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ORIGINAL RESEARCH

Risk Factors Involved in the Blood (Leukocyte-Depleted Suspended Red Blood Cells and Plasma) Transfusion During Glioma Operations

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Video abstract

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Background: The use of blood transfusion in surgery is increasing, and the blood supply is getting tighter. The number of glioma surgeries is increasing year by year, and reports of studies on blood transfusion in glioma surgery are relatively rare.

Purpose: To investigate the risk factors for intraoperative blood (leukocyte-depleted suspended red blood cells and plasma) transfusion in glioma patients.

Patients and Methods: We retrospectively analyzed the data of 200 glioma patients who had been operated on in a general teaching hospital in China from January 1, 2018 to March 31, 2022. In terms of whether blood transfusion (leukocyte-depleted suspended red blood cells and plasma) was used intraoperatively, patients were divided into a transfusion group (n=82) and a non-transfusion group (n=118). Multivariate Logistic regression analysis was conducted to identify the risk factors for intraoperative blood transfusion.

Results: The rate of intraoperative transfusion rate in the 200 glioma patients was 41%. Multivariate Logistic regression analysis showed that operation time, intraoperative blood loss ≥500 mL, vascular involvement, and the extent of tumor resection (total resection) were independent risk factors for intraoperative blood transfusion (P<0.05). Patient height was a protective factor against intraoperative blood transfusion (P<0.05).

Conclusion: The risk of intraoperative blood transfusion was higher in glioma patients with longer operation time, more intraoperative blood loss, vascular involvement, and total tumor resection. Clinically, efforts should be made to avoid these transfusion-related risk factors to minimize the risk of blood transfusion in patients.

Keywords: gliomas, blood transfusion, risk factors, intraoperative blood loss

Introduction

Gliomas are common primary intracranial tumors with an incidence of approximately 26.5% of all primary brain and other central nervous system tumors.[1] The World Health Organization (WHO) classification of central nervous system tumors classifies gliomas into grades 1–4, of which grade 1–2 is low-grade glioma and grade 3–4 is high-grade glioma,[2,3] grade 4 glioma is also called glioblastoma. Gliomas have high mortality and recurrence rates, especially glioblastomas. At present, surgery is the most commonly used method to treat glioma. Glioma surgery is difficult and risky, and intraoperative blood transfusion is difficult to avoid. Studies have shown that perioperative red blood cell transfusion can shorten the survival time of patients with glioblastoma.[4] Excessive blood transfusion rate in glioma patients during surgery will cause immunosuppression, which will lead to an increase in postoperative adverse events,[5] The amount of blood loss and blood transfusion during

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emergency surgery of glioma is significantly higher than that of non-emergency surgery, resulting in an increased risk of death.[6] Other studies have shown that previous antiplatelet therapy, low preoperative platelet count and long operation time are important risk factors for platelet transfusion in glioblastoma surgery.[7] Lower body weight, higher ASA (American Society of Anesthesiologists, ASA) grade, preoperative anemia, larger tumor size, and longer operative time were found to be significant factors predicting blood transfusion during craniotomy for pediatric craniocerebral tumors.[8] At present, due to the shortage of blood supply and the increasing risk of surgical blood transfusion,[9–13] how to control the amount of blood transfusion in glioma surgery is the focus of surgeons and blood transfusion doctors. Reducing blood transfusion is of great significance to improve the prognosis of glioma patients and reduce tumor recurrence. Because leukocyte-depleted suspended red blood cells and plasma can effectively reduce the incidence of adverse reactions of blood transfusion and improve the safety and efficacy of blood transfusion, they are widely used in clinical surgical blood transfusion.[14–17] At present, there are few studies on the risk factors of leukocyte-removed suspended red blood cells and plasma transfusion during glioma surgery. We retrospectively analyzed the case data of 200 patients undergoing glioma surgery. The purpose is to explore the risk factors of blood transfusion (leukocyte removal, red blood cells and plasma suspension) during glioma surgery, and to provide reference for surgical treatment of glioma.

Materials and Methods

Study Area and Setting

The patients of this study were diagnosed with brain gliomas and received surgery in the Department of Neurosurgery, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China, from January 1, 2018, to March 31, 2022. We observed intraoperative blood transfusion (Note: blood transfusion refers mainly to the transfusion of leukocyte-depleted suspended red blood cells and plasma) in glioma patients.The patients' clinical baseline data covered patients' gender, age, height, weight, and medical history. Laboratory tests involved preoperative hemoglobin, platelet count, and coagulation function indicators. Tumor status included the location, size, margin, extent of resection, vascular involvement, and grades of WHO classification. Surgery-related indicators were categories against the American Society of Anesthesiologists (ASA) classification, operation time, and intraoperative blood loss.

Study Design

The patients were divided into a blood transfusion group (n=82) and a non-blood transfusion group (n=118) on the basis of whether blood transfusion was performed intraoperatively. We did not apply any intervention measures to the two groups of patients, but only performed retrospective analysis.

Study Population

There were a total of 200 subjects in this study, including 111 males (55.5%) and 89 females (44.5%), with an age range of 2.58 to 80 years old, and an average age of 44.22 years old (standard deviation 17.39 years old).

Inclusion Criteria

Inclusion criteria involved (1) Patients diagnosed with brain gliomas based on clinical manifestations, CT/MRI, and pathological examinations; (2) Patients undergoing surgical treatment for the first time; (3) Medical records were complete.

Exclusion Criteria

Exclusion criteria included (1) Patients receiving blood transfusions before or after surgery; (2) those with abnormal coagulation function; (3) Patients having a history of long-term use of anticoagulants.

Sample Size Calculation

This study included 200 patients, with 82 experiencing transfusion events. Sample size calculation was based on the Events per Variable (EPV) rule of thumb, with the expectation of including no more than 8 independent variables in the final logistic regression model. With 82 events and 8 variables, the EPV was 10.25 (EPV=82/8), which meets the minimum recommended threshold of at least 10.

Sampling Method

Regarding sampling method, we adopted a combination of simple random sampling method and stratified sampling method.

Data Collection Procedure

We first query and sort out the complete clinical data of 200 patients through Tongji Hospital Information System (HIS), Electronic Medical Record System (EMS), Picture Archiving and Communication System (PACS) and Radiology Information Management System (RIS), and then submit an application to Tongji Hospital Information Management Center. After approval, the patients' data is exported and handed over to professional statisticians for data analysis.

Ethical Considerations

The institutional review board (IRB) that Medical Ethics Committee of Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology gave up the need for subjects' informed consent to participate (because some patients had passed away and could not sign the informed consent, otherwise this trial could not be carried out). This trial was only a retrospective analysis without intervention measures, and it was not necessary to obtain informed consent of all subjects according to national regulations. The relevant legislation is based on the Declaration of Helsinki (2013), the Measures for Ethical Review of Life Science and Medical Research Involving Human Beings (2023) and the Good Clinical Practice (2020).

Data Analysis and Interpretation

The statistical analysis of the data was performed by using SPSS 27.0 software package. Normally-distributed quantitative data were presented as mean ± standard deviation (SD), and non-normally-distributed quantitative data were expressed as the median and range. The *t*-test was conducted for inter-group comparison. The categorical data were given as case number or rates and the chi-square test was employed for inter-group comparison. Univariate and multivariate logistic regression analyses were carried out to analyze the influencing factors, and differences were considered to be statistically significant when a $P<0.05$.

Results

General Information

The transfusion rate during surgery in 200 patients with brain gliomas was 41% (82/200). The amount of leukocyte-depleted suspended red blood cells transfusion was 2.96±1.96 units (Note: 1unit=140mL, 2.96±1.96 units converted to volume is about 414.4±274.4mL), and the median amount of plasma transfusion was 92.5mL, with the maximum value being 1000 mL, and the minimum being 150 mL, and the range being 850 mL. The baseline data for the two patients groups are listed in Tables 1 and 2.

Univariate Logistic Regression Analysis of Intraoperative Blood Transfusion in Patients With Glioma

Univariate Logistic regression analysis exhibited that there were statistically significant differences ($P<0.05$) between the blood transfusion group (n=82) and non-transfusion group (n=118) in the grade of intraoperative blood loss (blood loss >500 mL), tumor location (in hemisphere), vascular involvement, presence of boundary, body weight and height, platelet count one week before the operation, operation time, tumor size and other parameters. On the other hand, no statistically significant differences ($P>0.05$) were found between the two group in gender, age, body weight, pass disease history, ASA grade, HB one week before the operation, preoperative blood coagulation function, multiple tumors, tumor resection scope and other parameters (Tables 3 and 4).

Multivariate Logistic Regression Analysis of Intraoperative Blood Transfusion in Patients With Glioma

We put the variables with $p < 0.10$ obtained by univariate analysis and the variables considered clinically meaningful (initial model) into the multivariate Logistic regression analysis model, and then manually adjusted the variables added to the

Table 1 General Data of the Patients

Parameters		**n = 200**
Age	Median (IQR)	46.50 (33.00, 56.00)
	Range	2.60, 80.00
Gender, n (%)	Male	111 (55.50)
	Female	89 (44.50)
Height (cm)	Median (IQR)	165.00 (158.00, 170.00)
	Range	50.00, 186.00
Body weight (kg)	Median (IQR)	62.00 (53.38, 70.00)
	Range	14.00, 155.00
Past history of disease, n (%)	1=Yes	70 (35.00)
	2=No	130 (65.00)
#HB (g/L) 1 week pre-op	Mean (SD)	135.53 (16.54)
$PLT (10*9/L) 1 week pre-op	Median (IQR)	215.50 (177.75, 259.25)
	Range	63.00, 476.00
※PT (seconds)	Median (IQR)	13.20 (12.80, 13.90)
	Range	11.00, 15.90
©APTT (seconds)	Median (IQR)	36.40 (34.40, 38.60)
	Range	25.70, 113.00
&inR	Median (IQR)	1.01 (0.97, 1.07)
	Range	0.79, 100.00
@FIB (g/L)	Median (IQR)	2.65 (2.34, 3.26)
	Range	0.93, 5.18
Prothrombin activity (PTA) (%)	Median (IQR)	99.00 (91.00, 107.00)
	Range	69.00, 158.00
Thrombin time (TT) (seconds)	Median (IQR)	16.65 (16.00, 17.40)
	Range	12.60, 48.30
*ASA surgical grades, n (%)	1	19 (9.50)
	2	137 (68.50)
	3	37 (18.50)
	4	7 (3.50)
Operation time	Median (IQR)	5.07 (4.35, 6.20)
(hours)	Range	2.62, 10.83
Intra-op blood loss (mL)	Median (IQR)	400.00 (300.00, 600.00)
	Range	0.00, 1,800.00
Grades of intra-op blood loss, n (%)	1 (≤500 mL)	128 (64.00)
	2 (>500 mL)	72 (36.00)
Resection, n (%)	Total resection	179 (89.50)
	Subtotal resection	21 (10.50)
Transfusion 1 week pre-op, n (%)	No	200 (100)
Intraop transfusion, n (%)	Yes	82 (41.00)
	No	118 (59.00)

Abbreviations: #HB, Haemoglobin.Haemoglobin levels conform to normal distribution, while other indicators do not; $PLT, Platelet; ※PT, Prothrombin time; ©APTT, Activated partial thromboplastin time; &inR, International normalized ratio; @FIB, Fibrinogen; *ASA surgical grades, American Society of Anesthesiologists surgical grades, for 1 to 6 grades.

model several times. After adjusting the variables added to the model, there were 8 independent variables finally included in the multivariate analysis model. The model results showed: Operation time, intraoperative blood loss (> 500mL), tumor involvement of blood vessels, and extent of resection (total resection) are the risk factors for intraoperative blood transfusion, and height is the protective factor for intraoperative blood transfusion (Table 5).

Table 2 Characteristic Data of Glioma

Parameters		n = 200
Tumor size (cm^3)	Median (IQR)	56.02 (23.13, 116.95)
	Range	0.30, 520.96
Tumor location, n (%)	1 (cerebral hemisphere)	163 (81.50)
	2 (not in cerebral hemisphere)	37 (18.50)
Grades of WHO classification, n (%)	1	14 (7.00)
	2	67 (33.50)
	3	58 (29.00)
	4	61 (30.50)
Vascular involvement, n (%)	Yes	20 (10.00)
	No	180 (90.00)
Multiple tumors, n (%)	Yes	16 (8.00)
	No	184 (92.00)
Whether the tumor has boundaries, n (%)	Yes	96 (48.00)
	No	104 (52.00)

Table 3 Univariate Logistic Regression Analysis of Intraoperative Blood Transfusion in Glioma Patients (Continuous Variables)

Parameters	Intra-op transfusion group (n = 82)	Non-intra-op transfusion group (n = 118)	OR (95% CI)	*P*
Age (year)	41.49 (20.97)	46.11 (14.18)	0.98 (0.97~1.00)	0.066
Height (cm)	159.09 (22.61)	164.31 (7.88)	0.98 (0.96~1.00)	0.033
Body weight (kg)	59.45 (21.66)	63.99 (12.09)	0.98 (0.96~1.00)	0.064
#HB (g/L) 1 week pre-op	133.44 (18.05)	136.97 (15.31)	0.99 (0.97~1.00)	0.139
$PLT (10*9/L) 1 week pre-op	232.33 (71.79)	216.03 (59.48)	1.00 (1.00~1.01)	0.084
※PT (sec.)	13.31 (0.84)	13.33 (0.72)	0.97 (0.67~1.41)	0.884
©APTT (sec.)	36.63 (4.06)	37.38 (7.71)	0.98 (0.91~1.03)	0.437
&inR	2.29 (10.93)	1.06 (0.32)	1.20 (1.01~2.78)	0.661
@FIB (g/L)	2.76 (0.79)	2.78 (0.77)	0.97 (0.67~1.39)	0.848
Prothrombin activity (PTA) (%)	99.76 (13.59)	99.24 (11.78)	1.00 (0.98~1.03)	0.773
Thrombin time (s)	16.54 (1.22)	16.90 (3.14)	0.92 (0.73~1.05)	0.364
Operation time (min)	388.78 (126.55)	286.89 (58.49)	1.01 (1.01~1.02)	<0.001
Operation time (h)	6.48 (2.11)	4.78 (0.97)	2.04 (1.63~2.64)	<0.001
Intra-op blood loss (mL)	681.10 (414.23)	370.34 (204.88)	1.00 (1.00~1.00)	<0.001
Tumor size (cm^3)	105.01 (106.37)	73.69 (78.03)	1.00 (1.00~1.01)	0.022

Abbreviations: #HB, Haemoglobin; $PLT, Platelet; ※PT, Prothrombin time; ©APTT, Activated partial thromboplastin time; &inR, International normalized ratio; @FIB, Fibrinogen.

Table 4 Univariate Logistic Regression Analysis of Intraoperative Blood Transfusion in Patients With Glioma (Categorical Variables)

Parameters	Intra-op transfusion group (n = 82)	Non-intra-op transfusion group (n = 118)	OR (95% CI)	*P*
Gender, male, n (%)	47 (57.32)	64 (54.24)	1.13 (0.64~2.01)	0.667
Past disease history, Yes, n (%)	27 (32.93)	43 (36.44)	0.86 (0.47~1.55)	0.609
ASA surgical grades, n (%)				
1	6 (7.32)	13 (11.02)	Reference	
2	55 (67.07)	82 (69.49)	1.45 (0.54~4.35)	0.475
3	19 (23.17)	18 (15.25)	2.29 (0.74~7.73)	0.163
4	2 (2.44)	5 (4.24)	0.87 (0.10~5.46)	0.883

(*Continued*)

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Table 4 (Continued).

Parameters	Intra-op transfusion group (n = 82)	Non-intra-op transfusion group (n = 118)	OR (95% CI)	*P*
Grades of intra-op blood loss, n (%)				
1 (≤500 mL)	34 (41.46)	94 (79.66)	Reference	
2 (>500 mL)	48 (58.54)	24 (20.34)	5.53 (2.99~10.51)	<0.001
Tumor location, n (%)				
1 (in hemisphere)	62 (75.61)	101 (85.59)	Reference	
2 (not in hemisphere)	20 (24.39)	17 (14.41)	1.92 (0.93~3.97)	0.077
Grades of WHO classification, n (%)				
1	6 (7.32)	8 (6.78)	Reference	
2	18 (21.95)	49 (41.53)	0.49 (0.15~1.67)	0.239
3	26 (31.71)	32 (27.12)	1.08 (0.33~3.67)	0.894
4	32 (39.02)	29 (24.58)	1.47 (0.46~4.95)	0.518
Vascular involvement, Yes, n (%)	14 (17.07)	6 (5.08)	3.84 (1.47~11.29)	0.009
Multiple tumors, Yes, n (%)	5 (6.10)	11 (9.32)	0.63 (0.19~1.81)	0.412
Boundary, Yes, n (%)	33 (40.24)	63 (53.39)	0.59 (0.33~1.04)	0.068
Resection, (%)				
Subtotal	7 (8.54)	14 (11.86)	Reference	
Total	75 (91.46)	104 (88.14)	1.44 (0.57~3.97)	0.452

Table 5 Multivariate Logistic Regression Analysis of Intraoperative Blood Transfusion in Glioma Patients

Parameters	Intra-op transfusion group (n = 82)	Non-intra-op transfusion group (n = 118)	OR (95% CI)	*P*
Age (year), Mean (SD)	41.49 (20.97)	46.11 (14.18)	0.97 (0.95~1.00)	0.056
Height (cm), Mean (SD)	159.09 (22.61)	164.31 (7.88)	0.96 (0.93~0.99)	0.009
Body weight (kg), Mean (SD)	59.45 (21.66)	63.99 (12.09)	0.98 (0.96~1.01)	0.199
Operation time (h), Mean (SD)	6.48 (2.11)	4.78 (0.97)	2.25 (1.69~3.16)	< 0.001
Grades of intra-op blood loss, n (%)				
1 (≤500 mL)	34 (41.46)	94 (79.66)	Reference	
2(>500 mL)	48 (58.54)	24 (20.34)	4.27 (1.93~9.72)	< 0.001
Glioma grades (WHO classification), n (%)				
1	6 (7.32)	8 (6.78)	Reference	
2	18 (21.95)	49 (41.53)	0.87 (0.15~6.09)	0.882
3	26 (31.71)	32 (27.12)	2.5 (0.42~18.49)	0.336
4	32 (39.02)	29 (24.58)	3.03 (0.53~22.19)	0.241
Vascular involvement, Yes, n (%)	14 (17.07)	6 (5.08)	9.14 (2.22~45.68)	0.004
Resection, n (%)				
Subtotal	7 (8.54)	14 (11.86)	Reference	
Total	75 (91.46)	104 (88.14)	9.37 (1.88~59.20)	0.011

Discussion

Glioma represents the most common primary malignant tumor of the brain, resulting from the malignant transformation of brain glial cells. Glioma is characterized by a high incidence, high recurrence rate, high mortality, and low cure rate. At present, the principal treatment for gliomas is surgical resection, in combination with postoperative radiotherapy and chemotherapy. The surgical resection of gliomas is prone to bleeding, and the adverse reactions caused by massive blood transfusions during surgery can also seriously affect the efficacy of glioma surgery. Due to the current shortage of blood supply, adverse transfusion reactions are becoming increasingly common. Therefore, reducing transfusions and avoiding

or minimizing adverse transfusion reactions are of great clinical significance for the surgical resection of gliomas. This study retrospectively analyzed the clinical data of 200 patients undergoing surgical resection of gliomas. By constructing univariate and multivariate regression models, we examined the risk factors for intraoperative blood transfusion in glioma surgery. We found that the operation time, intraoperative blood loss ≥ 500 mL, vascular involvement, and total resection were risk factors for intraoperative blood transfusion, while body height was a protective factor against intraoperative blood transfusion.

The results of this study have important implications for the clinical practice of glioma surgery. First, identifying risk factors for intraoperative blood transfusions (leukocyte-depleted suspended red blood cells and plasma) allows surgeons to better predict transfusion needs and prepare accordingly. By identifying patients who are at higher risk of needing blood transfusions, surgeons can ensure adequate blood products are available during surgery, reducing the risk of delays or complications due to blood shortages. The identification and correction of intraoperative blood transfusion risk is beneficial to reduce the probability of blood transfusion and improve the allocation efficiency of limited blood component resources.[8] Secondly, this study highlights the importance of minimizing blood loss during glioma surgery. Surgeons should strive to improve the fineness and efficiency of surgical techniques and avoid unnecessary tissue damage and vascular damage, as this may lead to increased blood loss and blood transfusion needs.

Many clinical studies[18–22] have shown that the length of operation time plays a decisive role in the success or failure of operation. The longer the operation time, the more difficult and complicated the operation, and the greater the dose of anesthetic needed by the patient, which is very challenging to maintain the patient's vital signs and the physical requirements of the operator. This study found that the longer the operation time of glioma, the higher the risk of intraoperative blood transfusion. Therefore, how to control the operation time is of great significance for glioma surgery. In addition to the complexity of the operation, this puts forward higher requirements for the surgical level of the surgeon. Only when the surgical skills are more exquisite and the anatomical structure of the brain and lesions is well understood, can the operation be performed leisurely, shortening the operation time and improving the success rate of the operation. Early studies have shown that long operation time is a risk factor for platelet transfusion during glioma operation,[7] and the results of this study are consistent with the research conclusions of other scholars.[7,23–25]

Clinical studies[26–28] have shown that the greater the amount of blood lost during surgery, the greater the risk of blood transfusion. This study found that during glioma surgery, the greater the blood loss, the higher the probability of blood transfusion, which is confirmed by other scholars,[29,30] which may be related to the characteristics of glioma and surgical wounds. Brain glial has various morphologies and multiple parts, and it is easy to invade blood vessels and surrounding brain tissues. In order to maximize the resection of lesions during the operation, surgeons can easily cause increased blood loss. In this study, it was found that when the blood loss was greater than 500mL, the risk of blood transfusion was 4.27 times higher than that of patients with blood loss less than 500mL (OR: 4.27, 95% confidence interval: 1.93–9.72). Thus, reducing blood loss is a key element in reducing blood transfusion.

Vascular invasion of glioma is very common. Because of the gene polymorphism of glioma, it is easy to grow invasively, especially the characteristics of vascular invasion have been confirmed by many scholars,[31–35] which is also an important factor for glioma to relapse and blood metastasis. The abundance of intracranial blood vessels provides convenient conditions for the growth, direct spread and blood metastasis of glioma. This study found that whether glioma involves craniocerebral blood vessels plays an important role in determining whether blood transfusion during operation. The risk of blood transfusion in patients with blood vessel involvement is 9.14 times higher than that in patients without blood vessel involvement (OR: 9.14, 95% confidence interval: 2.22–45.68). We speculate that because glioma involves blood vessels, it is easy to trigger massive bleeding during intraoperative tumor dissection or resection, which leads to an increased risk of blood transfusion.

Studies have shown that the extent of surgical resection of glioma is an important factor affecting the prognosis and bleeding of glioma.[36–39] The more and cleaner the tumor is removed, the longer the patient will survive. In this study, it was found that total tumor resection is a risk factor for blood transfusion, and we speculate that this may be related to surgical wounds and bleeding. Due to the diversity of tumor morphology, the degree of tumor invasion of surrounding tissues is also different. The larger the extent of lesion resection, the larger the surgical wound, the increased the probability of surgical bleeding, and the increased risk of blood transfusion. The finding that total glioma resection is

a risk factor for blood transfusion suggests that surgeons may need to balance the benefit of maximizing tumor resection with the increased risk of blood loss and blood transfusion. In some cases, in order to minimize the risk of blood transfusion and its associated complications, a more conservative resection may be preferable.

An interesting phenomenon was found in this study that height is a protective factor for blood transfusion, which means that the higher the height, the lower the risk of blood transfusion. There are many factors that affect height, mainly including growth hormone, sex hormone, thyroid hormone, heredity, nutrition, exercise, etc., and growth hormone plays an important role in the development of human height. Recent studies have shown that patients with chronic diseases related to growth hormone deficiency are at higher risk during the COVID-19 pandemic. Researchers analyzed that growth hormone deficiency leads to an increased risk of thrombosis in patients with severe COVID-19 infection, GHD is related to coagulation system dysfunction, and growth hormone replacement therapy is beneficial to improving hypercoagulability.[40,41] We speculate that height is a protective factor for glioma surgical blood transfusion, which may be related to growth hormone level and coagulation function. Compared with short patients, tall patients have higher growth hormone levels, and the probability of coagulation dysfunction may be lower, so the risk of surgical bleeding is lower than that of short patients. While the exact mechanism of this finding is unknown, it may be related to differences in coagulation function or physiological response to stress among people of different heights. Future studies should explore this potential association in more detail to better understand its clinical implications.

The shortcomings of this study are as follows: ① The sample size of patients is small (many patients cannot be included in the study group because of incomplete data), and no logistic regression analysis prediction model has been established. Only the risk factors and protective factors of blood transfusion during glioma surgery have been discussed. In the follow-up study, we will increase the sample size and establish a stable logistic regression analysis prediction model; ② It is a single-center retrospective study with certain selection bias. In the future, we hope to establish a multi-center and multi-regional cooperation platform to make the research data more homogeneous and reliable. ③ Because this study is retrospective and the detailed medication history of each patient is not recorded in detail, it is impossible to directly assess the specific impact of drugs on blood transfusion needs. We acknowledge that this is a limitation of this study. Drugs, particularly anticoagulants, hemostats, and anesthetics, may affect intraoperative blood loss and transfusion requirements. In future studies, we will systematically collect medication history, design prospective randomized controlled trials, and evaluate the specific effects of drugs on blood loss and blood transfusion to optimize blood transfusion management strategies. ④ The effects of different surgical techniques and methods on blood transfusion and glioma prognosis during glioma surgery were not discussed in this study. In the follow-up cohort study, we will increase the sample size and include these factors for analysis.

To sum up, this study deeply explored the risk factors related to blood transfusion in glioma surgery, and clearly pointed out that the duration of surgery, blood loss, tumor invasion of blood vessels and total resection all increased the risk of blood transfusion. In order to reduce risks, it is recommended that surgeons improve surgical skills, optimize procedures, adopt advanced hemostatic techniques, and fully prepare blood; For patients with tumor involvement of blood vessels, detailed imaging evaluation and personalized surgical plan are needed; Total resection needs to weigh the risk of blood transfusion, and sometimes conservative resection is required. Future research can further explore the influence of surgical skills, hemostatic techniques and anesthesia management on blood transfusion demand, and establish an accurate blood transfusion prediction model. In clinical practice, we should improve the blood transfusion management system, strengthen the training of medical staff, optimize blood transfusion management, improve the prognosis of patients and save blood resources. This study provides a reference for understanding the risk of blood transfusion in glioma surgery, helps improve surgical skills, promotes precise and individualized blood transfusion strategies, hopes to reduce adverse reactions, prolong survival, promote cooperation between surgery and blood transfusion doctors, and formulate more precise blood transfusion strategies. Fill the gap in the management of intraoperative blood transfusion (leukocyte-removed suspended red blood cells and plasma transfusion) for glioma.

Availability of Supporting Data

The authenticity and reliability of all the primary data, statistical methodologies, and statistical findings are unquestionable.

Ethical Approval and Consent to Participate

This study was approved by the Clinical Trial Ethics Committee of Tongji Hospital,Tongji Medical College, Huazhong University of Science and Technology (TJ-IRB202402061), The trial was overseen by an independent trial steering committee and data monitoring and ethics committee. China Clinical Trial Registration Center registration number: ChiCTR2400088931.This study is a retrospective observational study, without any intervention and without the need for patients to sign informed consent (some patients have passed away and cannot sign informed consent).

Human Ethics

The study complied with the Declaration of Helsinki and human ethical research requirements. There are no ethical violations in our study.

Consent for Publication

All the authors agreed to publish the results of this study.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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References

1. Ostrom QT, Gittleman H, Liao P. et al. CBTRUS statistical report: primary brain and other central nervous system tumors diagnosed in the United States in 2010-2014. *Neuro Oncol*. 2017;19(suppl_5):v1–v88. doi:10.1093/neuonc/nox158
2. Omuro A, DeAngelis LM. Glioblastoma and other malignant gliomas: a clinical review. *JAMA*. 2013;310(17):1842–1850. doi:10.1001/jama.2013.280319
3. Larsen J, Wharton SB, McKevitt F, et al. 'Low grade glioma': an update for radiologists. *Br J Radiol*. 2017;90(1070):20160600. doi:10.1259/bjr.20160600
4. Schneider M, Schäfer N, Potthoff AL, et al. Perioperative red blood cell transfusion is associated with poor functional outcome and overall survival in patients with newly diagnosed glioblastoma. *Neurosurg Rev*. 2022;45(2):1327–1333. doi:10.1007/s10143-021-01633-y
5. Zhang Q, Wu H, Zhang J, Qi Q, Zhang W, Xia R. Preoperative immune response is associated with perioperative transfusion requirements in glioma surgery. *J Cancer*. 2019;10(15):3526–3532. doi:10.7150/jca.28953
6. Deng Z, Wu W, Wang N, et al. Emergency glioma resection but not hours of operation predicts perioperative complications: a single center study. *Clin Neurol Neurosurg*. 2019;182:11–16. doi:10.1016/j.clineuro.2019.04.010
7. Lagman C, Sheppard JP, Romiyo P, et al. Risk factors for platelet transfusion in glioblastoma surgery. *J Clin Neurosci*. 2018;50:93–97. doi:10.1016/j.jocn.2018.01.072
8. Sangtongjaraskul S, Sae-Phua V, Amornfa J, Tuchinda L. Risk factors of intraoperative blood transfusion in pediatric craniotomy for intracranial tumor resection: a 10-year analysis. *J Neurosurg Pediatr*. 2023;32(1):115–123. doi:10.3171/2023.2.PEDS22535
9. Akita T, Tanaka J, Ohisa M, et al. Predicting future blood supply and demand in Japan with a Markov model: application to the sex- and age-specific probability of blood donation. *Transfusion*. 2016;56(11):2750–2759. doi:10.1111/trf.13780

10. Goel R, Tobian A, Shaz BH. Noninfectious transfusion-associated adverse events and their mitigation strategies. *Blood*. 2019;133(17):1831–1839. doi:10.1182/blood-2018-10-833988
11. Doughty H, Green L, Callum J, Murphy MF, National Blood Transfusion Committee. Triage tool for the rationing of blood for massively bleeding patients during a severe national blood shortage: guidance from the national blood transfusion committee. *Br J Haematol*. 2020;191(3):340–346. doi:10.1111/bjh.16736
12. Abdallah R, Rai H, Panch SR. Transfusion reactions and adverse events. *Clin Lab Med*. 2021;41(4):669–696. doi:10.1016/j.cll.2021.07.009
13. Sharp R, Turner L, Altschwager J, Corsini N, Esterman A. Adverse events associated with home blood transfusion: a retrospective cohort study. *J Clin Nurs*. 2021;30(11–12):1751–1759. doi:10.1111/jocn.15734
14. van der Wal J, van Heerde M, Markhorst DG, Kneyber MC. Transfusion of leukocyte-depleted red blood cells is not a risk factor for nosocomial infections in critically ill children. *Pediatr Crit Care Med*. 2011;12(5):519–524. doi:10.1097/PCC.0b013e3181fe4282
15. Bilgin YM, van de Watering LM, Eijsman L, et al. Double-blind, randomized controlled trial on the effect of leukocyte-depleted erythrocyte transfusions in cardiac valve surgery. *Circulation*. 2004;109(22):2755–2760. doi:10.1161/01.CIR.0000130162.11925.21
16. Raval JS, Griggs JR, Fleg A. Blood product transfusion in adults: indications, adverse reactions, and modifications. *Am Fam Physician*. 2020;102(1):30–38.
17. Saadah NH, Schipperus MR, Wiersum-Osselton JC, et al. Transition from fresh frozen plasma to solvent/detergent plasma in the Netherlands: comparing clinical use and transfusion reaction risks. *Haematologica*. 2020;105(4):1158–1165. doi:10.3324/haematol.2019.222083
18. Gillespie BM, Chaboyer W, Fairweather N. Factors that influence the expected length of operation: results of a prospective study. *BMJ Qual Saf*. 2012;21(1):3–12. doi:10.1136/bmjqs-2011-000169
19. Cheng H, Chen BP, Soleas IM, Ferko NC, Cameron CG, Hinoul P. Prolonged operative duration increases risk of surgical site infections: a systematic review. *Surg Infect (Larchmt)*. 2017;18(6):722–735. doi:10.1089/sur.2017.089
20. Cheng H, Clymer JW, Po-Han Chen B, et al. Prolonged operative duration is associated with complications: a systematic review and meta-analysis. *J Surg Res*. 2018;229:134–144. doi:10.1016/j.jss.2018.03.022
21. Fleming CA, Westby D, Ullah MF, et al. A review of clinical and oncological outcomes following the introduction of the first robotic colorectal surgery programme to a university teaching hospital in Ireland using a dual console training platform. *J Robot Surg*. 2020;14(6):889–896. doi:10.1007/s11701-020-01073-8
22. McHayle A, Pertsch NJ, Toms SA, Weil RJ. Operative duration and early outcomes in patients having a supratentorial craniotomy for brain tumor: a propensity matched analysis. *J Clin Neurosci*. 2021;92:207–214. doi:10.1016/j.jocn.2021.08.005
23. Tedesco NS, Korpi FP, Pazdernik VK, Cochran JM. Relationship between hypothermia and blood loss in adult patients undergoing open lumbar spine surgery. *J Am Osteopath Assoc*. 2014;114(11):828–838. doi:10.7556/jaoa.2014.169
24. Wang JQ, Chen LY, Jiang BJ, Zhao YM. Development of a nomogram for predicting blood transfusion risk after hemiarthroplasty for femoral neck fractures in elderly patients. *Med Sci Monit*. 2020;26:e920255. doi:10.12659/MSM.920255
25. Wang H, Wang K, Lv B, et al. Establishment and assessment of a nomogram for predicting blood transfusion risk in posterior lumbar spinal fusion. *J Orthop Surg Res*. 2021;16(1):39. doi:10.1186/s13018-020-02053-2
26. Graves SC, Dropkin BM, Keeney BJ, Lurie JD, Tomek IM. Does surgical approach affect patient-reported function after primary THA. *Clin Orthop Relat Res*. 2016;474(4):971–981. doi:10.1007/s11999-015-4639-5
27. Postlewait LM, Squires MH 3rd, Kooby DA, et al. The relationship of blood transfusion with peri-operative and long-term outcomes after major hepatectomy for metastatic colorectal cancer: a multi-institutional study of 456 patients. *HPB (Oxford)*. 2016;18(2):192–199. doi:10.1016/j.hpb.2015.08.003
28. Slattery C, Kark J, Wagner T, Verma K. The use of tranexamic acid to reduce surgical blood loss: a review basic science, subspecialty studies, and the evolution of use in spine deformity surgery. *Clin Spine Surg*. 2019;32(2):46–50. doi:10.1097/BSD.0000000000000808
29. Raman T, Varlotta C, Vasquez-Montes D, Buckland AJ, Errico TJ. The use of tranexamic acid in adult spinal deformity: is there an optimal dosing strategy. *Spine J*. 2019;19(10):1690–1697. doi:10.1016/j.spinee.2019.06.012
30. Enrique Bayter-Marin J, Cárdenas-Camarena L, Peña WE, et al. Patient blood management strategies to avoid transfusions in body contouring operations: controlled clinical trial. *Plast Reconstr Surg*. 2021;147(2):355–363. doi:10.1097/PRS.0000000000007524
31. Gritsenko PG, Ilina O, Friedl P. Interstitial guidance of cancer invasion. *J Pathol*. 2012;226(2):185–199. doi:10.1002/path.3031
32. Wang TC, Cheng CY, Yang WH, Chen WC, Chang PJ. Characterization of highly proliferative secondary tumor clusters along host blood vessels in malignant glioma. *Mol Med Rep*. 2015;12(5):6435–6444. doi:10.3892/mmr.2015.4228
33. Thompson EG, Sontheimer H. A role for ion channels in perivascular glioma invasion. *Eur Biophys J*. 2016;45(7):635–648. doi:10.1007/s00249-016-1154-x
34. Umans RA, Ten Kate M, Pollock C, Sontheimer H. Fishing for contact: modeling perivascular glioma invasion in the zebrafish brain. *ACS Pharmacol Transl Sci*. 2021;4(4):1295–1305. doi:10.1021/acsptsci.0c00129
35. Lee E, Lee EA, Kong E, et al. An agonistic anti-Tie2 antibody suppresses the normal-to-tumor vascular transition in the glioblastoma invasion zone. *Exp Mol Med*. 2023;55(2):470–484. doi:10.1038/s12276-023-00939-9
36. Brown TJ, Brennan MC, Li M, et al. Association of the extent of resection with survival in glioblastoma: a systematic review and meta-analysis. *JAMA Oncol*. 2016;2(11):1460–1469. doi:10.1001/jamaoncol.2016.1373
37. Villanueva KG, Rea ND, Krieger MD. Novel surgical and radiologic risk factors for progression or recurrence of pediatric pilocytic astrocytoma. *Pediatr Neurosurg*. 2019;54(6):375–385. doi:10.1159/000503110
38. Zhang Y, Ji P, Wang S, Qin H, Cai Q. Early unplanned reoperation after glioma craniotomy: incidence, predictor and process improvement. *Front Oncol*. 2022;12:898873. doi:10.3389/fonc.2022.898873
39. Jusue-Torres I, Lee J, Germanwala AV, Burns TC, Parney IF. Effect of extent of resection on survival of patients with glioblastoma, IDH-wild-type, WHO Grade 4 (WHO 2021): systematic review and meta-analysis. *World Neurosurg*. 2023;171:e524–e532. doi:10.1016/j.wneu.2022.12.052
40. Lubrano C, Masi D, Risi R, et al. Is growth hormone insufficiency the missing link between obesity, male gender, age, and COVID-19 severity. *Obesity*. 2020;28(11):2038–2039. doi:10.1002/oby.23000
41. Kopchick JJ, Basu R, Berryman DE, Jorgensen J, Johannsson G, Puri V. Covert actions of growth hormone: fibrosis, cardiovascular diseases and cancer. *Nat Rev Endocrinol*. 2022;18(9):558–573. doi:10.1038/s41574-022-00702-6