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

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ABSTRACT

Introduction: Patients receiving blood transfusions after total hip arthroplasty have increased morbidity and longer lengths of stay compared to non-transfused patients. The aim of this study is to create an algorithm in order to identify patients at risk for transfusion after total hip replacement and define a safe point in hemoglobin levels after which the need for blood, transfusion can be excluded.

Methods: This retrospective study analyzed hemoglobin (Hb) levels for 5 days in patients undergoing total hip replacement. An algorithm was implemented to identify the critical trends of Hb levels in the first two post-operative days, trying to identify the patients at high risk of transfusion. Specificity, sensibility and efficiency were calculated in relation to the capability of the algorithm to correctly identify transfused patients.

Results: The algorithm found a pre-operative Hb ≥ 13 g/dl as a cut off between patients at low-risk or high-risk for transfusion. When parameters were calculated considering 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%. Hb values > 10 g/dl in the first operative day for low-risk patients and Hb level > 11 g/dl the second post-operative day for high-risk patients led to exclusion of the need for transfusion.

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

1. Introduction

In the last few years, rapid recovery protocols have been introduced for elective primary total hip arthroplasty (THA). These protocols are based on analysis of clinical care principles and pain management, defining an optimized peri-operative period that is safe for the patient [1–3].

Blood loss and anemia management is a crucial part of fast track surgery. Many data have been published in literature about the transfusion rate after THA, with incidence ranging from 4.3% to 86.8% depending on surgeon and national protocols [4–6].

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 [6,7].

In current literature, it is impossible to find a reproducible algorithm able to identify patients at high risk for transfusion by analysis of hemoglobin (Hb) values obtained on the first two days after surgery. Such information could help clinicians in the management of these patients in order to adjust the rehabilitation protocol, evaluate on the need for further blood exams and program a safe domestic discharge. This data is relevant especially in the setting of a fast-track protocol, considered as an enhanced recovery after surgery [8].

Aim of this study is to create an algorithm to predict the need for transfusion in patients after THA.

2. Methods

After ethical committee approval, a research in electronic databases of two different hospitals was performed in October 2016. Aim of the investigation was to identify all patients treated with THA by the same senior surgeon for primary osteoarthritis between December

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Table 1
Hemoglobin trend after total hip arthroplasty.

Hb (g/dl) avg ± SD	All Patients n = 124	All patients Not transfused N = 89	All patients Transfused N = 35	Group A Not transfused N = 53	Group B Not transfused n = 36	Dir Lat Not transfused n = 36	Ant Dir Not transfused 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.

2012–December 2014. Exclusion criteria were femoral fractures, rheumatic diseases, hematologic diseases, ischemic heart disease, severe systemic pathologies and treatment with warfarin or other oral anticoagulants. Intra operative data (Age, surgical approach, surgical time, drainage) were recorded. Post-operative management as saline infusion, antibiotic and anti-thrombotic prophylaxis and clinical parameters were recorded. A search in electronic database was performed to find results of hematologic tests performed the first 5 days after surgery, and data were recorded in an Excel database. If some data were missing the patient was excluded from the study. Using this data an algorithm was created to predict risk of transfusion with the best 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.

2.1. Population

After application of inclusion and exclusion criteria a total of 124 patients were collected, 67 from the first hospital (Group A) and 57 from the second Hospital (Group B).

Group A included 67 patients treated with primary THA, 36 men and 31 women with an average age of 63.9 years (range: 29–80 years), enrolled from December 2010 to November 2013. Group B included 57 patients treated with primary THA, 27 men and 30 women with an average age of 66.6 years (46–88 y), enrolled from December 2013 to December 2014.

2.2. Post-operative management in included patients

An anti-thrombotic prophylaxis with Enoxaparin sodium was given 12 h before surgery as well as antibiotic prophylaxis with Cefazolin sodium administered 1 h before surgery.

In group A a direct lateral approach was performed in 37 patients and an anterior approach in 30 patients. A reinfusion drain system was used in all patients and blood was reinfused at an average 6 h after the surgical procedure. The drainage was maintained for about 24 h and removed the morning 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 further consequences. There were no cases of hematoma, delayed wound healing, infection or arthroplasty dislocation. None of the recorded complications had consequences of any kind on weight-bearing, discharge or final outcome.

In group B a direct lateral approach was performed in 16 patients and an anterior approach in 41 patients. A post-operative blood reinfusion wasn't used in this group due to the absence of this specific device in that hospital. Four complications have been recorded 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 reported complications had consequences of any kind on weight-bearing, discharge or final outcome.

A standard saline infusion of 1500 cc (100 cc/h for 15 h) was administered after surgery as well as the adoption of pain management with drugs not supposed to cause nausea or hypotension. Anti-thrombotic prophylaxis with Enoxaparin sodium was administered 6 h after surgery and every evening for at least 20 days following the national guidelines for THA. Antibiotic prophylaxis with Cefazolin sodium was continued for 24 h after surgery. Full weight bearing was allowed for all patients from the first day after surgery.

Vital signs such as blood pressure, heart rate and nausea were monitored continuously for the first 6 h from surgery. Afterwards a standard protocol for stable patients was applied. A blood test for Hb values was performed the day before surgery, 4 h after surgery and every morning for 5 consecutive days. Transfusions were prescribed when Hb level was below 8 g/dl or for such symptoms as chest pain, orthostatic hypotension and/or tachycardia unresponsive to intravenous fluid supplementation.

The trend of hemoglobin levels was analyzed considering the preoperative, 4 h post-operative level and the daily exams performed in the morning for the first five days after surgery. Data were analyzed considering subgroups in relation to surgical approach, transfusion occurrence and the belonging to group A or B as shown in Table 1.

2.3. Statistical analysis for creating the algorithm

Continuous data/variables were expressed by mean ± standard deviation (SD) or minimum and maximum values.

Categorical data were classified 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 Chi^2 test were used to compare categorical data. A p value < 0.05 was considered to be statistically significant.

An algorithm was implemented to identify the critical levels of Hb the first 2 postoperative days below which the risk of transfusion is high or it is necessary to continue with the blood tests.

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" (Fig. 1).

The algorithm was computed on Excel spreadsheets and tested for evaluation of binary classifiers applying it to the data of the two samples of patients. "True positive" were considered those patients