World Neurosurgery: X 22 (2024) 100289

Contents lists available at ScienceDirect

World Neurosurgery: X

journal homepage: www.journals.elsevier.com/world-neurosurgery-x

Incidence, risk factors and impact of anemia after elective neurosurgery: A retrospective cohort study

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ARTICLE INFO

Keywords:
Postoperative anemia
Neurosurgery
Incidence
Risk factors
Outcomes
Blood transfusion

ABSTRACT

Objectives: Anemia after surgery is common and is associated with adverse clinical outcomes. Understanding the incidence and risk factors for postoperative anemia is important to reduce anemia-related complications and blood transfusion. There is lack of data regarding postoperative anemia and its contributing factors in neurosurgery. This study evaluates the incidence and risk factors of postoperative anemia, and its impact on clinical outcomes.

Methods: This was a single centre, retrospective study of patients who underwent elective neurosurgery over seven months. Data regarding age, gender, body mass index, American Society of Anesthesiologists (ASA) physical status, diagnosis, surgery, preoperative hemoglobin, surgery duration, intraoperative blood loss and red blood cell (RBC) transfusion, dose of tranexamic acid, intraoperative fluid balance, years of surgeon's experience, postoperative hemoglobin, postoperative RBC transfusion, Glasgow Coma Scale (GCS) score at hospital discharge, and duration of postoperative intensive care unit and hospital stay were collected. Logistic regression was used to identify predictors of postoperative anemia.

Results: The incidence of postoperative anemia was 11.3% (116/1025). On univariate analysis; age, preoperative hemoglobin, surgery duration, gender, ASA grade, surgery type, and surgeon's experience were associated with postoperative anemia. Lower preoperative hemoglobin ($p<0.001$) and non-tumor surgery ($p<0.001$) were predictive of postoperative anemia on multivariate analysis. Postoperative anemia resulted in increased RBC transfusion ($p<0.001$) and lower GCS score at discharge ($p=0.012$).

Conclusions: Atleast one in ten patients undergoing elective neurosurgery develop postoperative anemia. Lower preoperative hemoglobin and non-tumor surgery predict anemia. Anemia results in increased RBC transfusion and lower discharge GCS score.

1. Introduction

Blood loss is a natural risk of any surgical intervention.[1] It often leads to intraoperative and postoperative anemia requiring blood transfusion. Both anemia and blood transfusion are however associated with risks for the patients in the perioperative period leading to poor outcomes. Acute perioperative anemia has been associated with hemodynamic instability, delayed recovery, increased blood product transfusion, re-do surgery or hospital readmission, myocardial infarction, and increased mortality.[2] On the other hand, red blood cell (RBC) transfusion to treat anemia can result in increased cost, and complications such as infections, immunological reactions, and decreased survival.[3]

Neurosurgical procedures are often associated with significant blood loss necessitating blood transfusion to maintain optimal cerebral hemodynamics and oxygenation. However, there are no clear guidelines regarding thresholds for blood transfusion in the perioperative period in neurosurgical patients.[4] Decision to diagnose and correct anemia by RBC transfusion is therefore difficult and is usually taken considering the risk-benefit ratio of anemia and transfusion for individual patients. Hemoglobin concentration of 9–10 g% is generally considered optimal for neurologically injured patients.[5]

The recent international consensus statement on the management of

Abbreviations: RBC, Red blood cells; AIMS, anesthesia information management system; BMI, body mass index; ASA, American Society of Anesthesiologists; GCS, Glasgow Coma Scale; ICU, intensive care unit; TKA, total knee arthroplasty.

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https://doi.org/10.1016/j.wnsx.2024.100289
Received 18 February 2023; Accepted 20 February 2024
Available online 24 February 2024

postoperative anemia after major surgery suggests screening for postoperative anemia in all patients undergoing major surgery (blood loss >500 ml or > 2 h duration) and having pre-operative anemia or moderate-to-severe blood loss during surgery.[2] Assessing hemoglobin in the immediate postoperative period not only helps in detecting postoperative anemia but also informs about the adequacy of intraoperative RBC transfusion and ensures appropriate use of scarce resource of blood products.

An audit of the postoperative anemia and perioperative blood transfusion patterns in neurosurgical patients will help understand factors contributing to postoperative anemia and facilitate development of better blood transfusion protocols for efficient resource utilization. However, we could not find studies in the literature evaluating the risk factors and outcomes of postoperative anemia in neurosurgical population. Hence, this study was conducted.

The primary objective of this study was to evaluate the incidence of immediate postoperative anemia in neurosurgical patients. Our secondary objectives were to identify its potential risk factors and to assess the impact of postoperative anemia on in-hospital clinical outcomes.

2. Materials and methods

This single centre, retrospective study was conducted at a tertiary neurosciences academic hospital, the National Institute of Mental Health and Neurosciences, Bengaluru, India, after obtaining approval from the institute's ethics committee (NIMHANS 31st IEC (BS & NS DIV)/2021 dated 19-08-2021). We included all patients who underwent elective neurosurgery over a period of seven months from 1st January 2019 till 31st July 2019. The data was extracted from the electronic patient health records - anesthesia information management system (AIMS), and e-hospital (the digital medical and laboratory records).

We collected demographic details (age, gender, body mass index [BMI]), clinical details (American Society of Anesthesiologists [ASA] physical status, diagnosis, surgery, preoperative hemoglobin, surgery duration, intraoperative blood loss and RBC transfusion, dose of tranexamic acid used during surgery, intraoperative fluid balance), and years of surgeon's experience to explore them as potential factors contributing to postoperative anemia. Based on earlier reports in non-neurosurgical population in the absence of data involving neurosurgery and our clinical experience, we hypothesized that older age,[6,7] female gender, lower BMI, lower preoperative hemoglobin values,[7,8] not using tranexamic acid during surgery,[9] perioperative blood loss, hemodilution from administration of large volumes of intraoperative fluids,[2] tumor (vs. non-tumor) surgery,[10] prolonged duration of surgery,[11] higher (3–5 vs. 1–2) ASA grade, cranial (vs. non-cranial) surgery, lesser intraoperative RBC transfusion (<2 units vs. ≥ 2 units) and lesser surgeon's experience (<6 years vs. ≥ 6 years) will be associated with postoperative anemia.

We also collected data regarding postoperative outcomes such as immediate postoperative hemoglobin, postoperative RBC transfusion, Glasgow Coma Scale (GCS) score at hospital discharge, and duration of postoperative intensive care unit (ICU) and hospital stay. Postoperative anemia was defined for this study as a hemoglobin level below 10 g/dL in the first 24 h after surgery based on our hospital practice of avoiding RBC transfusion above this threshold and previous reports.[12,13]

Considering the incidence of postoperative anemia of 16.7% in a previous study[8] involving patients who underwent total knee arthroplasty (TKA) and of about 13% in our pilot study and an alpha of 0.05 and power of 90%, the minimum number of patients needed was determined to be 986 for this study. The statistical analysis was performed using statistical package for social sciences version 28. Continuous variables were compared using *t* test and qualitative data using χ^2 test or Fisher exact test. Logistic regression was used to identify potential risk factors for postoperative anemia. A $p < 0.05$ was considered as statistically significant.

3. Results

A total of 1032 neurosurgical procedures were performed during the study period. In seven patients who underwent peripheral nerve surgeries, postoperative hemoglobin was not assessed. The incidence of postoperative anemia after elective neurosurgery in our cohort of patients was 11.3% (116/1025). Among the tumor diagnosis, postoperative anemia occurred in 10/141 patients with glioma, 10/129 in meningioma, 1/72 in schwannoma, and 20/215 patients with other brain tumors such as pituitary adenoma, colloid cyst, epidermoid, posterior fossa lesions, etc. In the non-tumor category, postoperative anemia was seen in 26/239 patients undergoing spine surgery, 0/18 patients after nerve surgery, 29/132 patients after vascular surgery, and 20/79 patients after cranial vault, cerebrospinal fluid diversion, epilepsy or functional surgery. Postoperative anemia was more in patients undergoing cranial surgeries (11.8%, 88/747) than in patients undergoing non-cranial neurosurgeries (10.1%, 28/278). The mean preoperative and postoperative hemoglobin concentrations were 13.16 ± 1.8 and 12.16 ± 1.8 g% respectively. Intraoperative RBC transfusion occurred in 233/1032 (22.6%) patients while postoperative RBC transfusion was performed in 40/1032 (3.9%) patients.

On univariate analysis, younger age, lower preoperative hemoglobin, shorter surgery duration, female gender, higher ASA grade, non-tumor surgery and higher operating experience of the surgeon were associated with occurrence of postoperative anemia (Table 1). When variables with $p \leq 0.1$ on univariate analysis were entered into a multivariate regression model, only lower preoperative hemoglobin ($p < 0.001$) and non-tumor surgery ($p < 0.001$) remained predictive of postoperative anemia (Table 2). Intraoperative blood loss was significantly more in patients undergoing tumor surgery than non-tumor surgery. In line with this, more number of patients undergoing tumor surgery than non-tumor surgery received atleast 2 units of RBC

Table 1
Factors associated with postoperative anemia on univariate analysis.

Variable	Anemia	No anemia	F/χ2	*p* value
Age (years)	32.09 ± 22.68	36.66 ± 18.21	17.78	**0.014**
BMI (kg/m2)	23.69 ± 4.49	23.62 ± 4.03	0.001	0.915
Preoperative hemoglobin (g %)	11.14 ± 1.45	13.40 ± 1.67	1.91	**<0.001**
Surgery duration (min)	209.86 ± 100.24	231.08 ± 111.99	2.02	**0.052**
Blood loss (ml)	470.19 ± 536.45	500.93 ± 472.54	0.31	0.538
Tranexamic acid dose (mg)	75.30 ± 339.71	120.46 ± 393.76	5.44	0.238
Fluid balance (ml)	781.83 ± 704.85	825.47 ± 730.52	0.67	0.543
Gender (n)	79	389	26.56	<
Female	37	520		**0.001**
Male				
ASA grade (n)	96	801	2.71	**0.100**
1–2	20	108		
3–5				
Surgery location (n)	88	659	0.59	0.506
Cranial	28	250		
Non-cranial				
Surgical pathology (n)	37	539	31.37	<
Tumor	79	369		**0.001**
Non-tumor				
Surgeon experience (n)	49	477	4.30	**0.039**
<6 years	67	432		
≥6 years				
Intraoperative RBC transfusion (n)	106	814	0.38	0.628
<2 units	10	95		
≥2 units				

BMI- body mass index; ASA- American Society of Anesthesiologists; RBC- red blood cells.

Table 2
Predictors of postoperative anemia on multivariate analysis.

Variables	B	S.E.	Wald	df	Sig.	Exp (B)	95% CI	
							Lower	Upper
Age (years)	−0.007	0.006	1.21	1	0.270	0.994	0.982	1.005
Female gender	0.423	0.247	2.94	1	0.086	1.527	0.941	2.476
Higher ASA grade (III to V)	0.288	0.335	0.74	1	0.389	1.334	0.692	2.570
Non-tumor surgery	1.146	0.246	21.69	1	<0.001	3.147	1.942	5.098
Preoperative hemoglobin (g %)	−0.857	0.084	104.36	1	<0.001	0.424	0.360	0.500
Surgery duration (min)	−0.001	0.001	0.46	1	0.499	0.999	0.997	1.001
Less experienced surgeon (<6 years)	−0.293	.237	1.53	1	0.216	0.746	0.469	1.187

ASA- American Society of Anesthesiologists.

transfusion in the intraoperative period. However, there was no difference in postoperative RBC transfusion between patients undergoing tumor and non-tumor surgeries (Table 3).

There was a significant association of immediate postoperative anemia with postoperative RBC transfusion ($p < 0.001$) and GCS at discharge ($p = 0.012$). Postoperative RBC transfusion was performed in 24/116 patients (20.7%) with postoperative anemia whereas transfusion was done in only 15/909 patients (1.7%) without postoperative anemia. Less number of patients with postoperative anemia had GCS score of 15 at discharge as compared to those without postoperative anemia [90.1% (102/113) vs. 96.2% (859/893)]. However, extubation rates and durations of postoperative ICU and hospital stay were similar between those with and without postoperative anemia (Table 4).

Table 4
Impact of postoperative anemia on clinical outcomes.

Variable	Anemia	No anemia	F/χ2	*p* value
Postoperative transfusion (n)	24/116	15/909	101.89	**<0.001**
Postoperative extubation in operating room (n)	37/116	244/909	1.32	0.269
GCS 15 at discharge (n)	102/113	859/893	8.25	**0.012**
Postoperative ICU stay (days)	1.48 ± 5.73	0.96 ± 4.29	4.53	0.239
Postoperative hospital stay (days)	7.52 ± 8.31	6.88 ± 8.41	0.08	0.440

GCS- Glasgow Coma Scale; ICU- Intensive Care Unit.

4. Discussion

The World Health Organization defines anemia as hemoglobin level <12 g% for females and <13 g% for males.[14] Based on this definition, postoperative anemia may be present in 80–90% of patients undergoing major surgeries.[2] However, for all practical purposes, a hemoglobin threshold of <10 g% is most often used for making a diagnosis of postoperative anemia.[12,13] Postoperative anemia is a common complication after surgery and has been shown to be associated with poor clinical outcomes including acute kidney injury, postoperative delirium and prolonged hospitalization.[13,15,16] Hence, early detection and correction of anemia in surgical patients is important to minimize anemia associated complications and improve outcomes.

The incidence of postoperative anemia after major surgery varies widely due to different definitions, pre-existing comorbid conditions and type of surgery performed.[17] The incidence of postoperative anemia (hemoglobin <10 g%) in patients undergoing total hip replacement surgery was 38% (938/2467)[13] and in TKA surgery (hemoglobin <9 g%) was 16.7% (253/1517).[8] The higher incidences observed in these studies could be due to the higher age in the hip surgery population and lower hemoglobin level used for diagnosing postoperative anemia in knee surgery population. There is absence of data regarding incidence, risk factors and outcomes of postoperative anemia in patients undergoing elective cranial neurosurgery. An earlier study involving patients undergoing posterior lumbar decompression surgery observed a mean drop in hemoglobin of 2.4 g % from 13.6 g% before surgery to 11.2 g % after surgery.[18] In contrast, the mean change in hemoglobin before and after surgery in our study was only 1 g% in our study. This minimal difference in pre- and postoperative hemoglobin values along with lower incidence of postoperative anemia compared to previous studies in non-neurosurgical population, suggests good intraoperative blood transfusion practices in our hospital. The availability of point-of-care hemoglobin assessment devices might have helped in judicious execution of RBC transfusion.

Several risk factors have been identified for postoperative anemia in non-neurosurgical population. In patients undergoing cardiac surgery, older age (>75 years) was associated with increased postoperative but not intraoperative blood transfusion.[19] Our study population was young (32 and 37 years in anemia and no anemia groups, respectively) and age was not predictive of postoperative. Similar to previous reports,[2,8] we too observed female gender to be associated with postoperative anemia. However, on multivariate analysis, it was not predictive of postoperative anemia. The mean preoperative hemoglobin was 13.8 g% and 12.4 g% in males and females respectively. Similarly, the postoperative hemoglobin was 12.8 g% and 11.4 g% respectively. Thus, the mean change in post- and preoperative hemoglobin levels was similar between males and females. Every 20 min increase in surgery duration increased the risk of postoperative anemia by 1.33 times in patients who underwent shoulder arthroplasty.[11] Neither surgery duration nor surgeon's experience were predictive of postoperative anemia in our study. We did not come across previous studies exploring relationship between surgeon's experience and postoperative anemia.

Although intraoperative blood loss is a major factor contributing to postoperative anemia, we did not observe difference in intraoperative blood loss between patients with and without postoperative anemia. Since this is unusual, we examined this in more detail by evaluating blood loss and transfusion patterns in patients with tumor and non-tumor surgery. Surprisingly, patients undergoing tumor surgery did not develop postoperative anemia in our study. However, both intraoperative blood loss and intraoperative RBC transfusion was higher in patients undergoing tumor surgery. Hence, it is likely that adequate replacement of blood loss during surgery prevented occurrence of postoperative anemia in these patients while blood loss was under-

Table 3
Association between tumor surgery and intraoperative and postoperative transfusion.

Variable	Tumor surgery	Non-tumor surgery	F/χ2	*p* value
Intraoperative blood loss (ml)	628 ± 563	320 ± 269	78.01	**<0.001**
Intraoperative transfusion (n)	89	16	39.34	**<0.001**
≥2 units	488	438		
<2 units				
Postoperative transfusion (n)	19/577	21/454	1.21	0.330

corrected in non-tumor patients which resulted in postoperative anemia. We did not observe difference in postoperative anemia occurrence between cranial and spine surgeries in our study population.

Previous studies have documented preoperative anemia as an important cause for increased intraoperative blood transfusion and postoperative anemia.[2,8] Since preoperative hemoglobin is a modifiable risk factor and has been a consistent predictor for postoperative anemia in several studies including ours, emphasis should be to improve preoperative hemoglobin levels before elective neurosurgery. Implementation of a simple measure of preoperative oral iron supplementation is likely to reduce the occurrence of postoperative anemia and minimize anemia-related complications in elective neurosurgical patients. This should be considered in every patient where anticipated intraoperative blood loss >500 ml, as early as possible and preferably as soon as the decision for surgery is made.[20] A period of atleast 4 weeks of oral iron supplementation is suggested for elective surgery and if no improvement is observed, intravenous supplementation should be considered.[21] However, these measures may not be feasible for urgent surgeries such as for some brain tumors, where alternative methods of anemia correction should be considered.

There is some data regarding impact of preoperative anemia on postoperative outcomes in neurosurgical patients but the findings have been conflicting. A preoperative hemoglobin <11 g% was associated with three times increase in 30 day mortality in patients undergoing elective cranial neurosurgery.[22] In contrast, another study involving elective cranial neurosurgical population did not find higher mortality or postoperative adverse events with preoperative anemia though postoperative hospital stay was longer in patients with preoperative anemia.[23] We observed that lower preoperative hemoglobin is a predictor of postoperative anemia in neurosurgical patients and that postoperative anemia resulted in increased postoperative blood transfusion and lower GCS score at discharge from hospital. A recent study in children undergoing neurosurgery demonstrated higher ASA grade, lower preoperative hemoglobin and lower intraoperative RBC transfusion to be associated with postoperative anemia.[24]

To our knowledge, this is the first study evaluating the incidence, risk factors and impact of postoperative anemia in neurosurgical patients. However, this study has limitations of a retrospective study. The anesthesiologists' decision regarding intraoperative transfusion is often dependent on the severity and nature of cranial disease, underlying cardiovascular morbidity and transfusion threshold selection. These factors might not be consistent in a retrospective study thus affecting postoperative hemoglobin levels. Secondly, we restricted the definition of postoperative anemia to first 24 h period after surgery. A longer period (till hospital discharge) might have resulted in a different incidence and risk factors.

5. Conclusions

Atleast one in ten patients undergoing elective neurosurgery develop postoperative anemia. Preoperative hemoglobin level and neurosurgical diagnosis are predictors of postoperative anemia. Patients with postoperative anemia are more likely to receive RBC transfusion after surgery and have lower GCS score at hospital discharge. Preoperative improvement of hemoglobin level may reduce occurrence of postoperative anemia and should be strongly considered in elective neurosurgical patients.

Prior presentations

Not applicable.

Funding

Non-funded

Ethics approval number

NIMHANS 31st IEC (BS & NS DIV)/2021 dated 19-08-2021.

Clinical trial registration number

Not applicable.

CRediT authorship contribution statement

Parthiban Giribabu: Data curation, Writing – original draft. **Nupur Karan:** Data curation, Investigation, Writing – review & editing. **Kamath Sriganesh:** Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Dhaval Shukla:** Supervision, Writing – review & editing. **B Indira Devi:** Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

None.

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