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Review Article

Perioperative blood transfusion management in surgical resection of intracranial meningiomas: A meta-analysis

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ABSTRACT

Background: Gross total resection (GTR) of intracranial meningiomas is curative in most cases. However, perioperative blood transfusions may be necessary for complex skull bases and/or high-grade meningiomas. Guidelines for blood transfusions during intracranial meningioma surgery remain unclear. This scoping review aims to delineate the main characteristics of patients who underwent intracranial meningioma surgery, the prevalence of the selected patients who required blood transfusions, and common causes for transfusion.

Methods: A scoping review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses-Extension for Scoping Reviews guidelines to include studies reporting eligibility, protocols, and potential complications related to blood transfusion within the perioperative management of intracranial meningiomas.

Results: A total of 33 articles encompassing 3009 meningioma patients were included in the study. The most common symptom was headache (18%), and the most frequent type of meningioma was World Health Organization grade-1 meningothelial (50.4%). The lateral supraorbital approach was the most common surgical corridor (59.1%) in skull base meningiomas, and most patients underwent GTR (69%). Blood transfusion was required for 20% of patients, with a mean estimated intraoperative blood loss of 703 mL (ranging from 200 mL to 2000 mL). The main indications for blood transfusion in meningioma surgery were intraoperative blood loss (86%) and preoperative anemia (7.3%).

Conclusion: This scoping found that 20% of the included patients required blood transfusion. It also points out that several factors could influence the necessity for a transfusion, encompassing surgical blood loss, pre-existing anemia, and the surgery's length. This scoping review may provide surgeons with a potential guide to inform their decision-making process regarding blood transfusions during meningioma surgeries.

Keywords: Blood loss, Blood transfusion, Intracranial meningioma, Surgical resection

INTRODUCTION

Meningiomas represent the most common type of brain tumor, accounting for more than 35% of all brain tumors according to the Central Brain Tumor Registry of the United States between 2006

and 2010.[30] Their management ranges from conservative "wait-and-monitor" approaches to surgical resection and/or radiotherapy. Gross total resection (GTR) is often curative, especially in the World Health Organization (WHO) grade-1 lesions. However, around 10–30% of patients undergoing GTR and 60% undergoing subtotal resection (STR) removal are expected to experience relapse within 10 years.[7,42] Patients with WHO grade-2 meningiomas have lower overall survival due to their higher risk of local invasion and recurrence.[51] The risk of perioperative surgical complications should also be considered, as it imposes a serious physical and mental burden on patients and may even increase mortality rates.[45] One potentially lethal complication is characterized by high intraoperative blood loss, which may occur especially after prolonged and extensive meningioma surgery, in particular skull base lesions, and may necessitate transfusion of allogeneic blood products.[27]

Numerous neurosurgery procedures may be associated with significant blood loss, having the neurosurgical team ready to plan and promptly request blood products intraoperatively. Most research is focused on transfusions in subarachnoid hemorrhage, traumatic brain injury, and spine surgery.[5] Although in most cases, meningiomas can be resected without the need for blood transfusion, some operations may require a perioperative blood transfusion in case of significant blood loss during the procedure, with the decision made by the neurosurgeons and the anesthetist based on the patient's blood loss, vital signs, and overall condition.[21] This is particularly true for skull base meningiomas, where several critical neurovascular structures may surround or be entangled by the tumor and where removal can be extraordinarily difficult. Blood transfusion may also become necessary and planned if the patient presents with anemia preoperatively.[3] However, neither the risk factors nor the clinical effects of red blood cell (RBC) transfusion during cranial meningioma surgery have been exhaustively studied.

In part due to the scarcity of relevant literature, blood transfusion guidelines after intracranial meningioma surgery have not been developed, with the current neurosurgical literature lacking any decisive knowledge on the topic. In this scoping review, we analyzed the literature to elucidate the selected patients' characteristics, the prevalence of patients who required blood transfusion among intracranial meningioma surgery, and the common causes of such transfusions.

MATERIALS AND METHODS

Literature search

A scoping review of the literature was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-analyses-Extension for Scoping Reviews guidelines.[33,48] PubMed, Scopus, Cochrane, and Web of Science databases were searched on October 17, 2022, using the Boolean operators "OR" and "AND" and the following keywords: "Meningioma," "Blood transfusion," and "Brain tumors." Studies were uploaded to Rayyan, and the duplicates were removed.

Study selection

The inclusion and exclusion criteria for the study were outlined a priori. Studies were included if they: (1) included ≥1 patient with histologically-proven intracranial meningioma; (2) reported available data on preoperative embolization and/or surgical management of underlying tumor, along with clinical characteristics and outcomes of intracranial meningioma; (3) mentioned the use of blood transfusion perioperatively (i.e., intra-operative or during postoperative hospitalization); and (4) were written in English. Studies were excluded if they: (1) were book chapters, conference abstracts, reviews, animal or cadaver studies; (2) featured patients with intracranial meningioma with no record of perioperative blood transfusion; (3) lacked a clear differentiation between patients with intracranial meningioma and those without; and (4) lacked adequate clinical data on intracranial meningioma management and/or blood transfusion.

Two reviewers (A.L. and L.G.) independently examined the titles and abstracts of the gathered publications and then evaluated the full texts of the studies that met the inclusion criteria. A third reviewer (M.I.) arbitrated any differences of opinion. According to the predetermined inclusion criteria, eligible publications were included, and references were explored for additional relevant studies.

Data extraction

One reviewer (A.L.) extracted the data, which was then validated by two independent reviewers (L.G. and M.I.). The following data were extracted: authors, year of publication, age, gender, clinical presentation, tumor location, histologic grade and type based on the WHO guidelines of central nervous system tumors available at the time of publication, molecular features, surgical approach, and duration, extent of resection, intraoperative estimated blood loss, extent and time of blood transfusion (i.e., intraoperatively and postoperatively), reoperation/other procedures, complications, and survival status. For articles with available data, the extent of tumor resection was categorized based on the Simpson grading[43] into "GTR" for complete tumor removal (Simpson grades I-III) and "STR" for STR entails the deliberate surgical excision of the majority of the tumor mass while intentionally leaving behind a residual portion. This

residual portion typically involves areas where the tumor is adherent to vital neurovascular structures, posing a high risk for significant neurological deficits if pursued aggressively (Simpson grades IV–V).

Data synthesis, quality assessment, and statistical analysis

The primary outcomes of interest were the characteristics and eligibility for blood transfusion of the included patients undergoing surgical resection of intracranial meningiomas. The secondary outcomes of interest were the additional factors related to blood loss and transfusion, including the amount of blood loss and the average blood transfusion quantity. The risk of bias was assessed by two independent authors (M.I. and A.L.) using the JBI checklists.[25] For each article, the level of evidence was evaluated based on the 2011 Oxford Centre for Evidence-Based Medicine guidelines.[17] Continuous variables were reported as mean with range, while categorical variables were reported as frequencies with percentages.

RESULTS

Study selection

Figure 1 exhibits the study selection process. A total of 33 articles were included after the full-text screening: 27 were cohort studies, and six were case reports, categorized as level IIIB and V of evidence, respectively [Table 1].[6-53] Critical appraisal returned a low risk of bias for all included articles [Supplementary File 1].

Demographics and clinicopathological features

A total of 3009 patients were reviewed. The mean age at tumor diagnosis was 51 years (range 14–87), with a female prevalence (71.4%) [Table 2]. The most common presenting symptom was headache (18%), followed by trigeminal nerve dysfunction (14.7%). Regarding the location, 775 were non-skull-based meningiomas (62.5%), and 465 were skull-based (37.5%). Based on the WHO classification, grade 1 was the most common type (73.2%). With regard to histological type, the meningoepithelial type was the most common (50.4%), followed by the transitional type (19%).

Management strategies for tumor resection

The most common surgical corridors for tumor resection across papers that discussed surgical approaches for skull base lesions were the lateral supraorbital (59.1%), frontotemporal (30.9%), and Kawase (9.2%) approaches. The mean duration of the surgeries was 5.2 h (ranging from 1.5 to 14.3 h). Data on the extent of the tumor resection were available for 342 cases.[43] A total of 69% of patients underwent GTR, whereas 31% went through STR.

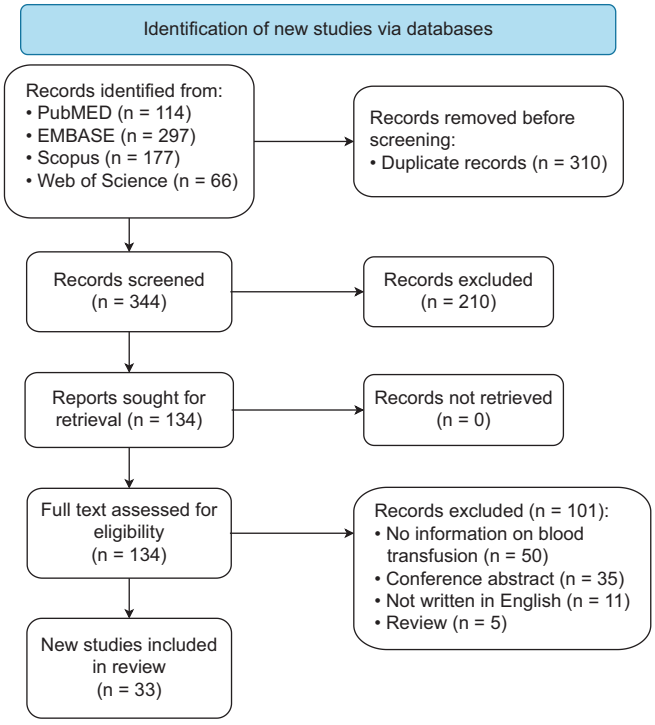

Figure 1: PRISMA flow diagram of the included articles. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Blood loss and transfusion management

The mean estimated intraoperative blood loss was 703 mL (1.41 units, ranging from 200 mL to 2000 mL). A total of 609 patients (20%) needed a blood transfusion, and the mean intraoperative estimated blood transfusion was 579 mL (1.15 blood units) (Ranging from 0.39 to 87 blood units). In addition, we found that the most common cause for transfusion was blood loss during surgery (86%), followed by preoperative anemia (7.3%). A total of 18 patients received postoperative blood, and 11 cases required 14 units of blood while they were hospitalized. Four hundred and sixty-two patients underwent preoperative embolization of intracranial meningioma.

Postoperative complications and other outcomes

Additional treatments were required in 47 cases: 26 patients (55%) necessitated repeated surgical exploration for suspected recurrence, and 17 (36%) were re-operated for the development of brain herniation. O'Reilly and Hamilton reported that one patient was diagnosed with intracerebral hemorrhage that necessitated reopening.[31] Data on postoperative complications were available in 214 cases. The most frequent postoperative complications comprised seizures 36 (16.8%), hemiparesis 22 (10%), pneumonia 14 (6.5%), surgical cavity hematoma

Table 1: Overview of all included studies.

Authors -Year	Study design-level of evidence.	Patients (No.)	Location (No. of cases)	Histologic Grade of P0 (Group or No. of cases)	Surgical approach (no.)	Extent of resection	Estimated intra-operative blood loss (mL)	Patients needing blood transfusion (No.)	Reasons for transfusions	Amount of intra-operative blood transfusion (No. of transfusions)	Amount of postoperative blood transfusion (no. of transfusions)	No. of the patients underwent preop embolization	Need for reoperation/ other procedures (No. of cases)	Other complications (No. of cases)	Median follow-up period (range) Months	Alive or Dead
O'Reilly and Hamilton 1980[31]	Case report-VI	1	NA	NA	NA	Total Resection	NA	1	Hemophilia	NA	(8 U)	NA	ICH	Right-sided hemiparesis	NA	Dead
Tarkkanen *et al.* 1981[46]	Cohort-IIIB	1093	NA	NA	NA	NA	NA	NA	NA	1965–66 (57 U), 1971–72 (86 U), and 1978–79 (87 U)	NA	NA	NA	NA	NA	
Perria *et al.* 1983[35]	Cohort-IIIB	13	CN, SR, OG, TS, FC, SLS, and PF.	NA	NA	NA	NA	39	Blood loss	(979 mL)	NA	NA	NA	NA	NA	Alive
Doran *et al.* 1994[11]	Case report-VI	1	OG	NA	Bifrontal craniotomy	NA	NA	1	Factor VII deficiency (Pre-Op)	(3 U of plasma and one U of packed RBC)	(One U) of plasma, (3U) of packed RBC	NA		No complications	NA	Alive
Dean *et al.* 1994[10]	Cohort-IIIB	226	NA	NA	NA	NA	(EG) 533 mL N-EG) 836 mL	11	Blood loss	AV of EG (0.39 U) and for N-EG (1.56 U)	NA	17	NA	EG (CSFL, TEA, TLFD, PFS, TSSS, TH, brain edema). N-EG (TRH, air embolism, RH, aphasia, MI, seizures, LTH, aphasia, subdural hematoma, postop seizures, TH, death pneumonia, CSFL	NA	9 matched pair deaths, pneumonia
Sato *et al.* 1997[41]	Cohort-IIIB	41	CN, PS (8), C-Pangle (5), SR (4), tentorial in (2), falx (3), TS (1), C (1), C (1), FM (1)	NA	NA	NA	NA	46	Blood loss	(600 mL, maximum 2400 mL) in 23 cases (62.2%), in 8 cases (21.7%) <400 mL, in 15 cases (40.5%) more than 400 mL	NA	41	NA	NA	NA	Alive
Oka *et al.* 1998[32]	Cohort-IIIB	20	Temporal (6), sphenoid (12), C (1) parasellar (1)	NA	NA	Total (12) and subtotal (8)	NA	16	Blood loss	EG (65 U) and N-EG (106 U)	NA	12	NA	Facial palsy and hearing loss (1 BS and loss of consciousness (2), HP (2), increase ICP and oculomotor palsy (1), postoperative bleeding (1)	NA	One dead due to BS
Bendszus *et al.* 2000[6]	Cohort-IIIB	60	Parietal CN, frontal CN, temporal, CN, SW, T, falx frontobasal, fetroclinoidal.	NA	NA	NA	NA	NA	NA	G1 (1.0 U) G2 (1.2 U) G3 (1.7 U)	NA	60	NA		NA	Alive

(Contd...)

Table 1: *(Continued).*

Authors -Year	Study design-level of evidence.	Patients (No.)	Location (No. of cases)	Histologic Grade of P0 (Group or No. of cases)	Surgical approach (no.)	Extent of resection	Estimated intra-operative blood loss (mL)	Patients needing blood transfusion (No.)	Reasons for transfusions	Amount of intra-operative blood transfusion (No. of transfusions)	Amount of postoperative blood transfusion (no. of transfusions)	No. of the patients underwent preop embolization	Need for reoperation/ other procedures (No. of cases)	Other complications (No. of cases)	Median follow-up period (range) Months	Alive or Dead
Paleologos *et al.* 2000[34]	Cohort-IIIB	60	CN, PS, sphenoid, SS, OG and PF	NA	NA	NA	(SS) 780 mL (IGS) 660 mL	50	NA	SS (29 cases with 1.7 U) and IGS (21 cases with 1.4 U)	NA	NA	NA	HM (4), swelling/edema (1), new neurological deficit (6), new seizures (4), infection (2), poor bone flap sitting (1), deep vein thrombosis (2), pulmonary embolism (1)	NA	One dead
Karadimov 2003[19]	Case report-VI	1	Bifrontal basal	NA	AN	NA	NA	1	Blood loss	NA	(2 U) of blood	NA	NA		NA	Alive
Lee *et al.* 2006[22]	Cohort-IIIB	13	CN (8), PS (3), SW (2). For the N-EG in PMH, CN (8), PS (10), SW (5)	NA	NA	NA	(EG) 775±406 mL (N-EG) 1100±520 mL	20	Blood loss	EG (1.13±1.13 U) and for N-EG (1.38±1.6 U)	NA	13	NA	NA	NA	Alive
Kai *et al.* 2007[18]	Cohort-IIIB	203	SR (36), frontal base (21), CN (16), Cavernous sinus and at the cerebellopontine (C-P) angle (8), middle fossa and falx(6); PS(18), petroclival (13), occipital (9).	NA	NA	Simpson's grade for (G 1) 2.60 and (G 2) 1.91	(G 1) 534 mL (G 2) 424 mL	NA	NA	G1 (1.0–9.0 U) G2 (1.0–6.0 U)		128	NA	ICH leading to CE, permanent hearing disturbance (1)	NA	Alive
Teitelbaum *et al.* 2008[47]	Case report-VI	1	NA	NA	From the posterior edge to the medial, then to the lateral edge	NA	NA	1	Blood loss	10 U of platelets, 10 U of cryoprecipitate, 10 mg of vitamin K, 1 g of calcium chloride, 8 U of FFP, and 20 U of vasopressin	NA	NA	A year later, MRI showed a 4 cm residual mass. She underwent a second operation for complete resection of the meningiom	Left lower lobe pneumonia, Prolonged bleeding time	NA	Alive
Firth and Szabo 2010[13]	Case report-VI	1	Frontoparietal	NA	NA	NA	NA	1	Sickle cells disease	(3 U)	NA	1		Grand-mal seizure	NA	Alive

(Contd...)

Table 1: *(Continued).*

Authors -Year	Study design-level of evidence.	Patients (No.)	Location (No. of cases)	Histologic Grade of P0 (Group or No. of cases)	Surgical approach (no.)	Extent of resection	Estimated intra-operative blood loss (mL)	Patients needing blood transfusion (No.)	Reasons for transfusions	Amount of intra-operative blood transfusion (No. of transfusions)	Amount of postoperative blood transfusion (no. of transfusions)	No. of the patients underwent preop embolization	Need for reoperation/ other procedures (No. of cases)	Other complications (No. of cases)	Median follow-up period (range) Months	Alive or Dead
Romani *et al.* 2011[38]	Cohort-IIIB	191	OG (66) anterior clinoidal (73), TS (52)	NA	Lateral supraorbital approach	NA	200 (range, 0-2000) mL.	17	Blood loss, Laceration of ICA (Intra-Op)	The RBC transfusions in 17 (9%) unknown U	NA	NA	Two had a postoperative HM requiring surgical evacuation		NA	Alive
Naqash *et al.* 2011[27]	Cohort-IIIB	40	NA	NA	NA	NA	(G I) 835.29±684.37 mL, (G II) 865±409.78 mL	25	Blood loss	(Control Group) (864.71±349.89 mL), G II (ANH G) (165±299.6 mL). The amount of s blood withdrawn and retransfused in G II was (802.5±208 mL).		NA	NA	NA	NA	
Yadav *et al.* 2012[49]	Cohort-IIIB	112	*CG* CN (27), PS (28), temporal base (6). N-CG CN (21), PS (27), temporal base (3).	NA	NA	Totally excised except one in the CG	(CG) 336.09 (±102.61) mL (N-CG) 826.96 (±191.73) mL	NA	Blood loss	CG (375.60±144.10 mL) N-CG (867.39±207.58 mL)	NA	NA	NA	NA	NA	Alive
Nania *et al.* 2014[26]	Cohort-IIIB	28	NA	WHO classification 2007 grade I, II	NA	NA	NA	31	Long duration (Intra-Op)	G 1 (87.5±129.78 mL) G 2 (326.6±192.41 mL) Group 3 (347.8±198.78 mL)	NA	28	NA	NA	NA	Alive
Yang *et al.* 2017[50]	Cohort-IIIB	80	NA	NA	NA	NA	(GA) 865.2±656mLand (GB)965.2±356mL	16	Blood loss	Blood loss < 2000 mL (8 transfusions between RBC and frozen plasma). Blood loss > 2000 (13 transfusions)	NA	NA	NA	Postoperative infections (11)	NA	Five dead
Hooda *et al.* 2017[16]	Cohort-IIIB	60	C (17), infratentorial (17), PS (12), skull base (09), juxta sellar (05).	NA	NA	GTR 50 (83.3%); STR 10 (16.7%)	NA	13	Blood loss	Transfused cell saver blood (13 patients with 630 mL), number of patients transfused FFP (8 patients with 1500 mL) and transfused Platelet concentrate (5 patients with 556 mL)	Yes.	NA	Four patients needed re exploration	Re-exploration, HC, seizures, new neurologic deficit, postoperative RBC transfusion	NA	Three dead

(Contd...)

Table 1: *(Continued).*

Authors -Year	Study design-level of evidence.	Patients (No.)	Location (No. of cases)	Histologic Grade of P0 (Group or No. of cases)	Surgical approach (no.)	Extent of resection	Estimated intra-operative blood loss (mL)	Patients needing blood transfusion (No.)	Reasons for transfusions	Amount of intra-operative blood transfusion (No. of transfusions)	Amount of postoperative blood transfusion (no. of transfusions)	No. of the patients underwent preop embolization	Need for reoperation/ other procedures (No. of cases)	Other complications (No. of cases)	Median follow-up period (range) Months	Alive or Dead
Nguyen *et al.* 2017[29]	Cohort-IIIB	42	PS (13), CN (12), tentorial (1), middle fossa (2), OG (4), SS (1), SR (9)	Grade I (26) and Grade II/III (16)	NA	GTR 34 (%); STR 8 (%)	276.20±193.31 mL	6	Blood loss	Yes	NA	NA	NA	NA	NA	NA
Song *et al.* 2018[44]	Cohort-IIIB	30	Petroclival	NA	Kawase approach	Bone removal (%)	NA	NA	Blood loss	Pre-Op EG (185.35±46.15 mL) N-EG (488.63±62.32 mL)	NA	15	NA	Scalp heat pain	NA	Alive
Saringcarinkul and Chuasuwan 2018[40]	Cohort-IIIB	79	NA	NA	NA	NA	500 (50–2600) mL	39	Blood loss	(96 total U)	Yes. (14 total U) in 11 patients	NA	NA	NA	NA	Alive
Hegazy *et al.* 2018[14]	Cohort-IIIB	94	The medial SW (35), the lateral SW (12), the middle SW (38), en-plaque (9).	WHO grade I (2)	Fronto-temporal	NA	(No outer cavernous mobilization) 1403.21 mL. (With outer cavernous mobilization) 994 mL	1	Blood loss	One case 6 U	NA	49	NA	Aggravation of visual deficit. Post craniotomy syndrome. Weakness or dysphasia. Epilepsy. Wound infection. Cranial nerve palsy. Cerebrospinal fluid collection. HC.	(3–6)	Alive
Lagman *et al.* 2018[20]	Cohort-IIIB	7	Skull base	WHO grade I (5) and WHO grade II (2)	NA	Simpson grade I–III (2) and Simpson grade IV-V (5)	NA	7	Blood loss	NA	NA	10	NA	Stroke (1), seizure (2); other (3)	NA	NA
Lagman *et al.* 2018[21]	Cohort-IIIB	51	(EG) anterior clinoid, petroclival, parietal, PS, frontal-parietal, middle fossa, SW, ASB, temporal, cerebellar, parafalcine, frontal-orbital, temporal-occipital	WHO grade I (36) and WHO grade II (15)	NA	Simpson grade 1 (27), grade 2 (4), grade 3 (4), grade 4 (15), and grade 5 (1)	239±176 mL	2	Blood loss	1 U (range 1–3 U)	1 U (range 1–3 U)	21	NA	Intraoperative CE (1), TIH (1), and temporary loss of somatosensory evoked potentials (1)	NA	Alive
Zuo *et al.* 2019[53]	Cohort-IIIB	1156	Skull base (421) Non-skull base (735)	Grade I (947) and Grade II/III (209)	Number: 90	NA	NA	90	NA		NA	NA	NA	NA	NA	Alive

(Contd...)

Table 1: *(Continued).*

Authors -Year	Study design-level of evidence.	Patients (No.)	Location (No. of cases)	Histologic Grade of P0 (Group or No. of cases)	Surgical approach (no.)	Extent of resection	Estimated intra-operative blood loss (mL)	Patients needing blood transfusion (No.)	Reasons for transfusions	Amount of intra-operative blood transfusion (No. of transfusions)	Amount of postoperative blood transfusion (no. of transfusions)	No. of the patients underwent preop embolization	Need for reoperation/ other procedures (No. of cases)	Other complications (No. of cases)	Median follow-up period (range) Months	Alive or Dead
Catapano *et al.* 2020[8]	Cohort-IIIB	35	CN (12) falcine (6), SW (5), anterior cranial fossa (4), petrous/petroclival (2), tentorial (6).	WHO grade I (24) WHO grade II and III (11)	NA	NA	576±341 mL	4	Blood loss	NA	NA	NA	NA	NA	NA	Alive
Ali *et al.* 2020[2]	Cohort-IIIB	42	NA	NA	NA	NA	NA	32	Blood loss	(58 blood U)	NA	NA	NA	NA	NA	Alive
Neef *et al.* 2021[28]	Cohort-IIIB	68	Non-skull base (40) Skull base (28)	grade I (35) grade II and III (33)	NA	Simpson grade <III/≥III (18 [58%]/13 [41.9%])	1125 (525–1675) mL*	68	Anemia (Pre-Op) Blood loss	NA	NA	1	Patients for re-craniotomy (22)	Acute renal failure (2), pneumonia (13), sepsis (2), pulmonary embolism (10), seizure (21), re-craniotomy (22)	15 (0–98)	Alive
Chand *et al.* 2021[9]	Case report-VI	1	NA	Grade 2	NA	NA	<1000 mL	1	Blood loss	Two U of autologous red cells and FFP	NA	NA	NA	NA	NA	Alive
Rebai *et al.* 2021[36]	Cohort-IIIB	91	CN (41), PS (34), OG (5), SS (5), SW (5)	NA	NA	NA	(Placebo G) 495±81 mL (TXA G) 244±68 mL)	7	Blood loss	No. of patients transfused (3) with volume 380 and in placebo (4) with volume 480	NA	NA	NA	Convulsions (4), HM (8)	NA	Alive
Yin *et al.* 2022[52]	Cohort-IIIB	132	CN (18), falcine (24), C (20), MSB (4)	(EG cohort) grade I (51), grade II (13), grade III (2) N-EG), grade I(58), grade II(8), grade III (0)	NA	NA	(EG) 600.00 (400.00) mL (N-EG) 500.00 (500.00) mL	63	Blood loss	NA	NA	66	Six patients in EG for brain herniation and 11 patients in N-EG for brain herniation	Hemiplegia (6), HP (19), CN VII palsy (2), Visual defect (3) Decreased hearing (1) Aphasia (4) Mental disorder (2) Infection (1) Seizure (3) CSF leakage (1) Respiratory failure (5) Mortality (1), Brain herniation (17)	6	One patient in N-EG

NA: Not available, ASB: Anterior skull base, AV: Average, BS: Brain swelling, C: Clivus, CE: Cerebral edema, CG: Clamping group, CN: Convexity, CSFL: Cerebrospinal fluid leak, EG: Embolized group, FC: Falx cerebri, FM: Foramen magnum, G: Group, HC: Hydrocephalus, HM: Hematoma, HP: Hemiparesis, ICH: Intracerebral hemorrhage, LTH: Left temporal hematoma, MSB: Middle skull base, N-CG: Non Clamping group, N-EG: Non-embolized group, OG: Olfactory groove, PF: Posterior fossa, PFS: Postop focal seizure, PS: Parasagittal, RBC: red blood cells, RH: right hemiplegia, SLS: Superior longitudinal sinus, SR: Sphenoid ridge, SS: Suprasellar, SW: Sphenoid wing, T: Tentorium, TEA: Transient expressive aphasia, TH: Transient hemiparesis, TIH: Transient intraoperative hypotension, TLFD: Transient left facial droop, TRH: Transient right hemiparesis, TS: Tuberculum sellae, TSSS: Tear of superior sagittal sinus, U: Units, Pre-Op: Preoperative, GTR: Gross total resection, STR: Subtotal resection, FFP: Fresh frozen plasma, WHO: World Health Organization, ANH: Acute normovolemic hemodilution

Table 2: Summary of all the analyzed parameters.

	***n* (%)**
Characteristics	
Cohort studies	33
Patient no	3009
Demographics (*n*=3009)	
Age in year, mean (SD)	51.78±(9.28)
Gender, female (*n*=2507)	1789 (71.4%)
Symptoms (*n*=61)	
Headache	11 (18.0)
Trigeminal nerve dysfunction	9 (14.8)
Dizziness	4 (6.6)
Limb movement disorder	4 (6.6)
Diplopia	4 (6.6)
Seizure	2 (3.3)
Personality changes	2 (3.3)
Memory loss	1 (1.6)
Gait abnormality	1 (1.6)
Urine incontinence	1 (1.6)
Aphasia	1 (1.6)
Other	24 (39.3)
Location (*n*=1138)	
Non-skull base	775 (68.1)
Skull base	465 (40.9)
Histologic WHO grade (*n*=1494)	
Grade I	1184 (73.2)
Grade II	39 (2.4)
Grade III	2 (0.1)
Grade II and III	269 (16.6)
Histological type (*n*=248)	
Meningiothelial meningioma	125 (50.4)
Transitional	47 (18.9)
Fibroplastic	45 (18.1)
Angiomatous	21 (8.5)
Atypical	6 (2.4)
Fibrous	2 (0.8)
Invasive	1 (0.4)
Microcytic	1 (0.4)
Surgery approach (*n*=323)	
Lateral supraorbital	191 (59.1)
Fronto-temporal craniotomy	100 (30.9)
Kawase	30 (9.2)
Frontal	2 (0.6)
Duration of surgery, Mean (Range)	
Mean of surgery duration and range	315.6 min (5.2 h) (ranging from 1.5 to 14.3 h)
Extension of resection (*n*=342)	
Gross total resection	236 (69.0)
Subtotal resection	106 (31.0)
Estimated blood loss intraoperatively, Mean (Range)	
Mean of estimated blood loss and range	703.37 mL (1.41 unit) (ranging from 200 mL to 2000 mL)
Blood transfusion intraoperatively, Mean (Range)	
Mean of blood amount	579.5 mL (1.15 units); range (0.39–87 blood units)
Blood transfusion postoperative during hospitalization (*n*=18)	
14 units	11 (61.1)
1 unit	4 (22.2)
2 units	1 (5.5)

(Contd...)

Table 2: *(Continued).*

	***n* (%)**
3 units pRBC, 8 units plasma	1 (5.5)
8 units	1 (5.5)
Patients needed a blood transfusion (*n*=609)	
The selected patients who needed blood transfusion	609 (20.23)
Reasons for transfusions (*n*=465)	
Blood loss	400 (86.02)
Anemia (pre-op)	34 (7.31)
Long duration of surgery	31 (6.66)
Patients underwent pre-op embolization (*n*=462)	
The selected patients who had pre-op embolization	462 (15.35)
Need for reoperative/other procedures (*n*=47)	
Recurrence	26 (55.0)
Brain herniation	17 (36.1)
Surgical evacuation	2 (4.3)
Complete resection	1 (2.1)
Increase intracerebral hemorrhage	1 (2.1)
Complications (*n*=214)	
Seizure	36 (16.8)
Hemiparesis	22 (10.3)
Re-craniotomy	22 (10.3)
Pneumonia	14 (6.5)
Infection	14 (6.5)
Brain herniation	17 (7.9)
Hematoma	12 (5.6)
Pulmonary embolism	11 (5.1)
Scalp heat pain	8 (3.7)
Hemiplegia	6 (2.8)
New neurological deficit	6 (2.8)
Respiratory failure	5 (2.3)
Aphasia	5 (2.3)
Visual defect	3 (1.4)
Cerebrospinal fluid leak	1 (0.4)
Others	32 (15.0)
Follow-up period, Median (range)	
The median and range of the follow-up period in months	10.5 (0–98)
Status (*n*=2920)	
Alive	2899 (99.3)
Dead	21 (0.7)

Pre-Op: Preoperative, pRBC: Packed red blood cell, WHO: World Health Organization, SD: Standard deviation

12 (5.6%), scalp heat pain 8 (3.7%), aphasia 5 (2.3%), visual defect 3 (1.4%), and cerebrospinal fluid leak 1 (0.4%). A total of 21 (0.7%) patients died, and 99% of the patients remained alive, with a median overall follow-up period of 10.5 months (ranging from 0 to 98 months).

DISCUSSION

The neurosurgical literature frequently discusses the role of blood transfusion in cerebrovascular, trauma, and spine but scarcely reports its benefits and nuances in neuro-oncology.[24] In particular, the topic of blood transfusion related to intracranial meningioma surgery is controversial and depends on several factors. In our scoping review, we found that the main indicators for blood transfusions during intracranial meningioma surgery were blood loss and preoperative anemia.

Several measures for blood conservation have been implemented in an effort to reduce homologous blood transfusion. Messmer and Sunder-Plassman established a multitude of blood conservation procedures, including autologous blood extraction.[24] Autologous transfusions, either through presurgical autologous blood donation, acute normovolemic hemodilution (ANH), or intraoperative blood salvage, have been beneficial in reducing the use of homologous blood in surgical patients. ANH with autologous

transfusion minimizes the need for homologous blood during and after surgery. Still, the lack of widespread acceptance may be due to the lack of infrastructure and the cost. Contrary to preoperatively given autologous units, blood extracted during hemodilution is not subject to the biochemical changes associated with blood storage. By storing blood at room temperature, platelet function is retained, and hypothermia related to refrigerated blood transfusion is avoided.[15] This method also eliminates any clerical error that could result in an ABO-incompatible blood transfusion and mortality.

In our review of 3009 resected meningiomas, we found that patients lost a mean of 703 mL, and 609 patients were transfused with a mean of 579 mL of blood. Neef *et al*. found that 16.1% of the 423 patients surgically treated for meningioma resection received RBC transfusions, noting that these patients were significantly older ($P = 0.0153$) and more likely to have comorbidities such as cardiovascular disease ($P = 0.0107$) and diabetes ($P = 0.0210$). The authors also found that tumor size in the RBC transfusion group was significantly larger ($P < 0.0001$) compared to the non-RBC transfusion group.[28] Regarding other blood products, the authors reported that the transfusion rate of platelets (10.3%), fresh frozen plasma (14.7%), fibrinogen (27.9%), and prothrombin complex concentrate (14.7%) was significantly higher in the RBC-transfusion group compared to the non-RBC transfusion group (0.6%, 0.3%, 1.4%, and 2.5%, respectively). Multiple medical conditions render RBC transfusion in meningioma surgery, which includes preoperative anemia in elective cases.[1] Intraoperative blood loss proved to be an independent risk factor for blood transfusion perioperatively.[28] Such results indicate that patients who obtained RBC transfusions were more likely also to get other blood products because the RBC-receiving group is more elderly and has comorbidities that may increase their risk for coagulopathy. In our review of 465 patients who underwent intracranial meningioma surgery, 86% of them were transfused due to blood loss, followed by preoperative anemia (7.3%) and longer intraoperative duration (6.66%).

The different locations of intracranial meningiomas may also affect the decision-making of ordering blood transfusion perioperatively. Blood transfusion during convexity meningioma surgery is a typical procedure used to restore blood loss and maintain proper blood pressure and oxygenation of the patient. The decision to perform a transfusion is primarily influenced by various possible factors which include the patient's age, pre-operative hemoglobin levels, the length of surgery, and the surgeon's experience and preferences. Depending on the patient's medical history and the surgeon's decision, autologous or allogenic blood may be used for blood transfusions during this type of surgery. Blood transfusions pose risks such as transfusion reactions, the transmission of infections, and an increased chance of bleeding.[21,44] Skull-based meningioma procedures may require a greater amount of blood transfusion than convexity-based meningioma surgeries. Blood loss during skull base surgeries varies based on the size and location of the tumor, surgical approach, and the patient's unique anatomy and blood clotting capabilities. In some instances, skull base meningioma resection may result in higher blood loss due to extensive exposure of the skull and surrounding tissues, necessitating an increased requirement for blood transfusions. Lagman *et al*.[21] reported 51 (14 males and 37 females) cases of meningioma with the WHO grade-1[35] and grade-2[15] cases with a mean intraoperative blood loss of 239 mL. Their findings were that the location of the meningioma as skull-based type, size more than 5 cm, and the duration of the surgery >10 h were the main risk factors for blood transfusion in meningioma surgery. They also mentioned that around 18.7% of patients undergoing craniotomy for skull base meningioma resection required a blood transfusion.[21] Those who received a transfusion were hospitalized for 19.9 days longer than those who did not (4.9 days), which may be linked to various complications apart from blood transfusion. The location of the meningiomas at the level of the skull base was also found as an independent risk factor for blood transfusion, regardless of lesion size.[21] However, this varies widely and must be evaluated on a case-by-case basis, with the choice to perform a blood transfusion often depending on the patient's vital signs and laboratory results, such as hemoglobin levels.

Preoperative embolization of intracranial meningioma may have several advantages. A total of 462 patients across our pooled studies have received preoperative embolization anteceding meningioma resection. Several primary benefits of preoperative embolization for meningioma surgery have been outlined.[41] Preoperative embolization may shrink the tumor's size by occluding the prominent arterial feeders to the tumor, thus reducing the amount of tissue that needs to be removed intraoperatively and reducing the risk of bleeding.[12,23] Preoperative embolization may also minimize the surgical time of tumor resection by reducing the tumor's size, thus minimizing the patient's time under anesthesia and the risk of blood loss.[37,41] Preoperative embolization may lower the risk of bleeding during surgery, directly reducing the need for blood transfusion and minimizing the risk of transfusion-related complications.[12,23,39] However, preoperative embolization is not appropriate for all patients, and the choice to conduct it should be based on a comprehensive evaluation of the patient's unique circumstances and the surgeon's judgment. Yin *et al*. compared two groups of meningioma patients undergoing surgery, either receiving preoperative embolization or not.[52] The authors found no significant difference between the two groups in terms of surgical time, GTR rate, estimated blood loss, or decrease in hemoglobin level within the two groups.

Yet, they found that a non-significantly higher percentage of patients in the embolization group were a recipient of blood transfusion during surgery (53.03%) compared to the non-embolization group (42.42%) (P = 0.35). In addition, the difference was not statistically significant in the amount of blood transfused within the two groups (P = 0.63).[18,52] Based on these results, the effects of preoperative embolization on perioperative blood transfusion during surgery for intracranial meningioma remain controversial.

Limitations

Several limitations of this review should be mentioned. The lack of individual-patient data prevented to conduct of additional statistical analyses, such as correlations and analyses, to identify the risks of extensive blood loss during intracranial meningioma surgery based on multiple parameters, including the meningioma size, location, and grading and how this may impact the need of blood transfusion. Six case reports were included, adding a lower level of evidence. There is limited data on the various blood product transfusions during meningioma surgery, and the literature also lacks data on the complications that could arise from them. Different anesthesia schemes were not reported in detail across the included studies. However, this is the first review that summarizes the current literature on the topic, advocating the need to conduct multicenter prospective databases to develop standardized guidelines for planning perioperative blood transfusion schemes during intracranial meningioma resection.

CONCLUSION

This scoping found 20% of the patients that underwent intracranial meningioma surgery, which required blood transfusion. Our review also pointed out that, during meningioma surgery, the need for a blood transfusion can be impacted by a number of variables, including blood loss due to the surgery, preoperative anemia, and the duration of the surgery. This scoping review may give the surgeons a possible map to aid in the decision of blood transfusion during intracranial meningioma surgery.

Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

Patient's consent was not required as there are no patients in this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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SUPPLEMENTARY FILE

Supplementary File 1. Risk of bias assessments for included studies

Joanna Briggs Institute Checklist for Case Reports – Criteria

1. Were patient's demographic characteristics clearly described?
2. Was the patient's history clearly described and presented as a timeline?
3. Was the current clinical condition of the patient on presentation clearly described?
4. Were diagnostic tests or assessment methods and the results clearly described?
5. Was the intervention (s) or treatment procedure (s) clearly described?
6. Was the post-intervention clinical condition clearly described?
7. Were adverse events (harms) or unanticipated events identified and described?
8. Does the case report provide takeaway lessons?

Responses Options: Yes, No, Unclear, Not Applicable (NA)

Quality Rating: Poor 0 – 2; Fair 3 – 5; Good 6 – 8

Study	1	2	3	4	5	6	7	8	Rating
Chand S 2021	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8 – Good
Firth *P* 2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8 – Good
Teitelbaum J 2008	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8 – Good
Karadimov D 2003	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8 – Good
Doran S E1994	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8 – Good
O'REILLY RA 1980	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8 – Good

Joanna Briggs Institute Checklist for Case Series – Criteria

1. Were there clear criteria for inclusion in the case series?
2. Was the condition measured in a standard, reliable way for all participants included in the case series?
3. Were valid methods used for identification of the condition for all participants included in the case series?
4. Did the case series have consecutive inclusion of participants?
5. Did the case series have complete inclusion of participants?
6. Was there clear reporting of the demographics of the participants in the study?
7. Was there clear reporting of clinical information of the participants?
8. Were the outcomes or follow up results of cases clearly reported?
9. Was there clear reporting of the presenting site (s)/clinic (s) demographic information?
10. Was statistical analysis appropriate?

Responses Options: Yes, No, Unclear, Not Applicable (NA)

Quality Rating: Poor 0 – 3; Fair 4 – 7; Good 8 – 10

Study	1	2	3	4	5	6	7	8	9	10	Rating
Yin Y 2022	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Rebai L 2021	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Neef V 2021	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Ali Z 2020	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Catapano JS 2020	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Zuo MR 2019	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Lagman C 2018	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	8 – Good
Saringcarinkul A 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	unclear	9 – Good
Hegazy A 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10 – Good
Song G 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Lagman C 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Yang L 2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10 – Good
Hooda B 2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Nguyen H A 2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Nania A 2013	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Yadav YR 2012	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Naqash IA 2011	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Romani R 2011	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10 – Good
Kai Y 2007	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Lee S S 2006	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	unclear	8 – Good
Bendszus M 2000	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Paleologos T S 2000	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Oka H 1998	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Sato H1997	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Dean BL 1994	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	9 – Good
Perria C 1983	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	unclear	8– Good
Tarkkanen L 1981	yes	yes	yes	no	no	no	no	no	no	yes	4-fair