Risk analysis of blood transfusion requirements in emergency and elective spinal surgery

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Abstract Spinal surgery has long been considered to have an elevated risk of perioperative blood loss with significant associated blood transfusion requirements. However, a great variability exists in the blood loss and transfusion requirements of differing patients and differing procedures in the area of spinal surgery. We performed a retrospective study of all patients undergoing spinal surgery who required a transfusion ≥ 1 U of red blood cells (RBC) at the National Spinal Injuries Unit (NSIU) at the Mater Misericordiae University Hospital over a 10-year period. The purpose of this study was to identify risk factors associated with significant perioperative transfusion allowing the early recognition of patients at greatest risk, and to improve existing transfusion practices allowing safer, more appropriate blood product allocation. 1,596 surgical procedures were performed at the NSIU over a 10-year period. 25.9% (414/1,596) of these cases required a blood transfusion ($n = 414$). Surgical groups with a significant risk of requiring a transfusion >2 U RBC included deformity surgery (RR = 3.351, 95% CI 1.123–10.006, $p = 0.03$), tumor surgery (RR = 3.298, 95% CI 1.078–10.089,

$p = 0.036$), and trauma surgery (RR = 2.444, 95% CI 1.183–5.050, $p = 0.036$). Multivariable logistic regression analysis identified multilevel surgery (>3 levels) as a significant risk of requiring a transfusion >2 U RBC (RR = 4.682, 95% CI 2.654–8.261, $p < 0.0001$). Several risk factors in the spinal surgery patient were identified as corresponding to significant transfusion requirements. A greater awareness of the risk factors associated with transfusion is required in order to optimize patient management.

Keywords Blood loss · Transfusion requirement · Spinal surgery

Introduction

Blood transfusion practices in orthopedic surgery have been receiving greater attention with an increased awareness of perioperative blood loss. Blood transfusion is costly and associated with substantial risks including the transmission of infectious disease [1]. Blood transfusion is also associated with potentially fatal noninfectious risks such as clerical error, hemolytic reactions, transfusion-related lung injury, and transfusion-associated graft-versus-host diseases [1]. Most concerning is the impaired immune response attributed to blood transfusion, the key implication being an increased risk of postoperative infectious complications and tumor recurrence which has been observed in the spectrum of surgical oncology procedures [2–4]. This has led to a trend towards safer transfusion practices, minimizing the need for allogenic blood transfusion [5].

Spinal surgery has long been considered to have an elevated risk of perioperative blood loss with significant associated blood transfusion requirements due to extensive

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surgical dissection, complexity of technique, and prolonged operative duration. However, great variability exists in the blood loss and transfusion requirements of differing patients and procedures in the field of spinal surgery.

Emerging evidence has associated a variety of risk factors, such as advancing age, preoperative anemia, tumor surgery, and posterior stabilization procedures with increased blood transfusion requirements [6, 7]. These data have been generally derived from small patient cohorts utilizing differing statistical models for risk analysis.

In the current study the blood transfusion requirements at a national referral center for spinal surgery to identify risk factors associated with significant perioperative transfusion. The purpose of this study was first, to allow the early recognition of patients at greatest risk, and second, to improve existing transfusion practices allowing safer, more appropriate blood product allocation.

Patients and methods

A retrospective study of all patients undergoing spinal surgery who required a transfusion ≥ 1 unit (U) of red blood cells (RBC) at the National Spinal Injuries Unit (NSIU) in the Mater Misericordiae University Hospital (MMUH) between 1st January 1996 and 31st December 2005 was performed ($n = 414$). The NSIU is the tertiary referral center for all spinal injuries and diseases of the spine warranting surgical intervention in the Republic of Ireland.

The Hospital Inpatient Enquiry (HIPE) System and NSIU databases were used to identify our study cohort. Data were collected from the MMUH prospectively maintained transfusion laboratory database and supplemented with data from Hospital Inpatient System (HIS) and the medical records of patients.

Patient data collected included age, sex, preoperative hemoglobin (Hb), platelet count, prothrombin time, international normalized ratio (INR), preoperative anti-coagulant medications, preoperative medical health, type of surgery, spinal region involved, number of spinal levels involved, surgical approach, and number of levels instrumented. The number of allogenic blood units and additional blood products transfused perioperatively and throughout hospitalization were noted. While no formal policy for a transfusion threshold has been established at our institution, there is a general consensus among our surgeons to transfuse spinal surgery patients with hemoglobin of less than 10 g/dL. A consensus on the definition of significant blood transfusion has not been established among orthopedic surgeons. For the purposes of this study a significant transfusion was defined as that over 2 U RBC.

Differences between mean transfusion requirements per indication for surgery were assessed using a Mann–Whitney *U* test. Variables deemed important potential predictors of transfusion were initially assessed on univariate analysis. These variables were then included in a stepwise multiple logistic regression model. Both the univariate and multivariable logistic regression analyses performed determined the relative risk (RR) of requiring a transfusion of over 2 U RBC perioperatively in the evaluated cohort. A confidence interval (CI) of 95% and $p < 0.05$ was considered to be statistically significant. Statistical analysis was performed using the SPSS 12.01 software (SPSS Inc, Chicago, IL).

Results

1,596 surgical procedures were performed at the NSIU over the 10-year period examined. 25.9% (414/1,596) of these cases required a blood transfusion ($n = 414$). This subgroup of patients was the subject of our subsequent analysis to assess risk factors associated with significant transfusion (Table 1).

The surgical approach was anterior in 6.0% (25/414), posterior in 88.6% (367/414), and both anterior and posterior in 5.3% (22/414). 72.9% of patients (302/414) had neurological deficit pre-operatively. 45.0% of these patients (136/302) had a complete neurological deficit below the level of injury. Of the 274 cases operated upon for trauma the most common mechanisms of injury were falls (25.9%, 71 patients) and road traffic accidents (43.4%, 119 patients). 45.6% of patients (125/414) had associated non-spinal injury secondary to trauma.

The median (interquartile range (IQR) patient age requiring transfusion was 48 (28–63) years. There was a greater proportion of males, representing 64.3% of the cohort (male:female = 1.8:1). Mean ($\pm$ standard deviation) preoperative laboratory values noted included hemoglobin 12.2 ± 1.92 g/dL, platelet count $269 \pm 78 \times 10^9/L$, prothrombin time 11.5 ± 1.9 s, and INR 1.15 ± 0.37 .

All 414 patients in the cohort received an allogenic blood transfusions and the median number of units transfused was three. 7.5% of patients (31/414) received a platelet transfusion, 14% of patients (58/414) received a transfusion of FFP, and 1.2% of patients (5/414) received cryoprecipitate. One patient received an auto-transfusion of 3 units of RBC.

When classified our patient cohort according to type of surgery 66.4% (275/414) were for trauma, 13.5% (56/414) for malignancy, 7.8% (32/414) for stenosis, 5.8% (24/414) for deformity, 3.9% (16/414) for infection, 1% (4/414) for spondylolisthesis, 1% (4/414) for rheumatoid, and 0.8% (3/414) were classified as being for another indication.

Table 1 Patient demographics

Male:female	266:148 (64.3%:35.7%)
Length of stay (days)	21 (12–33)
Age (years)	48 (28–63.25)
Pre-operative hemoglobin (g/dL)	12.4 (11–13.5)
Pre-operative INR	1.1 (1–1.2)
Blood type	
O	206 (49.8%)
A	154 (37.2%)
B	46 (11.1%)
AB	8 (1.9%)
Rhesus negative	64 (15.5%)
Region operated upon	
Cervical	66 (15.9%)
Cervico-thoracic	4 (1%)
Thoracic	121 (29.2%)
Thoraco-lumbar	108 (26.1%)
Lumbar	113 (27.3%)
Sacral	2 (0.5%)
Pathology	
Trauma	275 (66.4%)
Neoplasm	56 (13.5%)
Stenosis	32 (7.8%)
Deformity	24 (5.8%)
Infection	16 (3.9%)
Spondylolisthesis	4 (1%)
Rheumatoid arthritis	4 (1%)
Other	3 (0.8%)
Levels injured by trauma	2 (1–3)
Levels operated upon	3 (3–5)
RBC units transfused	3 (2–6)
Platelet units transfused	2 (2–4.5)
FFP units transfused	4 (3–4)
Cryoprecipitate units transfused	2 (2–2)

Data are presented as median (interquartile range)

RBC red blood cell, FFP fresh frozen plasma

The median (IQR) RBC transfusion requirement for each indication was 2 U (2–2.75) for spondylosis, 2 U (2–3) for spinal stenosis, 2.5 U (2–3.75) for spinal rheumatoid arthritis, 3.5 U (2–6) for spinal malignancy, 4 U (2–6) for spinal infection, 4 U (2–6) for spinal trauma, and 5.5 U (2.25–8.5) for spinal deformity correction (Fig. 1). On univariate analysis of indications for spinal surgery and risk of requiring a transfusion of over 2 U RBC, surgery for trauma (RR 2.4, 95% CI 1.2–5.1, $p = 0.016$), surgery for spinal malignancy (RR 3.3, 95% CI 1.1–10.1, $p = 0.036$), and surgery for spinal deformity (RR 3.6, 95% CI 1.1–10.0, $p = 0.03$) were each associated with an significantly increased risk relative to other indications (Table 2).

Fig. 1 Red blood cell transfusion requirement per indication for spinal surgery. *differs from all other indications, $p = 0.02$, Mann–Whitney U test

Table 2 Analysis of the effect of indication for surgery on the requirement for blood transfusion during spinal surgery

	RR	95% CI	p Value
Spondylolisthesis	0.667	0.025–18.059	0.810
Spinal stenosis	0.958	0.155–5.92	0.964
Rheumatoid	2.484	0.259–23.856	0.43
Neoplasm	3.298	1.078–10.089	0.036
Infection	3.429	0.916–12.835	0.067
Trauma	2.444	1.183–5.050	0.016
Deformity	3.351	1.123–10.006	0.030

Univariate logistic regression analysis assessing independent predictors of transfusion >2 U RBC during a spinal procedure in the evaluated cohort ($n = 414$)

CI confidence interval, INR international normalized ratio

In the first step of our risk analysis, univariate analysis, the following variables were identified as significant predictors ($p < 0.05$) of transfusion >2 U RBC in our spinal surgery cohort: injury level of greater than 3 vertebrae (RR 1.8, 95% CI 1.2–2.7, $p = 0.005$), having over 3 vertebrae operated upon (RR 5.6, 95% CI 3.5–8.7, $p < 0.0001$), a posterior surgical approach (RR 2.217, 95% CI 0.667–7.367, $p = 0.194$), and an elevated INR (RR 6.8, 95% CI 1.6–29.4, $p = 0.01$). Age greater than 65 was associated with reduced risk of requiring a transfusion of over 2 U RBC (RR 0.51, 95% CI 0.3–0.8, $p = 0.004$) (Table 3).

Table 3 Multivariable logistic regression analysis of the effect of peri-operative patient characteristics on the requirement for blood transfusion during spinal surgery

Univariate analysis				Multivariable analysis		
	RR	95% CI	<i>p</i> Value	RR	95% CI	<i>p</i> Value
Age >65 years	0.51	0.323–0.804	0.004	0.636	0.35–1.155	0.137
Sex (male)	1.441	0.955–2.175	0.082	1.39	0.808–2.392	0.235
Anemia	1.408	0.945–2.098	0.093	1.657	0.964–2.85	0.068
INR	6.843	1.595–29.366	0.010	2.407	0.538–10.767	0.251
Approach						
Anterior	0.944	0.38–2.345	0.901	0.575	0.191–1.728	0.324
Posterior	2.217	0.667–7.367	0.194	1.828	0.478–6.996	0.378
Injury level >3	1.793	1.19–2.701	0.005	0.961	0.542–1.703	0.892
Surgery level >3	5.552	3.533–8.727	<0.0001	4.682	2.654–8.261	<0.0001

Multivariable logistic regression analysis assessing predictors of transfusion >2 U RBC during a spinal procedure in the evaluated cohort ($n = 414$), with remaining variables inserted as cofactors in a multivariable model in order to adjust for respective effects

CI confidence interval, INR international normalized ratio

In the second step of our analysis, stepwise multivariable logistic regression analysis, we included all variables previously selected from univariate analysis as independent predictors in a multivariable model. The only significant predictor ($p < 0.05$) of transfusion >2 U RBC in our spinal surgery cohort was having had over 3 vertebrae operated upon (RR 4.7, 95% CI 2.7–8.3, $p < 0.0001$) (Table 3).

Discussion

Spinal surgery has long been associated with considerable perioperative blood loss and significant transfusion requirements [8–10]. With an ever increasing trend towards minimizing the need for allogenic blood transfusion, a variety of blood conservation techniques have been employed to minimize the transfusion requirements in the spinal surgery patient. Techniques utilized have included preoperative autologous blood donation, appropriate patient positioning, adequate muscle paralysis to minimize intra-abdominal pressure, infiltration of paraspinal tissues with epinephrine, intraoperative blood salvage, use of controlled hypotensive anesthesia, and use of anti-fibrinolytic agents [11–16].

Despite use of these measures, allogenic blood transfusion still remains a widely used strategy to treat perioperative blood loss in spinal surgery. Of recent there has been an increased awareness of the risks associated with allogenic blood transfusion such as allogenic reactions, hemolytic reactions, increased infection rates, and disease transmission, particularly human immunodeficiency virus and hepatitis [17–21].

Our study attempted to identify risk factors associated with significant perioperative transfusion in the spinal

surgery patient in order to allow early recognition of the patients at greatest risk of requiring significant transfusion. From our national spinal service,

1,596 surgical procedures were performed over a 10-year period. 25.9% (414/1,596) of these cases required a blood transfusion. Surgical groups with a significant risk of requiring a transfusion >2 U RBC included deformity surgery, tumor surgery, and trauma surgery. Multilevel surgery (>3 levels) was identified on multivariate regression analysis as having a significant risk of requiring a transfusion >2 U RBC.

Deformity surgery was identified in our study to convey a significant transfusion risk. Considerable intraoperative hemorrhage is a well-established complication associated with major deformity surgery, in particular cases involving corrective vertebral osteotomies [7, 22, 23]. Tumor surgery was also found to have a significant risk of associated allogenic blood transfusion, with tumors of the vertebral column tending to be very vascular in nature leading to significant intraoperative blood loss. This situation is complicated by the lack of intraoperative autotransfusion secondary to concerns over tumor metastasis. Multilevel surgery with fusion of multiple levels was also identified from our data as carrying a significant risk of intraoperative hemorrhage and postoperative blood transfusion. This is also in line with findings in current world literature [7, 14, 24, 25].

It must be acknowledged that an obvious limitation to our study is that it is a single-center observational study. As a result, the findings from our study, although significant in our patient cohort, may not be generalizable and caution must be taken when attempting to extrapolate to different patient populations.

There have been several clinical studies investigating methods of reducing the allogenic blood transfusion

requirements in the orthopedic setting while minimizing post-operative anemia [26–29]. Allogenic blood transfusion is unavoidable in certain situations, such as the multiple trauma patient. However, in the elective surgery setting, there should be a greater awareness of the risk factors associated with transfusion and the transfusion requirements should be evaluated well in advance. Furthermore, a number of measures should be considered in order to reduce the probability of having to resort to allogenic blood transfusion. Key elements which should be taken into consideration are the pre-operative erythrocyte stock, the anticipated peri-operative blood loss, and the acceptable blood loss for that specific patient [5].

The need for allogenic blood transfusion may be reduced by various measures [5] which include the optimization of the patient's preoperative erythrocyte stock (i.e. administration of erythropoietin, oral or intravenous iron) [30]. A prospective, open-label, randomized, parallel-group study assessing the effects of erythropoietin in spinal surgery at 80 centers demonstrated a high incidence of deep vein thrombosis and other clinically relevant thrombovascular events in patients administered epoetin alfa 600 U/kg subcutaneously once weekly starting 3 weeks before spinal surgery [31].

Other measures aimed at reducing allogenic blood transfusion requirements include minimizing of peri-operative blood loss, such as, pre-operative cessation of low-molecular-weight-heparins, vitamin K antagonists, aspirin, and NSAIDs [32]. Use of controlled hypotensive spinal or epidural anesthesia has been demonstrated to be associated with reduced perioperative blood loss and need for transfusion, although most studies to date have been small poorly designed studies [33–35].

Additionally, it has been suggested that lowering of the transfusion trigger (i.e. reducing the transfusion trigger from 10 g/dL Hb to 8 g/dL in older patient with no comorbidities and 7 g/dL in young healthy patients) [36] and increasing the use of pre-operative autologous blood donation [37, 38] can also contribute to reducing allogenic blood transfusion requirements.

As blood management is undoubtedly a complex issue, an integrated approach is required to minimize the allogenic transfusion requirements of the spinal patient and optimize perioperative patient care.

Conclusions

Several risk factors in the spinal surgery patient were identified as corresponding to significant transfusion requirements. Surgical groups with a significant risk of requiring a transfusion >2 U RBC included deformity surgery, tumor surgery, and trauma surgery. Multilevel

surgery (>3 levels) was identified on multivariate regression analysis as having a significant risk of requiring a transfusion >2 U RBC. A greater awareness of the risk factors associated with transfusion is required in order to optimize patient management.

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