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Effect of Perioperative Blood Transfusion on Postoperative Complications of Free-Flap Reconstruction for Oral Cancer: Analysis of Propensity Score-Matched Cohorts

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Abstract

Background It has been confirmed in other fields that perioperative blood transfusion (PBT) will increase the incidence of complications after free-flap reconstruction and increase the risk of patients returning to the operating room within 48 hours after the initial operation. However, for head and neck tumors, whether PBT is related to postoperative complications is debatable. The aim of this study was to control the demographic and comorbidity characteristics of patients by propensity score matching (PSM) as well as to investigate the relationship between PBT and postoperative complications after oral cancer free-flap reconstruction.

Methods A total of 597 patients who underwent microvascular free tissue transfer in two top three hospitals in Southwest China from January 2015 to July 2023 were retrospectively reviewed. The study population was divided based on PBT within 24 hours of the start of the operation and to ensure homogeneity between groups by using the PSM. The primary outcomes were postoperative complications; secondary outcomes were to explore the intraoperative risk factors of PBT.

Results A total of 597 patients were included. Among them, 90 patients received a PBT. Those patients were successfully matched with 86 similar patients who did not receive a transfusion on a ratio of 1:1. This study did not find that patients receive a transfusion had a significantly higher risk of vascular pedicle thrombosis ($p = 1.000$), hematoma ($p = 1.000$), flap failure ($p = 0.398$), flap-related complications ($p = 0.470$), and other medical complications ($p = 1.000$). After controlling the preoperative confounding factors and adjusting the

Keywords
- blood transfusion
- complication
- free flap
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- flap reconstruction

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logistic regression model, it was concluded that the tumor location-mandible (odds ratio [OR] = 19.923, 95% confidence interval [CI]: 1.213–327.302, $p = 0.036$) and operation time (OR = 1.011, 95% CI: 1.008–1.014, $p < 0.001$) were the intraoperative risk factors for PBT.
Conclusion PBT is not associated with an increased probability of postoperative complications. Mandibular tumor may have a higher risk of PBT.

With the development of microsurgery, free tissue reconstruction has become the main treatment for oral and maxillofacial defects. Although the probability of successful free-flap transplantation is as high as 94 to 98.71%.[1–3] In clinical work, the occurrence of postoperative complications such as flap failure, hematoma, wound infection, lung infection, etc. are still the most concerned topic of every doctor. The reconstruction of oral and maxillofacial tissues often involves the removal of jaw bones, which requires longer operative times and higher intraoperative blood loss. Therefore, perioperative blood transfusion (PBT) is often required. Some studies have found that PBT after breast reconstruction will increase the probability of flap-related complications but will not reduce the risk of other postoperative medical complications.[4] The main reason may be related to the change of blood components during blood storage, which leads to vascular thrombosis, the release of cytokines, and the circulation overload caused by blood transfusion.[5–7] However, in the field of head and neck tumors, there are few studies on whether PBT is associated with postoperative complications such as flap complications and medical complications, and the conclusions are conflicting. Some studies believe that PBT are associated with flap complications,[4,8–10] whereas others emphasize that PBT does not affect flap complications.[11–13] In addition to the small sample size and commonly evaluated single-center outcomes, these studies are often not limited to the head and neck, so the research results need to be further demonstrated. In this study, we used propensity score matching (PSM) to control the confounding factors of PBT and evaluated the impact of PBT on flap complications and medical complications in patients undergoing oral free-flap reconstruction.

Methods

Patients Select

This study included patients who underwent microvascular free tissue transplantation between January 2015 and July 2023 at two hospitals (Affiliated Hospital of Southwest Medical University and Zunyi Medical University Affiliated Stomatological Hospital) in Southwest China. Criteria for exclusion included preoperative severe cardiopulmonary dysfunction, blood and coagulation dysfunction, history of deep vein thrombosis, history of other malignant tumors, and incomplete electronic information data. Finally, 597 patients were included for analysis. This study had been ethically registered in Zunyi Medical University and the Affiliated Hospital of Southwest Medical University and was conducted according to the principles of the Declaration of Helsinki.

Data Collection

The following variables were collected, preoperative variables: gender, age, body mass index (BMI), history of smoking, history of drinking, history of preoperative chemoradiotherapy, a history of comorbidities (hypertension, diabetes mellitus, preoperative pulmonary disease, preoperative cardiovascular disease, preoperative cerebrovascular disease, preoperative pleural effusion, peripheral vascular disease), the American Society of Anesthesiologists (ASA) classification, preoperative red blood cell count, preoperative hemoglobin (Hgb), preoperative fasting blood glucose, tumor location; intraoperative variables: jawbone resection, titanium plate and nail placement, neck dissection, flap type, osseous free flap, operation time; outcome variables: vascular pedicle thrombosis, flap failure, hematoma, flap-related complications, wound infection, pulmonary infection, deep vein thrombosis, medical complications. In this study, flap-related complications were defined as vascular pedicle thrombosis, hematoma, and total or partial flap failure within 30 days after operation. Medical complications mainly include wound infection, pulmonary infection, and deep vein thrombosis. The study population was divided into two groups based on the use of PBT defined as transfusion within 24 hours of the start of the operation. Primary outcomes were the postoperative complications. Secondary outcomes were to identify perioperative independent risk factors for blood transfusion.

Statistical Analysis

In this study, patients were divided into two groups based on the presence of PBT. The test group were patients receiving PBT, and the control group consisted of patients who underwent free-flap reconstruction without PBT. A univariate analysis was used to compare the difference between two groups of characteristics. Binary variables were compared using the chi-square test or the Fisher's exact test as appropriate. Normally distributed continuous variables were compared with the Student's *t*-test, whereas non-normally distributed variables were compared using the Mann–Whitney's U test. A logical regression model was used to calculates propensity score with the following covariates that present significant differences between the groups: BMI, history of smoking, history of drinking, history of preoperative radiotherapy and chemotherapy, history of preoperative pulmonary disease, preoperative red blood

cell count, preoperative Hgb. Each patient was then matched with controls on a 1:1 ratio with a narrow caliper (0.02) of propensity without replacement. After PSM, the McNemar chi-square was used to compare the proportions and the Wilcoxon signed rank test was used to compare the means to ensure the suitability and applicability of the process. The intraoperative variables and complications of all differences were included in the binary logistic regression model to observe the correlation between blood transfusion and postoperative complications as well as the independent risk factors of PBT. Statistical significance was defined as p-value less than 0.05. All analyses were performed using IBM SPSS Statistics 29 (IBM Corp., Armonk, NY).

Results

Patient Characteristics

A total of 597 patients were included, predominantly male; the median age was 58 years (interquartile range [IQR]: 50–66), and the median BMI was 22.69 (IQR: 20.88–25.00). A total of 45.9% had a history of smoking, 39.5% had a history of drinking, and 5.4% had a history of preoperative radiotherapy and chemotherapy. Tumors were mainly located in the tongue (33.5%), buccal mucosa (17.3%), and jawbone (16.9%). A total of 86.0% of ASA score was Grade II, and 90 patients (15.08%) received a PBT. There were significant differences between the PBT group and the nontransfusion group in BMI ($p = 0.041$), history of smoking ($p = 0.001$), history of drinking ($p = 0.013$), history of preoperative radiotherapy and chemotherapy ($p < 0.001$), and history of preoperative pulmonary disease ($p = 0.046$), preoperative red blood cells count ($p = 0.028$), and preoperative Hgb ($p < 0.001$; ►**Table 1**).

Propensity Score Matching

The patients were matched using PSM on a ratio of 1:1; the 90 patients who received a blood transfusion were matched with 507 patients who did not, and finally 86 pairs were successfully matched. Following PSM, the two groups had no difference in demographic and clinical characteristics (►**Table 2**). It had shown that there were differences in postoperative complications between the two groups, including wound infection ($p < 0.001$), flap failure ($p = 0.047$), flap-related complications ($p = 0.042$), and medical complications ($p < 0.001$). After PSM, the two groups showed that PBT were not related to postoperative complications (►**Table 3**). Meanwhile, these postoperative complications were included in the logistic regression model, and the results were shown in ►**Table 4**. This study concluded that PBT would not lead to vascular pedicle thrombosis, hematoma, flap failure, postoperative lung infection, postoperative wound infection, postoperative deep vein thrombosis, and other complications.

Perioperative Risk Factors of Blood Transfusion

Following PSM, the variables that were significantly different between groups, including osseous free flap ($p = 0.022$), tumor location ($p = 0.055$), jawbone resection ($p = 0.085$), flap type ($p < 0.001$), and operation time ($p < 0.001$) were included in the logistic regression equation, and by adjusting the model, tumor location-mandible (odds ratio [OR] $= 19.923$, $p = 0.036$) and operation time (OR $= 1.011$, $p < 0.001$) were independent risk factors for PBT. Flap type, osseous free flap, and jawbone resection were not related to PBT after adjusting the model (►**Table 5**).

Discussion

At present, in the field of head and neck cancer, there is controversy regarding whether PBT leads to postoperative complications after free-flap reconstruction. Zhao et al found that blood transfusion would cause postoperative wound complications and reoperation[9]; Puram et al found that blood transfusion was related to wound dehiscence, myocardial infarction, congestive heart failure, respiratory distress, and pneumonia in patients with head and neck free flaps[8]; Szakmany et al believed that blood transfusion significantly increased the mortality of patients with head and neck free flaps.[14] In recent years, studies have yielded conflicting results. PBT may not increase the risk of vascular pedicle thrombosis and affect the flap survival,[11,15] but it may increase the occurrence of other postoperative complications.[4,10] The latest study concluded that PBT may not increase the occurrence of medical complications through the change of blood transfusion strategy.[16] The impact of PBT on postoperative complications is still controversial. We designed this study and used PSM for the first time to explore the correlation between PBT and postoperative complications. To compare the differences between the PBT group and the nontransfusion group and to select the variables with differences between the groups for PSM, the matching variables included BMI, history of smoking, history of drinking, history of preoperative radiotherapy and chemotherapy, history of preoperative pulmonary disease, preoperative red blood cells count, and preoperative Hgb. Previous studies had shown that the patient's smoking and comorbidity affected the postoperative complications of patients with head and neck cancer reconstruction.[17–20] This study matched the basic demographic and comorbidity characteristics of patients who received PBT and attempted to control the baseline confounding factors related to PBT that might affect postoperative complications, so as to achieve more objective results.

Karamanos et al described a higher incidence of reoperation within 48 hours after the first surgery in patients undergoing preoperative blood transfusion, mainly due to flap-related complications such as returning to the operating room to repair the anastomotic site and wound dehiscence.[4] Blood transfusion increases the risk of wound dehiscence, but the study focuses on breast reconstruction patients. Some scholars suggested that the occurrence of flap-related complications (thrombosis, hematoma, wound dehiscence) may be related to the longer storage time of red blood cells (> 14 days), which reduces the ability of free circulation, and thus decrease the microvascular flow and produces hypoxia that leads to thrombosis. It may also be related to possible

Table1 Demographic and clinical characteristics before propensity score matching

Characteristics[a]	All patients			
	Total	Transfusion	No transfusion	p^b
	($n = 597$)	($n = 90$)	($n = 507$)	
Male	429 (71.9%)	57 (63.3%)	372 (73.4%)	0.051
Age	58 [50, 66]	58 [50, 64]	56 [49, 66]	0.572
BMI	22.69 [20.88, 25.00]	22.11 [19.89, 24.22]	22.98 [21.11, 25.39]	**0.041**
Smoking	274 (45.9%)	27 (30.0%)	247 (48.7%)	**0.001**
Alcohol	236 (39.5%)	25 (27.8%)	211 (41.6%)	**0.013**
Preoperative radiotherapy and chemotherapy	32 (5.4%)	13 (14.4%)	19 (3.7%)	< **0.001**
Diabetes	45 (7.5%)	7 (7.8%)	38 (7.5%)	0.925
Hypertension	129 (21.6%)	19 (21.1%)	110 (21.7%)	0.901
Pulmonary disease	91 (15.2%)	20 (22.2%)	71 (14.0%)	**0.046**
Pleural effusion	16 (2.7%)	4 (4.4%)	12 (2.4%)	0.441
Cardiovascular disease	197 (33.0%)	24 (26.7%)	173 (34.1%)	0.166
Cerebrovascular disease	39 (6.5%)	8 (8.9%)	31 (6.1%)	0.326
Peripheral vascular disease	88 (14.7%)	11 (12.2%)	77 (15.2%)	0.465
ASA				0.243
I	14 (2.9%)	4 (4.7%)	10 (2.5%)	
II	419 (86.0%)	69 (80.2%)	350 (87.3%)	
III	54 (11.1%)	13 (15.1%)	41 (10.2%)	
Preoperative red blood cells (10^{12}/L)	4.41 [4.11, 4.74]	4.40 [3.92, 4.64]	4.44 [4.18, 4.75]	**0.028**
Preoperative hemoglobin (g/L)	135 [126, 145]	133 [119, 135]	136 [130, 146]	< **0.001**
FBG (mmol/L)	5.19 [4.70, 5.68]	5.34 [4.73, 5.71]	5.19 [4.70, 5.71]	0.419
Tumor location				0.146
Tongue	200 (33.5%)	30 (33.3%)	170 (33.5%)	
Floor of mouth	78 (13.1%)	8 (8.9%)	70 (13.8%)	
Gingiva	53 (8.9%)	11 (12.2%)	42 (8.3%)	
Mandible	101 (16.9%)	22 (24.4%)	79 (15.6%)	
Buccal mucosa	103 (17.3%)	10 (11.1%)	93 (18.3%)	
Palatal mucosa	21 (3.5%)	3 (3.3%)	18 (3.6%)	
Oropharynx	25 (4.2%)	2 (2.2%)	23 (4.5%)	
Other parts	16 (2.7%)	4 (4.4%)	12 (2.4%)	

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; FBG, fasting blood glucose.
[a]Data are depicted as numbers (proportions) or median (interquartile range).
[b]Variables $p < 0.05$ are in bold.

changes in the coagulation system due to prolonged storage.[21] The author's previous research found that PBT may be related to the formation of vascular pedicle thrombosis in oral flap reconstruction. Torres et al found that red blood cell infusion did not cause vascular pedicle thrombosis. The research subjects in this study were not limited to the head and neck, and the observation time for vascular pedicle thrombosis was only 7 days.[11] However, there are also instances of thrombosis in clinical practice beyond 7 days. In this study, we focused on oral free-flap reconstruction and vascular pedicle thrombosis over a 30-day period. We used the PSM method for the first time to explore the correlation between PBT and postoperative complications of oral free-flap reconstruction. We concluded that PBT would not increase the occurrence of flap-related complications (thrombosis, flap failure, hematoma) and medical complications (wound infection, lung infection, deep vein thrombosis) in patients with oral cancer after reconstruction.

Table 2 Demographic and clinical characteristics after propensity score matching

Characteristics[a]	Matched cohorts			
	Total	Transfusion	No transfusion	p^b
	($n = 172$)	($n = 86$)	($n = 86$)	
Male	115 (66.9%)	56 (65.1%)	59 (68.6%)	0.627
Age	59 [51, 66]	58 [50, 64]	58.5 [52, 67]	0.116
BMI[c]	22.17 [20.41, 24.09]	22.05 [19.73, 24.22]	22.34 [20.53, 23.90]	0.983
Smoking	55 (32.0%)	27 (31.4%)	28 (32.6%)	0.870
Alcohol	49 (28.5%)	25 (29.1%)	24 (27.9%)	0.866
Preoperative radiotherapy and chemotherapy	20 (11.6%)	10 (11.6%)	10 (11.6%)	1.000
Diabetes	11 (6.4%)	7 (8.1%)	4 (4.7%)	0.350
Hypertension	35 (20.3%)	19 (22.1%)	16 (18.6%)	0.570
Pulmonary disease	40 (23.3%)	18 (20.9%)	22 (25.6%)	0.470
Pleural effusion	9 (5.2%)	4 (4.7%)	5 (5.8%)	1.000
Cardiovascular disease	49 (28.5%)	22 (25.6%)	27 (31.4%)	0.398
Cerebrovascular disease	18 (10.5%)	8 (9.3%)	10 (11.6%)	0.618
Peripheral vascular disease	25 (14.5%)	11 (12.8%)	14 (16.3%)	0.516
ASA[c]				0.337
I	6 (3.7%)	4 (4.9%)	2 (2.5%)	
II	126 (77.3%)	66 (80.5%)	60 (74.1%)	
III	31 (19.0%)	12 (14.6%)	19 (23.5%)	
Preoperative red blood cell (10^{12}/L)	4.41 [4.05, 4.67]	4.41 [3.95, 4.66]	4.43 [4.11, 4.69]	0.273
Preoperative hemoglobin (g/L)	133 [121, 137]	134 [121, 136]	133 [122, 141]	0.615
FBG[c] (mmol/L)	5.19 [4.64, 5.68]	5.32 [4.72, 5.58]	5.08 [4.61, 5.70]	0.342
Tumor location				0.055
Tongue	71 (41.3%)	30 (34.9%)	41 (47.7%)	
Floor of mouth	23 (13.4%)	8 (9.3%)	15 (17.4%)	
Gingiva	18 (10.5%)	11 (12.8%)	7 (8.1%)	
Mandible	27 (15.7%)	20 (23.3%)	7 (8.1%)	
Buccal mucosa	13 (7.6%)	8 (9.3%)	5 (5.8%)	
Palatal mucosa	8 (4.7%)	3 (3.5%)	5 (5.8%)	
Oropharynx	6 (3.5%)	2 (2.3%)	4 (4.7%)	
Other parts	6 (3.5%)	4 (4.7%)	2 (2.3%)	

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; FBG, fasting blood glucose.
[a]Data are depicted as numbers (proportions) or median (interquartile range).

In this study, there were statistically significant differences between the two groups of patients in wound infection ($p < 0.001$), flap failure ($p = 0.047$), medical-related complications ($p < 0.001$), and flap-related complications ($p = 0.044$). We included postoperative complications into the regression equation. Multivariate analysis showed that PBT was not related to postoperative complications. Furthermore, after matching preoperative variables and comorbidities through PSM, it also showed that PBT would not lead to vascular pedicle thrombosis, hematoma, postoperative wound infection, postoperative lung infection, and other postoperative complications. It might be that we had formulated strict inclusion and exclusion criteria to exclude patients with severe liver and kidney dysfunction, hematological disorders, and coagulation disorders. PSM was used to match the preoperative red blood cells, Hgb, and comorbidities characteristics of the two groups of patients, which to some extent balanced the blood flow dynamics between the groups, made the blood viscosity consistent between the groups, and weakened the possibility of differences between the groups caused by changes in the fibrinolytic system.[22] Kim et al studied 674 patients that included head and neck and breast free flaps and believed that blood transfusion was not related to wound complications.[19] It was consistent with our research results is that PBT would not lead to postoperative wound infection ($p = 0.204$) and it was inconsistent with

Table 3 Comparison of patients' intraoperative characteristics and characteristics after propensity score matching

Characteristics[a]	All patients				Matched cohorts		
	Total	Transfusion	No transfusion	p[b]	Transfusion	No transfusion	p
	($n = 597$)	($n = 90$)	($n = 507$)		($n = 86$)	($n = 86$)	
Operation time (min)	465 [400, 533]	543 [469, 633]	450 [390, 505]	< **0.001**	560 [480, 640]	480 [414, 541]	< **0.001**
Jawbone resection	334 (55.9%)	62 (68.9%)	272 (53.6%)	**0.007**	58 (67.4%)	47 (54.7%)	0.085
Titanium plate and nail placement	185 (31.0%)	31 (34.4%)	154 (30.4%)	0.442	30 (34.9%)	31 (36.0%)	0.873
Neck dissection	530 (88.8%)	76 (84.4%)	454 (89.5%)	0.158	73 (84.9%)	77 (89.5%)	0.361
Flap types				< **0.001**			< **0.001**
ATFF	271 (45.4%)	34 (37.8%)	237 (46.7%)		33 (38.4%)	47 (54.7%)	
RFFF	209 (35.0%)	20 (22.2%)	189 (37.3%)		19 (22.1%)	30 (34.9%)	
FFF	84 (14.1%)	15 (16.7%)	69 (13.6%)		13 (15.1%)	4 (4.7%)	
Others	33 (5.5%)	21 (23.3%)	12 (2.4%)		21 (24.4%)	5 (5.8%)	
Osseous free flap[c]	94 (15.7%)	18 (20.0%)	76 (15.0%)	0.229	16 (18.6%)	6 (7.0%)	**0.022**
Flap-related complications	113 (18.9%)	24 (26.7%)	89 (17.6%)	**0.042**	22 (25.6%)	18 (20.9%)	0.470
VPT	36 (6.0%)	6 (6.7%)	30 (5.9%)	0.783	5 (5.8%)	4 (4.7%)	1.000
Flap failure				**0.047**			0.398
Total	43 (7.2%)	12 (13.3%)	31 (6.1%)		10 (11.6%)	5 (5.8%)	
Partial	43 (7.2%)	7 (7.8%)	36 (7.1%)		7 (8.1%)	7 (8.1%)	
No	511 (85.6%)	71 (78.9%)	440 (86.8%)		69 (80.2%)	74 (86.0%)	
Hematoma	28 (4.7%)	6 (6.7%)	22 (4.3%)	0.489	6 (7.0%)	6 (7.0%)	1.000
Medical-related complications	233 (39.0%)	51 (56.7%)	182 (35.9%)	< **0.001**	49 (57.0%)	49 (57.0%)	1.000
Wound infection	147 (24.6%)	37 (41.1%)	110 (21.7%)	< **0.001**	35 (40.7%)	27 (31.4%)	0.204
Pulmonary infection	92 (15.4%)	18 (20.0%)	74 (14.6%)	0.191	18 (20.9%)	23 (20.7%)	0.371
Deep vein thrombosis	53 (8.9%)	12 (13.3%)	41 (8.1%)	0.107	11 (12.8%)	12 (14.0%)	0.823

Abbreviations: ATFF, anterolateral thigh free flap; RFFF, radial forearm free flap; FFF, fibular free flap; VPT, vascular pedicle thrombosis.
[a]Data are depicted as numbers (proportions) or median (interquartile range).
[b]Variables $p < 0.05$ are in bold.
[c]Osseous free flap, include fibular free flap and Iliac muscle flap in this study.

our study is that it only focuses on patients with head and neck cancer.

During the reconstruction of oral free flap, due to the longer operative times and higher intraoperative blood loss, PBT is often unavoidable. With continuous development, PBT has experienced changes from free blood transfusion strategy (Hgb < 9–10 g/dL, hematocrit [Hct] < 26–30%) to restricted blood transfusion strategy (Hgb < 7–8 g/dL, Hct < 21–25%).[23,24] Studies have confirmed that the restrictive blood transfusion strategy will not increase the risk of flap failure and complications.[13] Our study supports the results of this study. Our blood transfusion rate was 15.08%, which is lower than the 18.07 to 58% reported in previous studies.[12,13,25] The two centers from which we collected data (the Affiliated Hospital of Southwest Medical University and Dental Hospital Affiliated to Zunyi Medical University) adopted a restrictive blood transfusion strategy. Doctors carefully considered blood transfusion according to the actual situation of patients and hemoglobin (Hgb < 7.0 g/dL). Our research results show that it may be slightly lower than the restrictive blood transfusion strategy and will not affect the survival of oral free flaps, increasing the risk of medical complications. This not only supports previous studies on carefully discussing blood transfusion strategies, but also provides new thinking for clinical blood transfusion strategies.

The study concluded that tumor location-mandible (OR = 19.923, $p = 0.036$) and operation time (OR = 1.011, $p < 0.001$) were identified as independent risk factors for PBT. This indicates that mandibular tumor may have a higher risk of PBT. Of course, other tumors that invade the mandible cannot be excluded. After jawbone resection, osseous free flaps need to be prepared; the operative time and blood loss

Table 4 Multivariate regression analysis of postoperative complications

Complications	Univariate analysis	p^a	Multivariate analysis	p
	OR (95% CI)		OR (95% CI)	
VPT	0.881 (0.356, 2.180)	0.783	0.587 (0.194, 1.779)	0.346
Hematoma	0.635 (0.250, 1.613)	0.340	1.234 (0.277, 5.505)	0.783
Flap failure		0.054		
Total	2.399 (1.177, 4.889)	**0.016**	1.908 (0.452, 8.049)	0.379
Partial	1.205 (0.516, 2.812)	0.666	0.971 (0.216, 4.361)	0.969
No	Ref		Ref	
Flap-related complications	0.586 (0.348, 0.985)	**0.044**	1.252 (0.290, 5.406)	0.764
Wound infection	2.520 (1.575, 4.031)	< **0.001**	2.072 (0.934, 4.599)	0.073
Pulmonary infection	0.684 (0.386, 1.212)	0.193	1.239 (0.579, 2.652)	0.581
Deep vein thrombosis	1.749 (0.880, 3.474)	0.111	1.374 (0.613, 3.081)	0.440
Medical-related complications	0.428 (0.272, 0.675)	< **0.001**	1.207 (0.492, 2.957)	0.681

Abbreviations: CI, confidence interval; OR, odds ratio; VPT, vascular pedicle thrombosis.
[a]Variables $p < 0.05$ are in bold.

Table 5 Multivariate logistic regression analysis of intraoperative risk factors of perioperative blood transfusion

Factors	(Nonadjusted model)[b]	p^a	Model-I	p	Model-II	p
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
Jawbone resection	1.913 (1.185, 3.089)	**0.008**	1.544 (0.732, 3.258)	0.254	NA	
Tumor location		0.166				0.185
Tongue	0.529 (0.160, 1.751)	0.297	6.264 (0.937, 41.875)	0.058	6.575 (0.787, 54.947)	0.082
Floor of mouth	0.343 (0.089, 1.319)	0.119	1.873 (0.261, 13.460)	0.533	2.280 (0.241, 21.541)	0.472
Gingiva	0.786 (0.212, 2.918)	0.719	5.982 (0.821, 43.561)	0.077	6.923 (0.729, 65.766)	0.092
Mandible	0.835 (0.245, 2.848)	0.774	19.959 (1.646, 242.042)	**0.019**	19.923 (1.213, 327.302)	**0.036**
Buccal mucosa	0.323 (0.087, 1.191)	0.09	4.163 (0.570, 30.419)	0.160	4.374 (0.459, 41.639)	0.199
Palatal mucosa	0.50 (0.095, 2.645)	0.415	4.715 (0.381, 58.366)	0.227	5.901 (0.390, 89.313)	0.200
Oropharynx	0.261 (0.042, 1.635)	0.151	Ref		Ref	
Other parts	Ref		NA		NA	
Flap types		< **0.001**		< **0.001**		0.994
ATFF	0.082 (0.037, 0.182)	< **0.001**	0.042 (0.012, 0.145)	< **0.001**	Ref	
RFFF	0.06 (0.026, 0.141)	< **0.001**	0.046 (0.013, 0.162)	< **0.001**	1.038 (0.518, 2.080)	0.916
FFF	0.124 (0.05, 0.306)	< **0.001**	0.256 (0.050, 1.325)	0.104	NA	1.000
Other	Ref		Ref		NA	
Osseous free flap	1.418 (0.801, 2.510)	**0.231**	0.033 (0.003, 0.385)	0.007	0.000	1.000
Operation time	1.009 (1.007, 1.012)	< **0.001**	1.011 (1.007, 1.014)	< **0.001**	1.011 (1.008, 1.014)	< **0.001**

Abbreviations: ATFF, anterolateral thigh free flap; CI, confidence interval; FFF, fibular free flap; OR, odd ratio; NA, not applicable; RFFF, radial forearm free flap.
[a]Variables $p < 0.05$ are in bold.
[b]NA: not involved, Ref: reference variable of classification covariate, No-adjusted model: single factor regression model without adjustment. Model I: adjust for jaw resection, tumor location, flap types, osseous free flap, and operation time. Model II: The adjustment variables were flap types, tumor location, and operation time.

increase during the operation, which increases the possibility of blood transfusion. There is no consensus on the type of flap related to PBT. Nguyen et al believed that the type of flap was not related to PBT,[12] and Zhao et al believed that osseous free flap (OR = 1.434, $p = 0.01$) was an independent risk factor for PBT.[26] In our study, we did not find a significant correlation between flap type, osseous free flap, and jawbone resection with PBT. It is possible that these variables are only

intermediate factors within the surgical process of jawbone tumor treatment, which indirectly affect the occurrence of PBT. Of course, when considering risk factors, the impact of preoperative related risk factors and the depth of tumor invasion on PBT cannot be ignored. This study has some limitations: first, this is a retrospective study with some data are missing, and there may be information bias. Second, fistula formation and flap infection were recorded as wound infection, which prevents separate analysis of these complications. Third, a dichotomy of some variables, such as smoking, drinking, and comorbidities, into "yes" or "no" without consideration of the time period and disease severity, which may also lead to bias. Furthermore, our data come from two different centers. Although both of them are top teaching hospitals in Southwest China, and the surgeons are the discipline leaders, both of them are equipped with the best nursing team, there are slight differences between the two centers in surgical techniques and perioperative program processing, which may cause bias.

Conclusion

Restrictive PBT strategy will not increase the occurrence of postoperative flaps and medical complications, and mandibular tumor may have a higher risk of PBT.

Authors' Contributions

Y.C. and M.T. contributed to the conception of the study. Y. C. and Y.L. contributed significantly to analysis and manuscript preparation. H.W. and X.P. performed the data analyses. D.G. and L.Z. helped perform the analyses with constructive discussions. All authors read and approved the final manuscript.

Availability of Data and Materials

The datasets generated and analyzed during the current study are not publicly available due to ownership of data but available from the corresponding author on a reasonable request.

Ethics Approval

This study is a retrospective study, without the informed consent of the patients but has passed the ethical permission of the Affiliated Hospital of Southwest Medical University and Zunyi Medical University. This research was conducted in accordance with international guidelines and the ethical standards outlined in the Declaration of Helsinki.

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Conflict of Interest

None declared.

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