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Introduction to Patient Blood Management in Clinical Practice at a Local-Regional Hospital: A Statistical In-Process Control of Anaemia and Transfusion Incidence in Knee and Hip Arthroplasty

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Abstract

Background: The aim of this study was to determine the influence of an active patient blood management (PBM) program in orthopedic surgery in clinical practice at a loco regional hospital.

Methods: After introduction of the PBM program in July 2013, we performed a statistical in-process control for the period between May 2012 and December 2014. The period between May 2012 and June 2013 was before the introduction of the PBM program and the period between July 2013 and December 2014 was after its introduction. During the observation 766 elective orthopedic operations were analyzed (489 hip and 277 knee prostheses). Preoperative anemia, blood transfusion rates and hospital stay were examined.

Results: There was no statistically significant change in preoperative anemia. Using statistical process control (SPC) techniques, we documented an impressive change in the system with a relevant decline of perioperative transfusion rate as a non-random change in the ongoing process. Transfusion probability was reduced risk adjusted by 53% from 7.4% to 3.5% ($p=0.008$) and length of hospital stay (LOS) dropped, risk adjusted from 9.6 to 9.0 days ($p<0.001$).

Conclusion: Initiation of a preoperative anemia-correction algorithm within the scope of a PBM-program in clinical routine with the inclusion of general practitioners in a regional hospital was effective in regard to a decrease in blood transfusion risk and in LOS.

Keywords: Preoperative anemia; Blood transfusion; Orthopaedic surgery; Statistical process control; CUSUM analysis

Introduction

The need for the transfusion of blood products during and after elective surgery is known to be a risk factor for a variety of complications and is an independent risk factor for adverse patient outcomes [1]. Blood products are associated with the transmission of bacterial or viral infections increased mortality, morbidity and immunomodulation [2-5] as well as prolonged time until discharge from the hospital, accompanied by higher costs [1]. In recent years transfusion policies have become more restrictive but the safest blood transfusion is still the one not given [6]. Surprisingly 20% to 51% of patients of elective surgery have preoperative anaemia [7-10]. Anaemia is the most important risk factor for blood transfusion and is independently associated with increased mortality and morbidity in patients undergoing non-cardiac surgery [9,11,12].

Patient blood management (PBM) is a multidisciplinary approach to reducing or preventing blood transfusions (the approach involves a surgeon, anaesthesiologists, critical care specialists, a general practitioner, and transfusion medicine specialists). PBM focuses on three "pillars" detection and treatment of perioperative anaemia, reduction of perioperative blood loss and optimizing the patient-specific physiological reserve of anaemia [13-15].

In up to one third of patients, iron deficiency is the cause of anaemia and must be corrected prior to surgery. If not corrected, an elective surgery should be delayed [7,13,16]. Several studies have already shown the feasibility of a reduction in blood transfusions and the attendant costs after the introduction of a PBM programme [7,15,17].

Implementing the multidisciplinary approach of a PBM programme in large institutions (and with all specialists on board) is a challenging and protracted process [14,18]. This study will look at whether or not the implementation of a simple PBM programme in a community hospital, together with a general practitioner (GP) and with a focus on preoperative anaemia, reduces the incidence of transfusion, the length of hospital stay (LOS), and the admission of anaemic patients.

Material and Methods

The study was performed according to the guidelines of the World Medical Association Declaration of Helsinki and was registered with the Ethics Committee of North-West and Central Switzerland (EKNZ 2014-148), Chairperson Prof. A.P. Perruchoud on 12 June 2014. The requirement for written informed consent for this quality-process control survey was waived by the EKNZ.

Data were obtained between May 2012 and December 2014 in a regional centre for orthopaedic surgery performing >300 endoprosthetic

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operations of the lower extremity (hip and knee) per year. Data from May 2012 until June 2013 were analysed retrospectively as a baseline for the incidence of preoperative anaemia, blood transfusion and LOS (Control group). In July 2013, the PBM programme was initiated according to the guidelines of the National Blood Authority (NBA) of Australia and data were included until December 2014 prospectively (PBM group). Between four to six weeks prior to elective orthopaedic surgery, all patients had to visit the GP to ascertain the latest haemoglobin and ferritin concentrations as well as the C-reactive protein level. Anaemia has been defined by the WHO guidelines: haemoglobin concentration <130 g/L for men or <120 g/L for women. In the case of iron-deficiency anaemia, the patient's GP had to treat it intravenously with iron. The doses and type of iron product, as well as a laboratory control were decided on by the GP. We provided the PBM protocol according to the above-mentioned guidelines from the NBA of Australia. Due to a lack of feedback from the GP regarding whether or not therapy was necessary or had already been carried out (these data were not part of the quality-process control survey), we focused on the preoperative haemoglobin concentration at hospital entry.

The surgeon and the anaesthesia team were unchanged during the entire observation period (Control group and PBM group). Also unchanged during the entire observation period were the orthopaedic techniques and the anaesthesiologic strategies implemented (for example the threshold for blood transfusion or the indication to administer Tranexamic acid). The anaesthesia team was not involved in the implementation of the PBM protocol; so a possible "Hawthorne effect" should be excluded. The letter to the GP with the preoperative haemoglobin assessment and optimisation template was the only new introduced parameter between the two observation periods.

Demographic data were collected: age, sex, weight, and height. Also collected were the patient's haemoglobin concentrations prior to surgery, the total blood transfusion during hospitalization, and the LOS in hospital.

Data were analysed with Excel (Microsoft Office 2010, Version 14.0.7166.5000 (32-Bit), (Microsoft Corporation, Redmond, WA, USA) and the statistics software R (Version 3.1.2 (2014-10-31, 64-Bit). We analysed the effect of the PBM protocol regarding influencing factors. These factors were determined by a multiple regression model using the GLM-function (generalized linear model) implemented in the statistics software R. Relevant factors were age and preoperative haemoglobin concentration. The influence of these two factors is shown in Figure 1. A regression tree was also done in R. Using an algorithm, regression trees identify the parameters that most benefit from the process change. They do this by optimally separating data as related to classification (here preoperative haemoglobin concentration and patient age). For factors with a binominal distribution, we used the exact binomial test. The LOS was log-normal distributed, so we used the Wilcoxon rank-sum test. For the analysis of the distribution of sexes, we used the chi-square test. All tests were done in R.

Process control should guarantee and monitor constant quality and was used as a continuous regulator of industrial processes [19]. Operative and anaesthetic management can be seen as a process with various interactions. Therefore, it is possible to demonstrate any change in anaesthetic process quality with statistical process control (SPC) [20-22]. We performed a CUSUM (this means "cumulative summation") analysis to chart the cumulative sum of the differences between the dates and a default value. This analysis method rapidly detects an "out-of-control" process within a sequential process. It does this through the use of an unknown sample number in respect to ongoing processes. This method is much faster than spot checks [22]. The mathematical model that is required for sequential testing and the details of the parameters has been described previously [20,22]. The CUSUM analysis is used to identify at which point to stop when a process is "out of control". We had to define the boundaries of the quality range. A transfusion value range between 5% and 20% was defined, and the mathematical model yielded a CUSUM value of 4.43 (represented by horizontal lines in the graph) (Figure 2). For presentation, the CUSUM value is plotted on the y-axis against the patient number on the x-axis [20]. With each successive failure or success of the process, CUSUM added positive or negative increments to a cumulative score (which increases with failure and decreases with success). In our study, after CUSUM starts at zero, a process success is indicated by a decrease of the CUSUM and a process failure by its increase. If the CUSUM stays between two boundaries, then the observation must be continued. A twofold crossing of the horizontal boundary from below is unacceptable and the process is "out of control" a crossing of the boundary from above is acceptable and shows a turning point in the process.

Results

From May 2012 to December 2014, we included 766 consecutive patients for 489 hip and 277 knee prosthesis operations. There was no difference in demographic data of the patients between the control and the PBM groups. There were 325 patients in the control-group with a mean age of 65.1 years (range 35-97years), 46% of patients (n = 150) were women. Of the 441 patients in the PBM group, the mean age was 65.4 years (range 26-89 years), 47% of patients (n = 204) were women. The body mass index was 28.6 kg/m² (range 16-49 kg/m²) in the control-group and 28.9 kg/m² (range 17-48 kg/m²) in the PBM group.

There was no change in prevalence of preoperative anaemia but the probability of blood transfusion relative decreased by 57% from 5.2% to 2.3% and risk-adjusted by 53% from 7.4% to 3.5%.

Risk adjustment considered patient age and preoperative haemoglobin concentration. The kind and number of operations don't change during the observation time. Multiple regression analysis showed no influence of the type of surgery – so it was not integrated to the model for risk adjustment. A diagram was created for the probability of receiving a blood transfusion according to patient age and preoperative haemoglobin concentration (Figure 1). After initiation of the PBM programme, the curves climb much more flatly than before. The regression tree determines a preoperative haemoglobin concentration of <132 g/L and a patient age >70 yrs as the optimal values for the patients who benefit from PBM (graphics not depicted). In this group, the PBM patients had the likelihood of receiving a blood transfusion of 22% versus 52% for the patients in the control group. The LOS also decreased after initiation of the PBM programme from 9.8 to 9.1 days ($p<0.001$) and from 9.6 to 9.0 days with risk adjustment ($p<0.001$) (Table 1). Applying SPC brought about a change in the system (Figure 2). After initiation of the PBM programme, the CUSUM analysis showed a short increase of transfusion likelihood without crossing the 4.43 boundary followed by a continuous decrease after 60 patients. This change was ongoing until the end of the observation time (a constant decrease of the CUSUM curve).

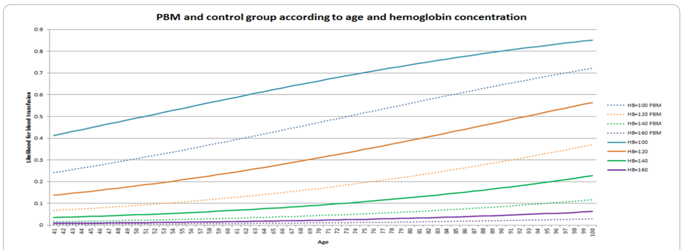
Discussion

After the introduction of an active PBM programme in clinical practice at a regional hospital, we found a relevant reduction of blood transfusions and a reduction of hospital length of stay after orthopaedic surgery. The prevalence of preoperative anaemia in the patients was not

	Control-Group	PBM-Group	P
Hb pre-OP (g/L)	140.3 (87-176)	141.4 (100-189)	0.319
Anaemia incidence			0.937 #
male	7.4%	8.1%	0.619
female	9.3%	5.9%	0.093
Probability of blood transfusion	5.2%	2.3%	0.003
Probability of blood transfusion (risk-adjusted)	7.4%	3.5%	0.008
LOS (days)	9.8	9.1	<0.001
LOS (risk-adjusted) (days)	9.6	9.0	<0.001

Hb pre-OP: Haemoglobin concentration by hospital entrance; LOS: Length of stay in hospital; PBM: Patient blood management; # Chi-square test

Table 1: Outcome data of blood transfusion and LOS.



Note: HB: Haemoglobin concentration in g/L; PBM: Patient blood management

Figure 1: Probability of receiving blood transfusion in relation to patient age and preoperative haemoglobin concentration.

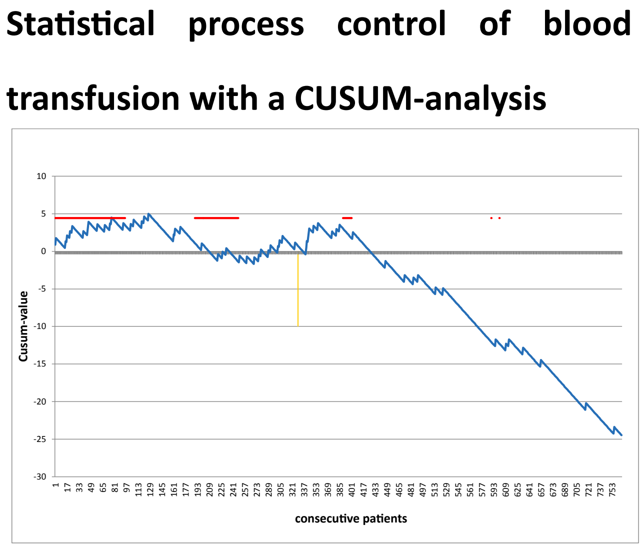


Figure 2: Statistical process control of blood transfusion with a CUSUM analysis CUSUM = Cumulative summation; PBM programme starts at Patient No: 326; The CUSUM analysis shows the CUSUM value plotted on the y-axis against the number of patients on the x-axis. In the CUSUM analysis, each increment represents a failure and each decrement a success of the running sum as a ratio between the two being determined according to a mathematical formula. A process is called "out of control" when the horizontal boundaries are crossed from below; a crossing from above is a sign of success. Expert opinion defines the transfusion value range between 5% and 20%, and a mathematical model yields a CUSUM value of 4.43 (dashed line). The CUSUM starts at zero. After 326 patients (red bar), the PBM programme was started; 60 patients later, the CUSUM began to decline continuously. This hurts the rule of random scattering of values around the mean, and is therefore an early sign of the shift of the process to avoid blood transfusions.

affected during the analysis. With the aid of statistical process control, we showed a continuous decline in the prevalence of blood transfusions. This continuous decline hurts the rule of random scattering of values around the mean and is, therefore, an early sign of a shift of the process to avoid blood transfusions.

After the start of the PBM programme, it was not possible to create a randomized controlled trial (RCT). In accordance with an observation study with before-after design we focused on an in-process analysis to look for a decrease in blood transfusions consistent with a positive changing culture. With the CUSUM analysis, we could illustrate this turnaround of the ongoing process. To find a statistical significance was not the principal aim of the statistical process control, hence data or defaults of clinical trials were not available (only clinical routine data). One explanation for the lack of a reduction in the prevalence of preoperative anaemia might be that in the period before the introduction of PBM, such prevalence was already very low, with 7.4% for women and 9.3% for men. To reduce these values, changing the process with only one pillar of the PBM programme was probably too little. In the relevant literature, the prevalence of anaemia in elective operations is described as between 20% to 51% [7-10]. However, a study in Austria found a similarly low prevalence of preoperative anaemia with only 7.3% [23]. This could be a manifestation of the high medical standard of GP medicine in Switzerland and Austria.

The key activity of the observed turnaround in the blood transfusion process was the patient's contact with his or her GP for evaluation of the haemoglobin and iron blood concentration at least four to six weeks before the planned operation. After the surgeon determined that an operation was necessary, he gave the patient the PBM algorithm to deliver to the GP. Usually, the time before surgery was long enough to perform the blood tests, the iron therapy, and, if required, to control the blood tests for a second therapy to correct anaemia. Due to the limited time before surgery, we recommended that the GP administer intravenous iron. Studies have shown higher levels of efficiency and safety of intravenous administration compared with oral iron administration [10,24].

Furthermore, there are indices that show that preoperatively administered intravenous iron in patients undergoing orthopaedic surgery could reduce nosocomial infections [24].

We only analysed one part of the PBM concept: preoperative anaemia. The two other pillars–the reduction of perioperative blood loss and optimizing the patient-specific physiological reserve of anaemia–were not analysed [13,14]. These aspects were not relevant in relation to changes during the observation time and are to be considered as constant (due to the use of an identical surgery and anaesthesia team, along with stable procedures and guidelines).

A limitation of this quality-process control survey is the absent data from the GP. We have no information in relation to how many patients went to the GP, or how many patients were diagnosed with anaemia and received iron and/or erythropoietin alpha. In the end, we changed only one aspect of the PBM concept: Once the surgeon had made the decision to operate, an information sheet with the PBM algorithm was given to the patient for delivery to the patient's GP. Interestingly, this simple and inexpensive process change resulted in outcome improvement by decreasing the probability of blood transfusion by more than 50% the LOS also showed a statistically significant drop. If the PBM programme is directly connected with anaesthesia consultation, the detection and correction of anaemia could be optimized and patient comfort improved by reducing doctor consultations. From an economic point of view, the PBM concept is also attractive (doctor consultation for blood analysis and anaemia correction) with a relevant reduction of costs (a decrease in blood transfusions and LOS) [14,25].

As mentioned above, the CUSUM analysis rapidly detects an "out of control" process within a sequential process through the use of an unknown sample number in respect to ongoing processes. It does this much faster than spot checks. After the introduction of the PBM programme, an impressive decrease of the CUSUM value was observed after 60 patients. This reflects a turnaround in the blood transfusion process. The initial increase in the CUSUM value can be interpreted as a learning phase in the new process. The decline illustrates a turning point of the process in regard to an improvement whereby all consecutive patients showed a lower prevalence than statistically defined. This indicates a non-random change in the ongoing process.

Interestingly, we observed a positive effect of the PBM programme in relation to the probability of blood transfusions for patients with or without anaemia at hospital admission. A patient who still has anaemia should normally have a second round of therapy before surgery. However, it seems that a first round of therapy was sufficient to make a difference to the probability of blood transfusions during time in hospital for patients of the control group without therapy and the same haemoglobin concentration. The same effect is observable in patients with no anaemia at hospital admission: They benefit from the previous therapy in comparison to patients of the control group with the same haemoglobin concentration. These effects increase distinctly with patient age. With the aid of a regression tree, we could identify the group that most benefited from the PBM programme: The algorithm shows an optimal effect of the PBM concept for a preoperative haemoglobin concentration under 132 g/L and a patient age of about 70 years. In this population, the likelihood of a blood transfusion was more than halved compared with the control group.

Conclusion

In conclusion, the implementation of a PBM programme with general practitioners in a regional hospital to correct preoperative anaemia before surgery significantly reduced the probability of blood transfusions and the length of hospital stay (LOS). A statistical process control showed an impressive turnaround of the blood transfusion risk after the PBM programme started. This study shows that the implementation of an inexpensive concept such as the PBM programme's preoperative algorithm for anaemia correction can result in blood transfusion reduction and patient outcome improvement with a decrease in LOS and consequent cost saving. This concept may be favourable for other medical departments that deal with the risk of patient blood loss, such as interventional cardiology, interventional radiology, and most surgical divisions.

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Conflict of Interest

None.

References

1. Spahn DR, Goodnough LT (2013) Alternatives to blood transfusion. Lancet 381: 1855-1865.
2. Isbister JP, Shander A, Spahn DR, Erhard J, Farmer SL, et al. (2011) Adverse blood transfusion outcomes: establishing causation. Transfusion medicine reviews 25: 89-101.
3. Mazer CD, Whitlock RP, Fergusson DA, Hall J, Belley-Cote E, et al. (2017) Restrictive or liberal red-cell transfusion for cardiac surgery. N Engl J Med 377: 2133-2144.
4. Feng S, Machina M, Beattie WS (2017) Influence of anaemia and red blood cell transfusion on mortality in high cardiac risk patients undergoing major non-cardiac surgery: A retrospective cohort study. Br J Anaesth 118: 843-851.
5. Shander A, Ferraris VA (2017) More or less? The Goldilocks principle as it applies to red cell transfusions. Br J Anaesth 118: 816-819.
6. Goodnough LT, Levy JH, Murphy MF (2013) Concepts of blood transfusion in adults. Lancet 381: 1845-1854.
7. Theusinger OM, Kind SL, Seifert B, Borgeat L, Gerber C, et al. (2014) Patient blood management in orthopaedic surgery: a four-year follow-up of transfusion requirements and blood loss from 2008 to 2011 at the Balgrist University Hospital in Zurich, Switzerland. Blood transfusion 12: 195-203.
8. Beattie WS, Karkouti K, Wijeysundera DN, Tait G (2009) Risk associated with preoperative anemia in noncardiac surgery: A single-center cohort study. Anesthesiology 110: 574-581.
9. Musallam KM, Tamim HM, Richards T, Spahn DR, Rosendaal FR, et al. (2011) Preoperative anaemia and postoperative outcomes in non-cardiac surgery: A retrospective cohort study. Lancet 378: 1396-407.
10. Theusinger OM, Leyvraz PF, Schanz U, Seifert B, Spahn DR (2007) Treatment of iron deficiency anemia in orthopedic surgery with intravenous iron: efficacy and limits: A prospective study. Anesthesiology 107: 923-927.
11. Goodnough LT, Maniatis A, Earnshaw P, Benoni G, Beris P, et al. (2011) Detection, evaluation, and management of preoperative anaemia in the elective orthopaedic surgical patient: NATA guidelines. Br J Anaesth 106: 13-22.
12. Baron DM, Hochrieser H, Posch M, Metnitz B, Rhodes A, et al. (2014) Preoperative anaemia is associated with poor clinical outcome in non-cardiac surgery patients. Br J Anaesth 113: 416-423.
13. Klein AA, Arnold P, Bingham RM, Brohi K, Clark R, et al. (2016) AAGBI guidelines: the use of blood components and their alternatives 2016. Anaesthesia 71: 829-842.
14. Gombotz H, Hofmann A (2013) Patient blood management: Three pillar strategy to improve outcome through avoidance of allogeneic blood products. Der Anaesthesist 62: 519-527.
15. Leahy MF, Hofmann A, Towler S, Trentino KM, Burrows SA, et al. (2017) Improved outcomes and reduced costs associated with a health-system-wide patient blood management program: A retrospective observational study in four major adult tertiary-care hospitals. Transfusion 57: 1347-58.
16. Munoz M, Acheson AG, Auerbach M, Besser M, Habler O, et al. (2017) International consensus statement on the peri-operative management of anaemia and iron deficiency. Anaesthesia 72: 233-247.
17. Kotze A, Carter LA, Scally AJ (2012) Effect of a patient blood management programme on preoperative anaemia, transfusion rate, and outcome after primary hip or knee arthroplasty: A quality improvement cycle. Br J Anaesth 108: 943-952.
18. Jin R, Zelinka ES, McDonald J, Byrnes T, Grunkemeier GL, et al. (2013) Effect of hospital culture on blood transfusion in cardiac procedures. The Annals of thoracic surgery 95: 1269-1274.
19. Lagasse RS, Steinberg ES, Katz RI, Saubermann AJ (1995) Defining quality of perioperative care by statistical process control of adverse outcomes. Anesthesiology 82: 1181-1188.
20. Kestin IG (1995) A statistical approach to measuring the competence of anaesthetic trainees at practical procedures. Br J Anaesth 75: 805-809.
21. Konrad C, Gerber H, Schupfer G, Jenzer S, Schmucki O (1999) Detection of fluid volume absorption by end-tidal alcohol monitoring in patients undergoing endoscopic renal pelvic surgery. J Clin Anesth 11: 386-390.
22. Bolsin S, Colson M (2000) The use of the cusum technique in the assessment of trainee competence in new procedures. Int J Qual Health Care 12: 433-438.
23. Enko D, Wallner F, von-Goedecke A, Hirschmugl C, Auersperg V, et al. (2013) The impact of an algorithm-guided management of preoperative anemia in perioperative hemoglobin level and transfusion of major orthopedic surgery patients. Anemia 2013: 641876.
24. Munoz M, Gomez-Ramirez S, Cuenca J, Garcia-Erce JA, Iglesias-Aparicio

D, et al. (2014) Very-short-term perioperative intravenous iron administration and postoperative outcome in major orthopedic surgery: a pooled analysis of observational data from 2547 patients. Transfusion 54: 289-299.

25. Trentino KM, Farmer SL, Swain SG, Burrows SA, Hofmann A, et al. (2015) Increased hospital costs associated with red blood cell transfusion. Transfusion 55: 1082-1089.