An algorithm for predicting blood loss and transfusion risk after total hip arthroplasty

Trevisan CL, Klumpp R, Auriemma L, Compagnoni R.

Abstract

Introduction

Blood loss and anemia management is a crucial part of a modern approach after total hip arthroplasty. Patients receiving blood transfusions had increased morbidity and longer lengths of stay compared to non-transfused patients. The aim of this study is to create an algorithm to predict the need of transfusion, give a safe point after that there is no need of further analysis and reduce the need of repetitive blood analysis in the days after surgery.

Methods

Retrospective study of 124 patients without ischemic heart diseases, severe systemic pathologies and treatment with anticoagulants who underwent surgery for primary total hip arthroplasty (THA) in two different Hospitals.

Trend of hemoglobin (Hb) levels in the first five days from surgery was analyzed. An algorithm was implemented to identify in the first two postoperative days the critical levels of Hb below which the risk of transfusion is high or it is necessary to continue with the blood tests. Specificity, sensibility and efficiency were calculated in relation to the capability of the algorithm to correctly identify transfused patients.

Results

The algorithm found a preoperative Hb ≥ 13 g/dl as a cut off between patients at low-risk or high-risk for transfusion.

When parameters were calculated taking account of the best efficiency with the least number of false negatives, the algorithm showed a specificity of 84% and a sensitivity of 70% with an efficiency of 80.6%.

Applying the algorithm, a first postoperative day Hb level > 10g/dl for low-risk patients and a second postoperative day Hb level > 11g/dl for high-risk patients led to exclude the risk of transfusion.

Conclusions

The algorithm suggested critical Hb levels to predict transfusion. In association with clinical data, the suggested Hb critical values may be useful to schedule lab tests and early discharge.

Introduction

In the last few years, rapid recovery protocols have been introduced for elective primary THA. These rapid recovery protocols are based on analysis of clinical care principles and pain management in combination with revision of organizational factors, giving an optimized peri-operative period that is safe for the patient (1,2).

Blood loss and anemia management is a crucial part of fast track surgery. Many data are published in literature about the transfusion rate after total hip arthroplasty, with incidence from 4.3% to 86.8% depending on surgeon and national protocols (3-5). An US Nationwide inpatient study reported an increase of blood transfusions after total hip arthroplasties from 11.8% in 2000 to 19.0% in 2009 (3). Two regional audits conducted in UK on the appropriateness of blood prescribing practice showed that in the orthopedic setting 47% and 50% of all red cells were transfused inappropriately, the highest level of all hospital specialties (6,7).

Patients receiving blood transfusions had increased in-hospital morbidity, longer lengths of stay, higher total charges and were less likely to actively participate to rehabilitation protocol compared to non-transfused patients (3,8).

Therefore, adherence to clinical practice guidelines supporting blood management and evidence-based restrictive strategy of red cell transfusion is an indispensable part of every fast track surgery protocol to reduce patient morbidity and enhance recovery (9).

In this regard, an instrument to predict hemoglobin values variation in the days after surgery and risk for transfusion should be useful to schedule an early but safe domestic discharge in fast track surgery.

Aim of this study is to evaluate the hemoglobin values in the days after total hip arthroplasty and to create an algorithm that could be a useful for predict the need of transfusion and give a safe point after that there is no need of further analysis permitting a safe domestic discharge. Secondary aim of this algorithm is to reduce the need of repetitive blood analysis in the days after surgery.

Methods

In this retrospective study were included 124 patients from two different consecutive series of patients who underwent surgery for total hip arthroplasty (THA) in two different Hospitals. A standard post-operative giving of saline, time of blood tests, and pain management with drugs that should not cause nausea or hypotension is adopted in both the hospitals.

The first group (Group A) includes 67 patients treated for primary THA, 36 men and 31 women with an average age of 63.9 years (29 - 80 y). Exclusion criteria were femoral fractures, rheumatic diseases, hematologic diseases, ischemic heart diseases, severe systemic pathologies and treatment with warfarin or other oral anticoagulants. A direct lateral approach was performed in 37 patients and an anterior mini-invasive approach in 30 patients. A reinfusion drain system was used in all patients and blood reinfused at an average time of 6 hours from the end of the surgical procedure. The drainage was maintained for about 24 hours, removed the morning after surgery. A blood test for hemoglobin values was performed the day before surgery, 4 hours after surgery and every morning for 5 days from surgery. An anti-thrombotic prophylaxis with Enoxaparin sodium was given 12 hours before surgery, 6 hours after surgery and every evening for at least 20 days, following the national guidelines for THA. A standard saline infusion of 1500 cc (100 cc/h for 15 hours) was given to all patients. Vital signs as blood pressure, heart rate, nausea were monitored continuously for the first 6 hours from surgery and then a standard protocol for stable patients was applied. Full weight bearing was allowed to all patients from the first day after surgery.

Four complications have been recorded in this group: two calcar fractures treated with a metallic cerclage, one transient lateral femoral cutaneous nerve palsy and a posterior cortical perforation without consequences. There were no cases of hematoma, delayed wound healing, infection or arthroplasty dislocation.

The second group (Group B) includes 57 consecutive patients who underwent primary THA in another hospital but performed by the same senior surgeon, 27 men and 30 women with an average age of 66.6 years (46-88 y). Exclusion criteria, anti-thrombotic prophylaxis, timing of blood tests after surgery and rehabilitation protocol were the same of the first group. No patient underwent a blood reinfusion in this group due to lack of this device in this hospital. A direct lateral approach was performed in 16 patients and an anterior mini-invasive approach in 41 patients.

Four complications has been recorded also in this group: one incomplete calcar fracture treated with additional cerclage, 1 posterior cortical perforation without consequences and 2 cases of hematoma. There were no cases of delayed wound healing, dislocation or infection. None of the recorded complications has evidenced any consequence on weight-bearing, discharge or final outcome.

In both groups, the trend of hemoglobin (Hb) levels was analyzed considering the preoperative, 4 hours post-operative level and the daily exams performed all the mornings in the first five days from surgery. A restrictive transfusion strategy has been applied and transfusion were prescribed when Hb was below 8 g/dl or for symptoms such as chest pain, orthostatic hypotension and/or tachycardia unresponsive to intravenous fluid supplementation.

Data were analyzed considering subgroups in relation to surgical approach, transfusion occurrence and the belonging to the group A or B as shown in table 2. An algorithm for the prediction of the risk of blood transfusion after total hip arthroplasty based on the trend of hemoglobin levels was created (see Statistical Analysis).

Statistical analysis

Descriptive statistical analysis summarized continuous data by mean and standard deviation (SD) or minimum and maximum values.

Categorical data were summarized by the number and percentage of individuals in each category.

Student t test for independent samples was used to compare continuous variables in normally distributed data. Fisher exact test or Person Chi² test were used to compare categorical data. A p value <0.05 was considered to be statistically significant.

An algorithm was implemented to identify in the first two postoperative days the critical levels of Hb below which the risk of transfusion is high or it is necessary to continue with the blood tests. Since the literature suggests a higher risk of transfusion in patients with low preoperative Hb, the algorithm provided two different pathways in relation to a preoperative Hb level greater than or less than a calculated critical value “Q”.

The first pathway of high risk patients with preoperative Hb < “Q” requested blood tests at day 1 and 2 whose critical values “X” and “R” determined the final risk level of each patient. The second pathway of low risk patients with preoperative Hb ≥ “Q” requested blood tests only at day 1 to decide their level of risk based on the critical value “Z” (Figure 1).

The algorithm was computed on Excel spreadsheets and tested for the evaluation of binary classifiers applying it to the data of the two samples of patients. “True positive” were considered those patients classified by the algorithm as at high risk for transfusion which were actually transfused, “true negative” those classified as at low risk for transfusion which were not transfused, “false positive” those patients classified as at high risk for transfusion which were not transfused and “false negative” those classified as at low risk for transfusion which were transfused,

Specificity (spec), sensitivity (sens), positive predictive value (PPV), negative predictive value (NPV) and efficiency (eff - percentage of true positives and true negatives) for each possible combination of the critical values were calculated.

The critical values for “Q”, “X”, “R” and “Z” were determined considering two criteria: those leading at the best efficiency with the least number of false negatives and those leading to a sensitivity and negative predictive value at 100%. The critical values were calculated separately for group A and B and for both groups together.

Results

Clinical parameters of the patients included in the study are described in table 1. Group A showed a significant difference with respect to group B in terms of ASA distribution (more favorable), lower percentage of anterior direct approach and lower percentage of transfused patients. Of the 124 enrolled patients, 35 were transfused (28,2%): 18 (51.4%) underwent blood infusion the first 24 hours after surgery, 27 (77.1%) in the first 48 hours and only 2 patients were transfused after 4 days or more from surgery.

Eighteen out of 71 patients (25.3%) operated by the direct anterior approach were transfused compared to 17 out of 53 (32.1%) for the lateral direct approach (NS, Fisher exact test). A significant lower percentage of patients operated by anterior approach underwent blood reinfusion (42.2% vs. 69.8%, p.<01 Fisher exact test).

Trend of Hb levels for all the patients, for group A and B and for subgroups are shown on table 2.

Preoperative Hb values in transfused patients were lower than values in patients not transfused ($p<0.05$) and Hb also remained lower after blood transfusion in the following days ($p<0.05$).

Trend of Hb levels in transfused and non-transfused patients was similar with a gradual fall until the 3° day and an essential stabilization the following days.

After computing the algorithm with patients data, the critical values for “Q”, “X”, “R” and “Z” were determined for group A and B and for both groups together (Table 3).

The algorithm showed a NPV between 89.8% and 94.6% and a PPV between 52.9% and 70% with an eff between 80.6% and 86%.

In group A, patients with a preoperative Hb levels < 13 g/dl and < 11 g/dl the first day after surgery were at high risk of blood transfusion while those with preoperative levels ≥ 13 g/dl where considered at high risk if at the first postoperative day Hb was < 10g/dl.

In this scenario, 25.4% of the patients were labelled as high-risk patients and 74.6% as low risk; nine patients out of 14 (64.3%) were correctly labelled as high-risk patients and 5 were not (35.7%).

In group B, patients with preoperative Hb levels < 13 g/dl and Hb < 10g/dl the first and/or the second postoperative day were identified as high-risk patients. In those with Hb levels ≥ 13 g/dl, Hb level < 9.5g/dl at the first postoperative day was the threshold to label the patient at high risk. In this scenario, 35.1% of the patients were labelled as high risk patients and 64.9% as low risk; nineteen patients out of 21 were correctly labelled as high risk patients (90.5%) and 2 were not (9.5%).

With both groups pooled together, whatever the preoperative Hb level, an Hb < 10g/dl the first and/or the second postoperative day was the best threshold to identify high risk patients. In this case, 29% of the patients were labelled as high-risk patients and 71% as low risk.

Twenty-eight patients out of the 35 transfused were identified by the algorithm as at high risk (80%) the remaining 7 being classified as at low risk (20%).

Critical values for the algorithm to classify correctly all the transfused patients at high risk (sensitivity and negative predictive value at 100%) are shown on Table 4. In this scenario, for patients with preoperative Hb ≥ 13 g/dl, a first postoperative day Hb level > 10g/dl led to exclude the risk of transfusion; for those with preoperative Hb < 13 g/dl, a second postoperative day Hb level > 11g/dl led to exclude the risk of transfusion;

Discussion

In this study, an algorithm was designed to identify individuals at risk of transfusion after THA by evaluating the hemoglobin levels in the first two days after surgery.

The model was developed based on retrospective data of 124 patients operated for hip replacement. The first finding is that the preoperative hemoglobin level of 13g/dl has proven a cutoff to distinguish two categories of patients with different risk for transfusion. This value has some evidence in the literature. In a 1999 study of 9482 patients, Bierbaum et al, found that the frequency of allogenic blood transfusion varied with respect to a baseline hemoglobin level of 130 grams per liter or less (10). In that same year, a post-hoc analysis of data from a study on Epoetin alfa has found that the placebo-treated patients with hemoglobin > 10 to < or = 13 g/dL had an approximately twofold greater risk of transfusion than patients with hemoglobin > 13 g/dL (11). Since the presence of preoperative anemia in patients operated on for hip replacement is estimated in 24% ± 9%, the definition of a precise threshold is important for preventive interventions (12). Actually, some studies took this value as a reference to decide on different preoperative strategies for reducing the risk of transfusions (13,14). Unfortunately, as described by observational studies in Europe, patient blood management measures such as iron status assessment and strategies to avoid transfusion are still underused (15).

Another achievement of the algorithm was the possibility to identify the hemoglobin values to place patients into categories of high or low risk of transfusion in the first two postoperative days. When the criteria of sensitivity and negative predictive value at 100% are used, the risk of transfusion is excluded when a first postoperative day Hb level is greater than 10g/dl for those with preoperative Hb ≥ 13 g/dl,; for those with preoperative Hb < 13 g/dl, when Hb level in the second postoperative day is greater than 11g/dl.

Although many studies have investigated the risk factors for blood transfusion in patients undergoing major orthopedic surgery, as far as we know, there are no studies with a methodological approach such as this in which the critical Hb values were identified in the first two days after surgery. This fact on one hand helps to avoid early discharge of the subjects considered at risk and on the other to be able to plan the real need for laboratory examination in relation to the patient's risk class. Based on our results, after controlling for the first one or two postoperative days, a further examination in low-risk subjects could be programmed at a distance if the clinical parameters are stable.

When the criteria of the best efficiency with the least number of false negatives are used, the algorithm evidenced a good efficiency (between 80.6 % and 86%) with negative predictor values between 89.8% and 94.6%. In this scenario, only 7 patients on 124 (5%) considered at low risk were transfused and only two patients included in the low risk group had a transfusion after 4 days from surgery. It is possible that the integration within the algorithm of clinical parameters and vital sign could help to identify correctly these patients. With these parameters, the number of low-risk patients who can be excluded by serial testing is between 65% and 75%.

The algorithm was implemented using data from two different groups of patients. They had similar management but they showed some differences. Group A had a more favorable ASA distribution, a systematic use of postoperative blood reinfusion, a prevalence of direct lateral approach and a lower transfusion rate.

Blood reinfusion can be considered a minor bias between the groups. It was performed just three hours after surgery, elevated the initial Hb levels after surgery and reduced transfusion rate but did not influence Hb trend the following days.

Rather than being a disadvantage, the use of two relatively homogeneous but somehow different groups is a point of strength of the study. Despite their differences, results obtained by the algorithm seemed consistent therefore potentially valid for all the patients candidate for primary THA not affected by ischemic heart diseases or severe systemic pathologies and no treated with warfarin or other oral anticoagulants.

The retrospective design of the study and the lack of integration of clinical parameters and vital sign within the algorithm are the main weakness of this study. Furthermore, it must be emphasized that no one of the patients in the study had incurred in intra- or perioperative complications at risk for unexpected bleeding. Therefore, the algorithm's predictive capability must be considered valid only in the absence of such complications.

In conclusion, this is the first time that an algorithm tries to predict the risk of blood loss and consequent need of transfusion with a restrictive blood management after THA. It suggests critical Hb levels to allocate patients in low-risk or high-risk classes and to schedule lab tests and early discharge.

The implementation with clinical signs would be ideal to make this algorithm more sensitive and specific and a prospective study is advisable to confirm results of this work on a larger cohort of patients having surgery for total hip arthroplasty.

References

1. Kehlet H, Comment. Fast-track hip and knee arthroplasty, The lancet Volume 381, No. 9878, p1600–1602, 11 May 2013 http://dx.doi.org/10.1016/S0140-6736(13)61003-X

2. Husted H, Lunn T H, Troelsen A, Gaarn-Larsen L, Kristensen B B, Kehlet H. Why still in hospital after fast-track hip and knee arthroplasty? Acta Orthop 2011; 82 (6): 679-84.

3. Saleh A, Small T, Chandran Pillai AL, Schiltz NK, Klika AK, Barsoum WK Allogenic blood transfusion following total hip arthroplasty: results from the nationwide inpatient sample, 2000 to 2009. J Bone Joint Surg Am. 2014 Sep 17;96(18):e155. doi: 10.2106/JBJS.M.00825.

4. Hart A, Khalil JA,Carli A,Huk, Zukor, Antoniou J Blood transfusion in primary total hip and knee arthroplasty. Incidence, risk factors, and thirty-day complication rates. J Bone Joint Surg Am. 2014 Dec 3;96(23):1945-51. doi: 10.2106/JBJS.N.00077.

5. A F. Chen, BA. Klatt, MD,MH Yazer, MD, JH. Waters, Blood Utilization After Primary Total Joint Arthroplasty in a Large Hospital Network HSS J. 2013 Jul; 9(2): 123–128. Published online 2013 Jun 21.doi:10.1007/s11420-013-9327-y

6. National Comparative Audit of Blood Transfusion. Comparative Audit of Red Cell Use in the Hospitals in the South West and West Midlands Regions. NCABT; 2008.

7. Northern Ireland Regional Transfusion Committee. Regional Appropriateness of Blood Transfusion Audit – Summary Report. NIRTC; 2006.

8. Browne JA, Adib F, Brown Te, Novicoff WM Transfusion rates are increasing following total hip arthroplasty: risk factors and outcomes. The Journal of Arthroplasty 29 Suppl. 2 (2014) 189–192 doi: 10.1016/j.arth.2013.03.035

9. Jørgensen CC, Petersen MA, Kehlet H; Lundbeck Foundation Centre for Fast-Track Hip and Knee Replacement Collaborative Group.Preoperative prediction of potentially preventable morbidity after fast-track hip and knee arthroplasty: a detailed descriptive cohort study. BMJ Open. 2016 Jan 12;6(1):e009813. doi: 10.1136/bmjopen-2015-009813.

10. Bierbaum BE, Callaghan JJ, Galante JO, Rubash HE, Tooms RE, Welch RB. An analysis of blood management in patients having a total hip or knee arthroplasty. J Bone Joint Surg Am. 1999 Jan;81(1):2-10.

11. Faris PM, Spence RK, Larholt KM, Sampson AR, Frei D. The predictive power of baseline hemoglobin for transfusion risk in surgery patients. Orthopedics. 1999 Jan;22 (1 Suppl): s135-40.

12. Spahn DR. Anemia and Patient Blood Management in Hip and Knee Surgery: A Systematic Review of the Literature. Anesthesiology 2010; 113:482–95.

13. Wong CJ, Vandervoort MK, Vandervoort SL, Donner A, Zou G, MacDonald JK, Freedman J, Karkouti K, MacDonald SJ, Feagan BG. A cluster-randomized controlled trial of a blood conservation algorithm in patients undergoing total hip joint arthroplasty. Transfusion 2007; 47(5): 832-41.

14. Callaghan JJ, Spitzer AI. Blood management and patient specific transfusion options in total joint replacement surgery. Iowa Orthop J. 2000;20:36-45.

15. Lasocky S, Krauspe R, Von Heymann C, Mezzacasa A, Chainey S, Spahn DR. PREPARE: the prevalence of perioperative anaemia and need for patient blood management in elective orthopedic surgery: a multicenter, observational study. Eur J Anaesthesiol 2015 Mar; 32(3):160-7 doi: 10.1097/EJA.00000000000202.

Tables

Table 1. Descriptive and clinical data for the two groups of patients

	Group A (n=67)	Group B (n=57)	p
Mean age (range)	63.9 (29-80)	66.6 (46-88)	NS*
♂ / ♀	36/31	27/30	NS§
Mean BMI (St.Dev.)	26.3 (3.6)	26.8 (4.1)	NS*
ASA 1/2/3/4	17/31/19/0	6/34/14/3	<.05 §§
Diagnosis OA PT AVN DDD	59 2 6 0	47 4 3 3	
Surg.Approach AD DL	30 37	41 16	<.01 §
N° pts Tranfused (%) ♂ / ♀	14 (20.9%) 5/9	21 (36.8%) 12/9	<.05 §
Avg units per patient	1.8	2.2	

BMI=body mass index, OA=primary osteoarthritis; PT=post-traumatic; AVN=avascular necrosis; DDD=dysplasia
DL=direct lateral, AD= Anterior Direct, Pts= patients * Student t-test; § Fisher exact test; §§ Person Chi square test.

Table 2. Hemoglobin trend after total hip arthroplasty

Hb (g/dl) avg±SD	All Pa-tients n=124	All patients Not trans-fused N=89	All patients Transfused N=35	Group A Not trans-fused N=53	Group B Not trans-fused n=36	Dir Lat Not trans-fused n= 36	Ant Dir Not trans-fused n= 53
Pre	14.2±1.3	14.5±1.3	13.4±1.4§	14.4±1.2	14.6±0.9	14.6±1.3	14.4±0.9
Day 0	11.6±1.6	12.1±1.1	10.4±1.8§	12.0±1.1	12.3±1.2	12.0±1.2	12.3±1.1
Day 1	10.9±1.3	11.2±1.1	9.9±1.0§	11.3±1.2	11.2±0.9	11.5±1.4*	11.1±0.9
Day 2	10.1±1.3	10.5±1.1	9.0±1.0§	10.4±1.2	10.6±1.1	10.7±1.2	10.3±1.0
Day 3	9.9±1.2	10.2±1.1	9.2±1.0§	10.3±1.2	10.2±0.9	10.5±1.3*	10.0±0.9
Day 4	10.0±1.0	10.2±1.1	9.6±0.9§	10.3±1.1	10.0±1.1	10.4±1.1*	10.0±1.0
Day 5	10.1±1.2	10.3±1.1	9.7±1.2#	10.3±1.1	10.1±1.3	10.5±1.1*	10.0±1.1

Dir Lat = patients operated with Direct Lateral approach; Ant Dir = patients operated with Anterior Direct approach§ p<.01 vs. all patients not transfused; # p<.05 vs. all patients not transfused; * p<.05 vs. Ant Dir not transfused

Table 3. Algorithm parameters and relative diagnostic findings

	Group A (n = 67)	Group B (n = 57)	Both Groups (n = 124)
Q (Hb preOP threshold)	13	13	13
X (Hb day 1 threshold for Hb preOP < Q)	11	10	10
Z (Hb day 1 threshold for Hb preOP > Q)	10	9.5	10
R (Hb day 2 threshold)	Not relevant	10	10
Specificity (%)	84.9	85.4	84.0
Sensitivity (%)	64.3	87.5	70.0
PPV (%)	52.9	70.0	58.3
NPV (%)	90.0	94.6	89.8
Eff (%)	80.6	86.0	80.6
High risk patients (TP+FP) (n, %)	17 (25.4%)	20 (35.1%)	36 (29%)
Low risk patients (TN+FN) (n, %)	50 (74.6%)	37 (64.9%)	88 (71%)

Table 4. Algorithm parameters to achieve a negative predictive values of 100% in which all patients that have been transfused were correctly labelled as high risk patients.

	Group A (n = 67)	Group B (n = 57)	Both Groups (n = 124)
Q (Hb preOP threshold)	13	13	13
X (Hb day 1 threshold for Hb preOP < Q)	11	10	10
Z (Hb day 1 threshold for Hb preOP > Q)	12.5	11.5	12.5
R (Hb day 2 threshold)	Not relevant	11	11
Specificity (%)	13.2	36.6	9.6
Sensitivity (%)	100	100	100
PPV (%)	23,3	38.1	26.1
NPV (%)	100	100	100
Eff (%)	31.3	54.4	31.5

High risk patients (TP+FP) (n, %)	60 (89.5%)	47 (70.1%)	115 (92.7%)
Low risk patients (TN+FN) (n, %)	7 (10.5%)	20 (29.9%)	9 (7.3%)

Figure 1. Algorithm for the prediction of the risk of blood transfusion based on hemoglobin levels after total hip arthroplasty. The values of algorithm parameters have been selected using two different criteria (see Methods)