European Spine Journal (2019) 28:1342–1348
https://doi.org/10.1007/s00586-019-05939-w

ORIGINAL ARTICLE

Predicting lowest hemoglobin level and risk of blood transfusion in spinal fusion surgery for adolescent idiopathic scoliosis

Hany Abdel Gawwad Soliman[1,2,3] · Marie Beausejour[1,2] · Julie Joncas[2] · Marjolaine Roy-Beaudry[2] · Soraya Barchi[2] · Jean-Marc Mac-Thiong[1,2,4] · Hubert Labelle[1,2] · Guy Grimard[1,2] · Stefan Parent[1,2,4]

Received: 6 December 2017 / Revised: 14 January 2019 / Accepted: 28 February 2019 / Published online: 8 March 2019

Abstract

Purpose The aim of this study was to evaluate the factors associated with timing of lowest hemoglobin (Hb) level and the need for postoperative blood transfusion in posterior spinal fusion for adolescent idiopathic scoliosis.

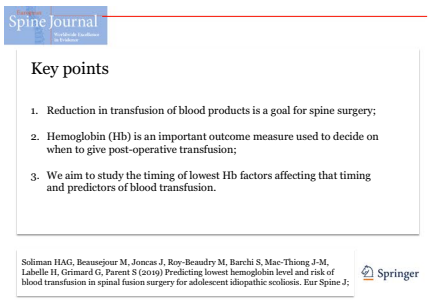
Methods We conducted a retrospective review of all adolescent scoliosis patients undergoing posterior spinal fusion at our institution, 2002–2014. Surgery consisted of segmental pedicle screw fixation using multi-level pedicle screws. Blood-saving techniques were used in all patients. Data included Cobb angle, pre- and postoperative Hb levels, preoperative autologous blood donation (PABD), surgery duration, and allogeneic or autologous transfusion. We used linear and logistic regressions for statistical analysis.

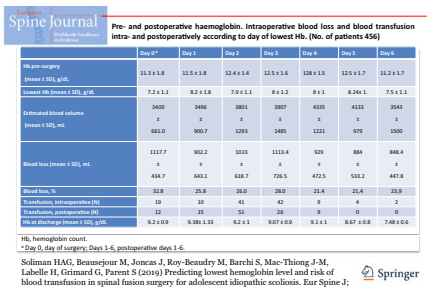
Results There were 456 patients (402 female, 54 male), mean age 16 ± 5 years. Lowest Hb was observed on postoperative Days 2 (32.2%) and 3 (33.3%); 45.1% of postoperative transfusions occurred on Day 2. One hundred and eighty-eight (41%) patients who provided PABD had significantly lower preoperative Hb and received more transfusions intraoperatively (22.6% vs. 5.2%) and postoperatively (20% vs. 6.3%) than others. Probability of transfusion increased 49.6 (95% CI 17.40–141.37) times with preoperative Hb < 11 g/dL as compared to preoperative Hb > 14 g/dL. Probability of transfusion increased 4.3- and 9.8-fold when surgery duration exceeded 5 and 6 h, respectively. Probability of transfusion increased 3.3- and 5.3-fold with Cobb angle > 70° and 80°, respectively.

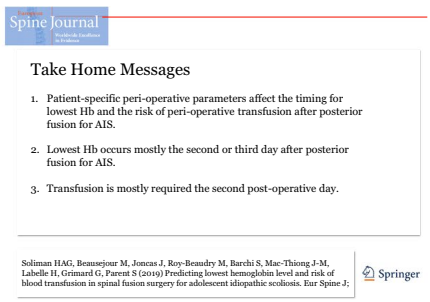
Conclusions We identified clear patient-specific perioperative parameters that affect risk of perioperative blood transfusion, including Cobb angle, PABD and preoperative Hb. Hb measurement beyond postoperative Day 3 is considered unnecessary unless clinically indicated.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.







Keywords Scoliosis · Spinal fusion · Hemoglobin · Blood loss · Transfusion · Preoperative autologous blood donation

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-019-05939-w) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

Introduction

Blood loss and the ensuing need for blood transfusion remain a major concern in corrective surgery for adolescent idiopathic scoliosis (AIS) [1–4]. Despite pharmacological and non-pharmacological blood-saving techniques such as tranexamic acid infusion, cell salvage, meticulous hemostasis with electrocautery, controlled hypotension, and warmed fluids and warming blanket to avoid hypothermia and minimize bleeding, blood loss during posterior spinal fusion can be substantial.

Hemoglobin (Hb) count is an important factor in deciding when to give postoperative blood transfusion [5–7]. Although predictive risk factors for postoperative transfusion are reported in the literature [2, 6, 8–11], the timing of lowest Hb levels, the factors affecting that timing and hence the timing of blood transfusion are unclear. Moreover, how these predictors affect the risk is not clear. Both autologous and allogeneic blood transfusions are associated with potential morbidity, longer hospital stays and higher costs [12–14].

The objective of this study was to better understand the effects of specific patient and surgical parameters on the risk of transfusion.

Methods

Participants and study design

We aimed to study the timing of lowest Hb, the factors affecting that timing, and the ensuing predictors of blood transfusion. With approval from the institutional research ethics board, we performed a retrospective analysis of a prospectively collected surgical database at our institution. Information was available from 2002 to 2014.

For each patient, the following information was recorded in the database:

1. Preoperative data: Age, sex, estimated blood volume using patient weight, autologous blood donation (PABD), Hb level, Cobb angle
2. Intraoperative data: Percentage of blood loss, duration of surgery, intraoperative allogeneic or autologous transfusion
3. Postoperative data: Hb levels, postoperative allogeneic or autologous transfusion.

Hb was measured and recorded on the day of surgery and daily for 6 days thereafter. The day that Hb was lowest over the course of the entire postoperative hospital stay was used for statistical analysis, whether or not the patient was transfused.

Surgical technique

All patients underwent segmental pedicle screw fixation using multi-level pedicle screws. Facetectomies were performed at all levels to increase flexibility and to facilitate spinal fusion. Decortication of transverse processes and laminae was performed for each instrumented vertebra. Fusion was augmented by autogenous local bone graft obtained from facet joints and spinous processes mixed with bone substitute. No drain was used.

Blood-saving techniques were used in all patients and therefore not analyzed as independent risk factors. These techniques included tranexamic acid, intraoperative salvage of shed blood (cell saver), monopolar dissection, hypotensive anesthesia and warming blanket.

Statistical analysis

The primary outcome was the timing of lowest Hb. Secondary outcomes included the timing of transfusion and associated factors (independent variables such as preoperative Hb level, PABD, estimated blood volume, duration of surgery, percentage of blood loss, intraoperative transfusion), as well as Hb at discharge. All data were analyzed using IBM SPSS Statistics 20. Bivariate associations were tested with ANOVA, logistic regression, Chi-square and Kruskal–Wallis tests. Multivariate associations were tested with linear regression models and multinomial logistic regression, at a significance level of 0.05.

Results

Participants

In total, 456 patients (402 female and 54 male) were included in the analysis. The mean age of the cohort was 16 ± 5 years. In all, 188 patients (41%) gave PABD.

Patient demographics, Lenke classification as well as pre- and postoperative curve magnitudes are given in Table 1.

Hb levels after surgery

The lowest measured Hb was observed on postoperative Days 2 (147 patients, 32.2% of cohort) and 3 (152 patients, 33.3%). Hb before discharge improved as compared to

Table 1 Demographics, preoperative and postoperative Cobb angel, duration of surgery and Lenke classification of all patients

No. of patients	456
Age (mean ± SD), years	15.6 ± 4.9
Weight (mean ± SD), kg	56.1 ± 21.3
Height (mean ± SD), cm	157.1 ± 19.3
Preoperative Cobb angle (°)	56.1 ± 16.7
Postoperative Cobb angle (°)	15.7 ± 5.6
Duration of surgery (min)	288.3 ± 92.5
Lenke types (no. of patients)	
Type 1	199
Type 2	44
Type 3	83
Type 4	30
Type 5	49
Type 6	51

lowest Hb, whether patients were transfused or not: Mean Hb loss at lowest Hb was 4.1 ± 0.5 g/Dl, while mean Hb loss at discharge was 2.1 ± 0.7 g/dL (Table 2). Hb at discharge showed no significant difference between transfused and non-transfused patients ($P = 0.7$).

Predictors of lowest Hb level

Significant bivariate associations were found between the timing of lowest Hb and the preoperative Hb level, PABD, weight/estimated blood volume, intraoperative blood loss and intraoperative blood transfusion. Multivariate analysis showed that PABD and weight/estimated blood volume were predictors of the timing of lowest Hb level ($P = 0.012$ and 0.003, respectively).

Predictors of early versus late lowest Hb

Patients who did not give PABD were more likely to reach lowest Hb on Day 2 or 3 versus Day 0 or 1 (OR 3.547; 95% CI 1.534–8.202; $P = 0.003$) (Table 3). They were less likely to reach lowest Hb at Days 2–3 versus Days 4–6 (OR 0.425; 95% CI 0.227–0.797; $P = 0.008$) (Table 4). Not having an intraoperative transfusion was also a significant factor in lowest Hb at Days 2–3 versus Days 4–6 (OR 0.450; 95% CI 0.207–0.978; $P = 0.044$).

Blood transfusion (Tables 2 and 5)

In total, 234 (51.2%) patients required transfusions, 127 (27.8%) during the surgery itself (Table 5). Of 113 patients with postoperative transfusions, 12 (10.6%) were transfused on Day 0, 15 (13.3%) on Day 1, 51 (45.1%) on Day

Table 2 Pre- and postoperative hemoglobin. Intraoperative blood loss and blood transfusion intra- and postoperatively according to day of lowest Hb

	Day 0[a]	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Hb pre-surgery (mean ± SD), g/dL	11.3 ± 1.8	11.5 ± 1.8	12.4 ± 1.4	12.5 ± 1.6	128 ± 1.5	12.5 ± 1.7	11.2 ± 1.7
Lowest Hb (mean ± SD), g/dL	7.2 ± 1.1	8.2 ± 1.8	7.9 ± 1.1	8 ± 1.2	8 ± 1	8.24 ± 1.	7.5 ± 1.1
Estimated blood volume (mean ± SD), mL	3400 ± 661.0	3496 ± 900.7	3801 ± 1293	3907 ± 1485	4335 ± 1221	4133 ± 979	3543 ± 1500
Blood loss (mean ± SD), mL	1117.7 ± 434.7	902.2 ± 643.1	1023 ± 618.7	1113.4 ± 726.5	929 ± 472.5	884 ± 533.2	848.4 ± 447.8
Blood loss, %	32.8	25.8	26.0	28.0	21.4	21.4	23.9
Transfusion, intraoperative (*N*)	19	10	41	42	9	4	2
Transfusion, postoperative (*N*)	12	15	51	26	9	0	0
Hb at discharge (mean ± SD), g/dL	9.2 ± 0.9	9.38 ± 1.33	9.2 ± 1	9.07 ± 0.9	9.1 ± 1	8.67 ± 0.8	7.48 ± 0.6

Hb hemoglobin count

[a]Day 0, day of surgery; Days 1–6, postoperative Days 1–6

Table 3 Predictors of timing of lowest Hb on postoperative Days 2–3 versus Days 0–1

Predictors of timing of lowest Hb	*P* value	Odds ratio	95% Confidence interval	
			Lower bound	Upper bound
Weight	0.066	1.029	0.998	1.061
Surgery duration	0.238	1.002	0.998	1.006
Pre-op Hb level	0.338	1.014	0.986	1.043
Percent blood loss	0.651	1.009	0.971	1.049
No intraoperative transfusion	0.825	0.922	0.448	1.898
No PADB	0.003	3.547	1.534	8.202

Hb hemoglobin count, *PABD* preoperative autologous blood donation

Table 4 Predictors of timing of lowest Hb on postoperative Days 2–3 versus Days 4–6

Predictors of timing of lowest Hb	*P* value	Odds ratio	95% Confidence interval	
			Lower bound	Upper bound
Weight	0.166	0.993	0.984	1.003
Surgery duration	0.222	0.998	0.995	1.001
Pre-op Hb level	0.444	1.008	0.987	1.030
Percent blood loss	0.295	1.017	0.985	1.051
No intraoperative transfusion	0.044	0.450	0.207	0.978
No PABD	0.008	0.425	0.227	0.797

Hb hemoglobin count, *PABD* preoperative autologous blood donation

Table 5 Intra- and postoperative blood transfusion (allogeneic and autologous)

Type and timing of transfusion	Number of patients (%)
Intraoperative transfusion	127 (27.8%)
Allogeneic	24 (5.2%)
Autologous	103 (22.6%)
Postoperative transfusion	113 (24.8%)
Allogeneic	32 (7.0%)
Autologous	81 (17.7%)
Total patients transfused	234 (51.2%)

2, 26 patients (23.0%) on Day 3 and 9 (8.0%) on Day 4. No transfusions were required after the fourth day.

Patients who gave PABD had significantly lower preoperative Hb levels (11.4 ± 1.37 g/dL; $P < 0.001$) than patients who did not give PABD (13.4 ± 1.4 g/dL; $P < 0.001$). They received significantly more transfusions both intraoperatively (22.6% vs. 5.2%) and postoperatively (20% vs. 6.3%).

The transfusion trigger value was significantly higher in patients who gave PABD than in those who did not (7.4 ± 0.9 g/dL vs. 7 ± 0.83 g/dL, respectively; $P = 0.029$).

Changes in trigger value and PABD over time

Comparing transfusion trigger values over the first 5 years of the study and the last 5 years showed that mean Hb for patients with surgery in 2006 or earlier was 7.65 ± 0.84 g/dL; starting in 2010, it was 7.3 ± 1.02 g/dL. This difference was not statistically significant ($P = 0.135$, Mann–Whitney test).

PABD was performed much less after 2006. The relationship between PABD and date of surgery was significant ($P < 0.001$).

Predictors of blood transfusion

Significant bivariate associations ($P < 0.01$) were found between blood transfusion and preoperative Hb, PABD, Cobb angle, duration of surgery, preoperative estimated blood volume and percentage of blood loss (Table 6). The probability of transfusion changed significantly for different levels of preoperative Hb, preoperative Cobb angle, duration of surgery and patient weight.

Odds ratios for the association between blood transfusion and preoperative Hb, using Hb > 14 g/dL as reference, showed that the probability of transfusion was 3.33 times greater (95% CI 1.21–9.18) when the preoperative Hb was 13–14 g/dL. The probability of transfusion increased 5.47-fold (95% CI 2.00–14.98) for Hb 12 and 26.8-fold (95% CI 9.59–74.8) for Hb 11. The probability of transfusion increased 49.6-fold (95% CI 17.40–141.37) when the preoperative Hb < 11 g/dL.

Table 6 Effect of predictors on the probability of autogenic or allogenic blood transfusion. The reference category did not receive transfusions

Blood transfusion (intraoperative or postoperative)	Predictor	Odds ratio	95% Confidence interval	
			Lower bound	Upper bound
Autologous	Pre-op Hb level	0.896	0.863	0.930
	Percent of blood loss	1.084	1.031	1.139
	Surgery duration	1.005	1.000	1.009
	Pre-op Cobb angle	1.038	1.011	1.067
	Weight	0.965	0.934	0.998
	PABD	76.68	28.58	205.71
Allogeneic or both	Pre-op Hb level	0.865	0.828	0.905
	Percent of blood loss	1.218	1.140	1.301
	Surgery duration	1.007	1.003	1.012
	Pre-op Cobb angle	1.037	1.007	1.067
	Weight	0.922	0.887	0.959
	PABD	1.566	0.571	4.295

Hb hemoglobin count, *PABD* preoperative autologous blood donation

Curve magnitude as measured by Cobb angle was significantly associated with an increased probability of transfusion. With a Cobb angle above 70° and 80°, the probability of transfusion increased 3.31 (1.70–6.44) and 5.36 (2.40–11.97) times, respectively. For major curves under 70°, however, there was no significant increase.

Surgery exceeding 5 and 6 h increased the probability of transfusion by 4.3 (1.84–10.14) and 9.8 (4.06–23.9) times, respectively, relative to duration less than 3 h.

For blood loss > 45% of estimated blood volume, the probability of transfusion increased (OR 1.94; 95% CI 1.01–3.71). No significant changes occurred with less loss of blood.

The patient's weight was associated with a significant increase in transfusion probability when < 40 kg or when 40–60 kg, with reference to no transfusion above 60 kg (OR 3.79; 95% CI 1.81–7.91, and OR 2.02; 95% CI 1.27–3.21, respectively).

Multivariate analyses suggested that the effect of all predictors except PABD was similar for allogeneic and autologous transfusions (Table 6). PABD, however, increased the likelihood of autologous transfusion 77 times but had no significant effect on allogeneic transfusion.

Multiple predictors in any one patient increased the risk of transfusion. For example, nine patients had an Hb level < 11 g/dL, with Cobb angle > 80°, and duration of surgery > 360 min; all (100%) were transfused. A total of 63 patients had an Hb level < 13 g/dL, with Cobb angle > 70°, and duration of surgery > 300 min; 81% received transfusions.

Discussion

This study showed that the lowest Hb levels occurred mostly on the second (32.2%) and third (33.3%) postoperative days. The mean Hb loss at lowest Hb was 4.1 ± 0.5 g/dL, which supports the recommendations for starting surgery at Hb levels ≥ 5 g/dL above the transfusion trigger value in order to minimize the need for transfusion [7].

Results showed that patients who provided PABD started surgery at significantly lower Hb levels than patients who did not, making PABD a major predictor of both blood transfusion and the timing of lowest postoperative Hb. Moreover, patients who provided PABD received significantly more transfusions, both intra- and postoperatively, than those who did not. This is in agreement with previous reports that PABD caused iatrogenic anemia and increased the transfusion rate; further, PABD is expensive [15–17].

In our study, PABD did in fact increase the rate of overall, but not allogeneic, transfusion. The potential economic benefit of not routinely offering PABD was not directly assessed in this study; intuitively, it could be a cost-saving measure. Cutting PABD would also reduce transfusion-associated morbidity and make the overall surgical trajectory less time-consuming for both patient and family. We believe that family counseling should include a discussion about PABD-associated risks.

Postoperative transfusion occurred most frequently on the second (45.1%) and third (23%) postoperative days. Only three of the patients needed allogeneic transfusion after the third postoperative day. Taking into account the timing of lowest Hb and most likely transfusion, it would seem that in AIS patients undergoing posterior spinal fusion, Hb analysis beyond the third postoperative day is therefore unnecessary unless clinically indicated.

Current postoperative management for patients with AIS includes routine daily measurement of Hb by venipuncture. This procedure adds to nursing time, cost of care, patient discomfort, and potential needlestick injury of healthcare professionals. There is no clear evidence for length of Hb measurement after surgery. The results of this study suggest

that Hb measurements after the third postoperative day may not be necessary unless clinically indicated. Limiting Hb measurement to 3 postoperative days would shorten hospital stay, in addition to the other considerations listed earlier.

Our results showed significant increases in the probability of transfusion by 4.3 and 9.8 times when the duration of surgery exceeded 5 and 6 h, respectively, as compared to less than 3 h. This confirms a previous study reporting an association between longer operative time and greater need for blood transfusion [18, 19].

Our findings are important for surgeons performing spinal fusion in the context of AIS. Predicting who may be at higher risk also enables better preoperative counseling of patients and families. Our results showed that the risk of transfusion varies significantly with change in predictor values. For instance, patients starting surgery at Hb < 11 g/dL are at a 49-fold greater risk of transfusion that those with preoperative Hb > 14 g/dL. Patients with a Cobb angle > 80° are at fivefold increased risk of transfusion. This knowledge gives us reason to operate as soon as curves reach 50°, rather than waiting for further curve progression. Keeping in mind the prolonged waiting times in our healthcare system, physicians might counsel families to start the process early on by signing up on waiting lists.

The main limitation of this study is the lack of strict transfusion trigger values, as it is a retrospective study of patients operated over a time span of 12 years. It was not possible to set strict transfusion trigger values in the absence of clear parameters in the literature to decide on when to transfuse, especially when Hb was 7–10 g/dL. However, a comparison of the first 5 years to the last 5 years of the study showed no significant difference in trigger value. We observed that postoperative transfusion occurred at higher transfusion trigger values in patients who gave PABD, which could be explained by the tendency to avoid wastage of PABD. Our institution is also heavily involved in blood transfusion protocols, and this could explain the stricter trigger values over the course of the study [20–24]. Another limitation was that we did not investigate the effect of fluid management and fluids perfused during and after the surgery, which may affect the timing of lowest Hb.

Conclusion

We have identified clear patient-specific perioperative parameters that affect the risk of perioperative blood transfusion. These factors include preoperative Hb levels, PABD, Cobb angle, duration of surgery, preoperative estimated blood volume and intraoperative blood loss. We believe that a better understanding of these parameters can lead to better preoperative prediction, assessment and counseling regarding the risk of blood transfusions.

Lowest Hb occurs mostly on the second or third day following posterior spinal fusion for AIS. However, transfusion is most often required on the second and maybe third postoperative day. In AIS patients undergoing posterior spinal fusion, Hb analysis beyond the third postoperative day is therefore considered unnecessary unless clinically indicated.

Acknowledgements The authors are grateful to Danielle Buch, medical writer, for critical revision and substantive editing of the manuscript.

Funding This study was supported by Academic Research Chair in Spinal Deformities at CHU Sainte-Justine.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

IRB approval Institutional review board approval was obtained for this study from CHU Sainte-Justine IRB.

References

1. Blanchette CM, Wang PF, Joshi AV, Asmussen M, Saunders W, Kruse P (2007) Cost and utilization of blood transfusion associated with spinal surgeries in the United States. Eur Spine J 16(3):353–363
2. Shapiro F, Sethna N (2004) Blood loss in pediatric spine surgery. Eur Spine J 13(Suppl 1):S6–S17
3. Segal JB, Guallar E, Powe NR (2001) Autologous blood transfusion in the United States: clinical and nonclinical determinants of use. Transfusion (Paris) 41(12):1539–1547
4. Yoshihara H, Yoneoka D (2014) National trends in spinal fusion for pediatric patients with idiopathic scoliosis: demographics, blood transfusions, and in-hospital outcomes. Spine 39(14):1144–1150
5. Nuttall GA, Horlocker TT, Santrach PJ, Oliver WC Jr, Dekutoski MB, Bryant S (2000) Predictors of blood transfusions in spinal instrumentation and fusion surgery. Spine 25(5):596–601
6. Koerner JD, Patel A, Zhao C, Schoenberg C, Mishra A, Vives MJ et al (2014) Blood loss during posterior spinal fusion for adolescent idiopathic scoliosis. Spine 39(18):1479–1487
7. van Popta D, Stephenson J, Patel D, Verma R (2014) The pattern of blood loss in adolescent idiopathic scoliosis. Spine J Off J N Am Spine Soc 14(12):2938–2945
8. Yu X, Xiao H, Wang R, Huang Y (2013) Prediction of massive blood loss in scoliosis surgery from preoperative variables. Spine 38(4):350–355
9. Li C, Yang M, Wang C, Wang C, Fan J, Chen Z et al (2015) Preoperative factors predicting intraoperative blood loss in female patients with adolescent idiopathic scoliosis. Medicine (Baltimore) 94(1):e359
10. Yoshihara H, Yoneoka D (2014) Predictors of allogeneic blood transfusion in spinal fusion for pediatric patients with idiopathic scoliosis in the United States, 2004-2009. Spine 39(22):1860–1867
11. Lam SK, Pan IW, Harris DA, Sayama CM, Luerssen TG, Jea A (2015) Patient-, procedure-, and hospital-related risk factors of allogeneic and autologous blood transfusion in pediatric spinal fusion surgery in the United States. Spine 40(8):560–569

12. Kennedy C, Leonard M, Devitt A, Girardi FP, Cammisa FP Jr (2011) Efficacy of preoperative autologous blood donation for elective posterior lumbar spinal surgery. Spine 36(26):E1736–E1743
13. Ialenti MN, Lonner BS, Verma K, Dean L, Valdevit A, Errico T (2013) Predicting operative blood loss during spinal fusion for adolescent idiopathic scoliosis. J Pediatr Orthop 33(4):372–376
14. Yilmaz G, Borkhuu B, Dhawale AA, Oto M, Littleton AG, Mason DE et al (2012) Comparative analysis of hook, hybrid, and pedicle screw instrumentation in the posterior treatment of adolescent idiopathic scoliosis. J Pediatr Orthop 32(5):490–499
15. Goldman M, Savard R, Long A, Gelinas S, Germain M (2002) Declining value of preoperative autologous donation. Transfusion (Paris) 42(7):819–823
16. Savoia HF, Metz J, Maxwell EL, Hauesler MN, Mellor J, Kiely S (2002) Utilization of preoperative autologous blood donation in elective surgery. ANZ J Surg 72(8):557–560
17. Billote DB, Glisson SN, Green D, Wixson RL (2002) A prospective, randomized study of preoperative autologous donation for hip replacement surgery. J Bone Joint Surg Am 84(A-8):1299–1304
18. Dupuis C, Michelet D, Hilly J, Diallo T, Vidal C, Delivet H et al (2015) Predictive factors for homologous transfusion during paediatric scoliosis surgery. Anaesth Crit Care Pain Med 34(6):327–332
19. Kwan MK, Chiu CK, Chan CY (2017) Single vs two attending senior surgeons: assessment of intra-operative blood loss at different surgical stages of posterior spinal fusion surgery in Lenke 1 and 2 adolescent idiopathic scoliosis. Eur Spine J 26(1):155–161
20. Desmet L, Lacroix J (2004) Transfusion in pediatrics. Crit Care Clin 20(2):299–311
21. Lacroix J, Hebert PC, Hutchison JS, Hume HA, Tucci M, Ducruet T et al (2007) Transfusion strategies for patients in pediatric intensive care units. N Engl J Med 356(16):1609–1619
22. Toledano B, Tucci M, Lacroix J (2011) Red cell transfusion to cardiac patients: facts and fallacies. Pediatr Crit Care Med 12(1):107–108
23. Fortin S, Cardona LG, Latreille M, Tucci M, Lacroix J (2016) Blood transfusion in acute and chronic pediatric settings: beliefs and practices. Transfusion (Paris) 56(1):130–138
24. Mazine A, Rached-D'Astous S, Ducruet T, Lacroix J, Poirier N (2015) Blood transfusions after pediatric cardiac operations: a North American multicenter prospective study. Ann Thorac Surg 100(2):671–677

Affiliations

Hany Abdel Gawwad Soliman[1,2,3] · Marie Beausejour[1,2] · Julie Joncas[2] · Marjolaine Roy-Beaudry[2] · Soraya Barchi[2] · Jean-Marc Mac-Thiong[1,2,4] · Hubert Labelle[1,2] · Guy Grimard[1,2] · Stefan Parent[1,2,4]

✉ Stefan Parent
stefan.parent@umontreal.ca

[1] University of Montreal, Montreal, Canada

[2] Division of Orthopedic Surgery, CHU Sainte-Justine, 3175Côte-Sainte-Catherine, Montréal, QC H3T 1C5, Canada

[3] Al zahraa University Hospital, Al-Azhar University, Cairo, Egypt

[4] Hôpital du Sacré-Coeur, Montreal, Canada