; Rknee, revision knee surgery

<table>
<thead>
<tr>
<th>Successful linked, $n=210$</th>
<th>Non-linked, $n=14$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb [mean (SD)] g litre$^{-1}$</td>
<td>113.3 (10.5)</td>
</tr>
<tr>
<td>Number (% with Hb $&lt;110$ g litre$^{-1}$)</td>
<td>75/210 (35.7)</td>
</tr>
<tr>
<td>Number (% with Hb $&lt;100$ g litre$^{-1}$)</td>
<td>17/210 (8.1)</td>
</tr>
<tr>
<td>Age [mean (range)]</td>
<td>68.7 (24–91)</td>
</tr>
<tr>
<td>Sex</td>
<td>45.7% F and 54.3% M</td>
</tr>
<tr>
<td>LOS [mean (SD)]</td>
<td>9.1 (5.5)</td>
</tr>
<tr>
<td>Hip ($n=107$)</td>
<td>103</td>
</tr>
<tr>
<td>Knee ($n=87$)</td>
<td>80</td>
</tr>
<tr>
<td>Rhip ($n=18$)</td>
<td>16</td>
</tr>
<tr>
<td>Rknee ($n=12$)</td>
<td>11</td>
</tr>
</tbody>
</table>

**Table 3** Summary of the number of anaemic MJA admissions with transfusion data ($n=210$ admissions) broken down by type of procedure, the proportion who were transfused, and the median (1st, 3rd quartile) number of red cell units transfused to the subgroup who received red cell transfusions

<table>
<thead>
<tr>
<th>Hip</th>
<th>Knee</th>
<th>Rhip</th>
<th>Rknee</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of admissions</td>
<td>104</td>
<td>79</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Number (%)</td>
<td>54 (52)</td>
<td>18 (23)</td>
<td>12 (67)</td>
<td>4 (36)</td>
</tr>
<tr>
<td>Median (Q1–Q3) units transfused</td>
<td>2 (2–3)</td>
<td>2 (2–2.25)</td>
<td>3 (2.25–4.75)</td>
<td>2 (2–2.75)</td>
</tr>
</tbody>
</table>

**Normochromic normocytic anaemia**

Mean preoperative Hb for admissions with normochromic normocytic indices ($n=135$) was 115.8 (8.7) g litre$^{-1}$. About 52/135 (38.5%) of these admissions received perioperative transfusions. Overall mean red cell use was 1.04 (95% CI: 0.78–1.31) units per case. For the transfused cases, the median (1st, 3rd quartile; range) red cell units received was 2 (2, 3; 1–7).

**Hypochromic anaemia**

Mean preoperative Hb for anaemic admissions with hypochromic indices ($n=49$) was 104 (10.3) g litre$^{-1}$. Around 22/49 (44.9%) of these cases received perioperative transfusions. Overall mean red cell use per case was 1.14 (95% CI: 0.71–1.57). For the transfused cases, the median (1st, 3rd quartile; range) red cell units received was 2 (2, 3; 1–7).

**Red cell use in relation to preoperative haemoglobin concentration**

Figure 2 summarizes the proportion of patients transfused and mean numbers of red cell units received for each preoperative haemoglobin range. For patients with Hb $<110$ g litre$^{-1}$, 76 admissions had perioperative transfusion records; of whom, 67.1% were transfused. Overall mean red cell use per case was 1.75 (95% CI: 1.39–2.11). For Hb $<100$ g litre$^{-1}$, 17 admissions had perioperative transfusion records; of whom, 88.2% were transfused. Overall mean red cell use per case was 2.53 (95% CI: 1.67–3.38).

**Factors associated with perioperative red cell transfusion**

Results of the regression analysis are shown in Table 4. Independent predictors of transfusion were patient age, preoperative haemoglobin band, and the procedure performed. The strongest independent associations with greater risk of transfusion were with a haemoglobin value $<110$ g litre$^{-1}$ and revision hip surgery.

**Overall red cell use in relation to preoperative haemoglobin concentration**

Although rates of transfusion were highest for anaemic patients, these patients used a relatively small proportion of total blood use by the MJA cohort (Fig. 3). Twenty per
cent of all red cell units transfused were administered to the 7% of patients with a preoperative haemoglobin concentration \( <110 \) g litre\(^{-1}\).

**Discussion**

In our cohort, 19.6% of admissions presenting for major orthopaedic joint arthroplasty were anaemic before operation, but in most cases, the anaemia was minor and only 7.1% and 1.6% had a preoperative haemoglobin concentration \( <110 \) and \( <100 \) g litre\(^{-1}\), respectively. Sixty-five per cent of anaemic admissions had normochromic normocytic indices, consistent with anaemia of chronic disease; only 23% had hypochromic indices that may have responded to iron therapy alone. Overall, 21.3% of admissions received perioperative transfusion with an overall mean transfusion requirement of only 0.58 red cell units per case. Of the anaemic admissions, 42% were transfused.
perioperatively receiving a mean 1.11 red cell units per case. The factors most strongly associated with perioperative transfusion were a low preoperative haemoglobin and revision hip surgery, although greater age was also associated with greater transfusion risk. Patients with a preoperative haemoglobin concentration ≤110 g litre⁻¹ used 20% of total red cell use by the cohort.

Our study included a large sample size comprising all admissions admitted to a dedicated elective orthopaedic hospital. The chance of selection bias or inclusion of misclassified admissions was therefore small. Despite applying stringent criteria, our linkage procedure showed a high success rate for both the haematology data and transfusion data set, which also minimized the chance of selection bias in the sample. The majority of admissions had a haemoglobin value measured at the pre-admission clinic 2–4 weeks before surgery, which represents the time most admissions are currently pre-assessed before elective orthopaedic surgery. It is possible that some patients were transfused before hospital admission or before surgery, but these transfusions should have been captured during linkage to the transfusion database, which included all requests for 1 month before surgery. There were potential errors from linkage, but we used several patient identifiers, together with manual checks, to minimize the chance of inaccuracies. We assumed that admissions that only had a G&S performed had received no blood and that the balance between blood issued and returned was an accurate representation of transfusion. Although our study was retrospective, we believe these assumptions were valid and in our experience this is a more accurate method of measuring transfusions retrospectively than case note review. Importantly, there was no autologous pre-donation programme at the time of the study, and perioperative cell salvage was not used; both were potential confounders if unaccounted for.

We defined anaemia using local laboratory and population reference ranges, because these were the values used by clinicians making transfusion decisions. The range for males (<130 g litre⁻¹) is identical to WHO values, but we used a slightly lower cut-off for females than recommended by WHO (<115 vs 120 g litre⁻¹). Our estimates of anaemia prevalence were therefore slightly lower for females than would be generated using a cut-off of 120 g litre⁻¹. As this was a retrospective study using hospital databases, it was not practical to describe the transfusion

Table 4 Results of binary logistic regression analysis (n=816 patients)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio (95% CI)</th>
<th>Significance (relative to index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (per increased year)</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Preoperative haemoglobin (g litre⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>131–150 (index)</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>111–130</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>≤110</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Procedure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee (index)</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Revision knee</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Hip</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Revision hip</td>
<td>1.03 (1.02–1.05)</td>
<td>P&lt;0.001</td>
</tr>
</tbody>
</table>

Fig 3 Total number of units transfused to patients in each preoperative haemoglobin band. A total of 679 units of RBC transfused for 1079 patients. Number of patients in each band was: 4 (81–90), 16 (91–100), 62 (101–110), 130 (111–120), 274 (121–130), 330 (131–140), 200 (141–150), 67 (151–160), and >160 (14).
triggers used. Our data reflect the practice of the 16 surgeons practicing during the study period and their clinical teams. Data were collected during initiatives to decrease transfusion triggers in line with transfusion guidelines published around the period examined. The relatively low perioperative transfusion rates were consistent with restrictive transfusion practice.

We classified the type of anaemia using red cell characteristics. This showed that most admissions had normochromic normocytic anaemia, which is consistent with a population that is usually elderly and has a high prevalence of rheumatoid arthritis. Although some admissions with normochromic normocytic anaemia may have some response to iron therapy alone, it would be anticipated that correction of anaemia without blood transfusion would require erythropoietin treatment, because of bone marrow suppression or under-activity resulting from chronic inflammation or renal impairment. Several studies have shown that anaemia can be corrected with erythropoietin plus/minus iron therapy before orthopaedic surgery, but these did not evaluate the likely impact on blood use. In our cohort, mean red cell use for these admissions was only 1.04 units per case. Our data suggest that preoperative correction of normochromic normocytic anaemia is unlikely to result in a major reduction in overall blood use for MIA when baseline transfusion requirements are similar to those in our centre, although such interventions may increase rates of transfusion avoidance. Our mean estimates for transfusion requirement may have decreased further since these data were collected, because perioperative cell salvage has subsequently become standard care for revision cases and high-risk procedures.

Treatment with oral or i.v. iron therapy is a cheaper treatment, which could be effective for admissions with iron deficiency anaemia or reduced iron stores. We used the presence of hypochromasias as a simple index of possible iron deficiency and found <5% of all cases with this type of anaemia. Additional investigations such as ferritin or soluble transferrin receptor measurement may have identified more admissions with iron deficiency, but are not routinely performed in our centre. Goodnough and colleagues studied 30 anaemic patients presenting for orthopaedic surgery and found that 30% had evidence of iron deficiency and 53% had unclassified anaemia of chronic disease. These proportions are similar to those in our much larger cohort, in which 23% of all anaemic admissions had hypochromasias. Several studies have investigated the effectiveness of preoperative iron therapy alone in orthopaedic surgery. Studies comparing the use of iron alone with combined iron and erythropoietin therapy suggest that iron is not effective as a preoperative intervention. In contrast, Andrews and colleagues showed that preoperative iron therapy could increase the preoperative haemoglobin concentration in unselected anaemic admissions, but did not quantify the impact on red cell transfusions.

Although our data suggest that preoperative treatment of anaemia is unlikely to have a significant impact on overall blood usage, the multivariate analysis provided some indication of the patients whose chance of transfusion avoidance is most likely to increase with a package of blood-sparing interventions. Hip surgery, particularly revision hip procedures, was a strong independent risk factor for transfusion exposure together with low preoperative haemoglobin concentration. Preoperative treatment of patients with haemoglobin \( \leq 110 \text{ g litre}^{-1} \) undergoing primary or revision hip surgery is most likely to be a cost-effective means of decreasing transfusion exposure, particularly if combined with perioperative cell salvage. Our data suggest that this would have a modest impact on total blood use, but this hypothesis requires prospective testing.

In conclusion, we have shown that approximately 20% of admissions presenting for major elective orthopaedic arthroplasty are anaemic, but most have either mild anaemia or a normochromic normocytic anaemia that is unlikely to respond to simple interventions before operation. With modern surgical and anaesthetic management, overall blood use for these procedures is small. The group most likely to benefit from pre- and perioperative interventions to correct anaemia and salvage perioperative blood are patients with haemoglobin \( \leq 110 \text{ g litre}^{-1} \) or those undergoing revision hip surgery.

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### References