Impact of preoperative Karnofsky Performance Scale (KPS) and American Society of Anesthesiologists (ASA) scores on perioperative complications in patients with recurrent glioma undergoing repeated operation

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complications; repeated craniotomy; glioma; Karnofsky Performance Scale (KPS) score; American Society of Anesthesiologists (ASA) score

ABSTRACT
Objective: The objective of this study was to document the impact of the preoperative Karnofsky Performance Scale (KPS) and American Society of Anesthesiologists (ASA) scores on perioperative complications in patients with recurrent glioma who underwent tumor resection via craniotomy.

Methods: A total of 96 patients were retrospectively reviewed. Based on KPS and ASA scores, patients were categorized into high KPS (> 70) or low KPS (≤ 70) and high ASA (3~4) or low ASA (1~2) groups. Differences in intraoperative risk factors and perioperative complications among the groups were analyzed. Multivariate analysis was performed to identify risk factors for perioperative complications.

Results: The most frequent perioperative complications were cerebrospinal fluid leakage (31.8%) and intracranial infection (27.0%); 30-day mortality was 5.2%. The incidence rates of severe complications, central nervous system complications, and total complications were comparable in the low and high KPS groups and in the low and high ASA groups (all p > 0.05). Multivariate analysis showed that low KPS and high ASA scores were not the independent risk factors for perioperative complications.

Conclusion: Low KPS and high ASA scores are not associated with increased postoperative complications in patients with recurrent glioma who undergo tumor resection via craniotomy.

1 Introduction
Glioma is the most common primary malignant brain tumor, accounting for 24% of brain tumors in adults [1]. The standard clinical treatment for glioma includes maximal safe resection, radiotherapy, and temozolomide chemotherapy. However, glioma recurrence is inevitable due to incomplete tumor resection and aggressive invasion. Repeated craniotomy is one of the common treatment strategies for patients with recurrent glioma and has been shown to prolong
postoperative survival, but it also increases the incidence rates of perioperative complications [2, 3]. Identifying preoperative risk factors could be critical for patients with recurrent glioma.

Patient age; Karnofsky Performance Scale (KPS); and tumor pathology, size, and location are among the risk factors for increased postoperative complications [4]. KPS is one of the widely studied risk factors for predicting mortality and morbidity in patients with glioma [4–8]. Increased postsurgical complications in patients with glioma with low KPS have been reported by several groups [4, 9–11]. In addition, the American Society of Anesthesiologists (ASA) score, which is a widely used clinical preoperative physical status classification, is a well-known risk factor for preoperative mortality and complications after craniotomy in patients with various brain tumors [12–18]. However, little is known about the impact of KPS and ASA scores in patients who undergo craniotomy for recurrent glioma.

In the present study, we aimed to evaluate the impact of KPS and ASA scores on perioperative complications in patients with recurrent glioma who undergo repeated craniotomy for glioma by comparing the incidence of perioperative complications in patients with high versus low KPS and with high versus low ASA scores.

2 Patients and methods

2.1 Patients

The medical records of patients who were pathologically diagnosed with recurrent glioma and underwent craniotomy at the First Affiliated Hospital of the Xi’an Jiaotong University between June 2008 and July 2014 were retrospectively retrieved and analyzed. The pathological diagnosis was determined by two senior neuropathologists according to the 2016 World Health Organization classification of central nervous system (CNS) tumors [19]. The study was approved by and conducted in accordance with the policies of the Scientific Ethics Committee of the Xi’an Jiaotong University.

Patients’ demographic characteristics, systemic diseases (hypertension, cardiovascular disease, lung disease, and diabetes mellitus), tumor characteristics (pathological diagnosis and tumor location and size), preoperative tumor-related stroke status (defined as hemorrhagic or ischemic stroke within the tumor area), pre- and postoperative laboratory blood test results (including routine blood test and blood coagulation and liver function tests), imaging (computed tomography or magnetic resonance imaging findings), neurosurgical intensive care unit (NICU) stay duration, KPS and perioperative complications were recorded. The operation-associated intraoperative risk factors (operation route, start and finish time, amount of intraoperative blood loss, and requirement of blood transfusion), extent of resection (gross total resection, TR, 95%–100% enhancement; subtotal resection, STR, 80%–95% enhancement; partial resection, PR, < 80% enhancement), and ASA score were extracted from operation and anesthesia records. The time of skin incision was defined as the start time of the procedure. All procedures were performed by senior neurosurgeons with >10 years of neurosurgical experience.

2.2 Study design

Patients were excluded from the study if they were <16 years old; if their medical records were incomplete; or if they presented with uncontrolled systemic disease, including abnormal blood pressure and blood glucose levels (even with medication), or with acute phase of cardiovascular or lung disease. Patients with a history of glioma who had undergone craniotomy before admission were included in the study. Data of 507 patients who had previously provided written consent for their medical records to be used in retrospective studies were retrieved, and 96 of these patients were included in the study.
The KPS was recorded on the day of admission, and the ASA scores was recorded on the day before operation. On the basis of KPS and ASA scores, patients were categorized into high KPS (> 70) or low KPS (≤ 70) and high ASA (3~4) or low ASA (1~2) groups.

Body mass index (BMI) was calculated using preoperative height and weight. Prognostic nutritional index (PNI) was calculated as follows: 

\[
PNI = 10 \times \text{serum albumin level (g/dL)} + 0.005 \times \text{peripheral blood lymphocyte count.}
\]

Intraoperative medical events (blood loss, blood transfusion, and operation duration) and postoperative complications were considered as perioperative complications. Postoperative complications were subdivided into severe complications, CNS complications, and systemic complications. Severe complications were defined as death within 30 days or unplanned reoperation within 7 days of the operation. CNS complications were defined as the occurrence of a seizure and presence of a neurological deficit, an intracranial infection, or cerebrospinal fluid (CSF) leakage. Systemic complications included deep venous thrombosis, electrolyte imbalance, systemic infections (pulmonary and urinary infections), and other medical conditions arising postoperatively. Neurological deficits that were newly diagnosed after the repeated operation and not present after the prior operation were considered as complications of the repeated operation.

2.3 Statistical analysis

Numerical data were expressed as mean ± standard deviation and compared between two groups using Student’s t-test. Categorical data were expressed as percentages and compared using chi-square test. Factors that were reported to be of significant prognostic value in the literature were included and analyzed in a multivariate Cox proportional hazards model. Statistical analyses were performed using SPSS 21.0 (Chicago, IL, USA). A p value < 0.05 was considered to be significant.

3 Results

A total of 550 craniotomies performed on 481 patients were retrospectively reviewed, and 96 patients were included in the present study. In this cohort of patients, CSF leakage (31.8%) and intracranial infection (27.0%) were the most frequent perioperative complications. The overall incidence of total complications was 60% (Table 1), which was higher than that after the first craniotomy (data not shown). Notably, the incidence of death within 30 days was 5.2% (Table 1), which was comparable to that reported in the literature [2, 3]. Baseline characteristics, stratified by KPS and ASA scores, are summarized in Tables 2 and 3, respectively.

### Table 1 Types of complications in 96 patients.

| Complications                  | Incidence, n (%) |
|-------------------------------|------------------|
| Extent of resection           |                  |
| GTR                           | 79 (82.3)        |
| STR                           | 14 (14.5)        |
| PR                            | 3 (3.1)          |
| Death within 30 days          | 5 (5.2)          |
| Re-operation                  | 1 (1.0)          |
| Hemorrhage                    | 4 (4.2)          |
| Severe edema                  | 3 (3.1)          |
| Hydrocephalus                 | 1 (1.0)          |
| Neurological deficit          | 19 (19.8)        |
| Intracranial infection        | 26 (27.0)        |
| Seizure                       | 13 (13.5)        |
| Systemic infection            | 10 (10.4)        |
| Pulmonary infection           | 9 (9.7)          |
| Urinary infection             | 1 (1.0)          |
| Venous thrombosis             | 0 (0)            |
| CSF leak                      | 21 (31.8)        |
| Porencephalia                 | 3 (3.1)          |
| Severe complication           | 7 (7.3)          |
| CNS complication              | 54 (56.3)        |
| Systemic complication         | 10 (10.4)        |
| Total complication            | 60 (62.5)        |
### Table 2  Clinical and pathological characteristics stratified by KPS in 96 patients received repeated surgery.

| Variable                      | KPS ≤ 70 | KPS > 70 | p value |
|-------------------------------|----------|----------|---------|
| Sex (male), n (%)             | 4 (36.4) | 49 (57.6)| 0.182   |
| Age (years)                   | 45 ± 15  | 45 ± 10  | 0.032   |
| Body mass index (kg/m²)       | 21.3 ± 2.7| 23.6 ± 3.1| 0.897  |
| Tumor stroke                  | < 0.001  |          |         |
| Hemorrhagic stroke, n (%)     | 6 (54.5) | 2 (2.4)  |         |
| Ischemic stroke, n (%)        | 0 (0)    | 4 (4.7)  |         |
| Hypertension, n (%)           | 2 (18.2) | 7 (8.2)  | 0.287   |
| Diabetes Mellitus, n (%)      | 0 (0)    | 2 (2.4)  | 0.607   |
| Cardiovascular Disease, n (%) | 0 (0)    | 2 (2.4)  | 0.607   |
| Chronic Lung Disease, n (%)   | 0 (0)    | 1 (1.2)  | 0.718   |
| Smoking, n (%)                | 1 (9.1)  | 12 (14.1)| 0.647   |
| Drinking, n (%)               | 2 (18.2) | 9 (10.6) | 0.457   |
| White blood cells (10⁹/L)     | 8.7 ± 4.1| 6.2 ± 2.9| 0.019   |
| Platelet count (10⁹/L)        | 162 ± 52 | 162 ± 45 | 0.570   |
| Hemoglobin (g/L)              | 13.0 ± 17.4 | 138.1 ± 17.7 | 0.695   |
| PT (s)                        | 12.7 ± 0.8| 12.5 ± 1.0| 0.516   |
| APTT (s)                      | 31.8 ± 5.5| 33.3 ± 4.8| 0.679   |
| Albumin (g/L)                 | 43.1 ± 5.9| 41.0 ± 3.3| 0.023   |
| PNI                           | 43.1 ± 5.9| 41.0 ± 3.3| 0.023   |
| Tumor Size (cm)               | 5.5 ± 0.9 | 4.9 ± 1.6 | 0.352   |
| Tumor Location, n (%)         |          |          | 0.686   |
| Frontal                       | 3 (27.3) | 35 (41.2)|         |
| Temporal                      | 3 (27.3) | 14 (16.5)|         |
| Parietal                      | 0 (0)    | 6 (7.1)  |         |
| Occipital                     | 0 (0)    | 2 (2.4)  |         |
| Thalamus                      | 5 (45.5) | 23 (27.1)|         |
| Multiple location             | 0 (0)    | 2 (2.4)  |         |
| Infratentorial                | 0 (0)    | 3 (3.5)  |         |
| Tumor Grade, n (%)            |          |          | 0.760   |
| WHO I                         | 0 (0)    | 5 (5.9)  |         |
| WHO II                        | 6 (54.5) | 35 (41.2)|         |
| WHO III                       | 4 (36.4) | 35 (41.2)|         |
| WHO IV                        | 1 (9.1)  | 10 (11.8)|         |

### Table 3  Clinical and pathological characteristics stratified by ASA score in 96 patients received repeated surgery.

| Variable                      | ASA = 1–2 | ASA = 3–4 | p value |
|-------------------------------|------------|------------|---------|
| Sex (male), n (%)             | 33 (63.5)  | 20 (45.5)  | 0.077   |
| Age (years)                   | 46 ± 8     | 44 ± 12    | 0.020   |
| Body mass index (kg/m²)       | 23.3 ± 2.9 | 23.3 ± 3.5 | 0.451   |
| Tumor stroke                  | < 0.001    |            |         |
| Hemorrhagic stroke, n (%)     | 1 (1.9)    | 7 (15.9)   |         |
| Ischemic stroke, n (%)        | 1 (1.9)    | 3 (6.8)    |         |
| Hypertension, n (%)           | 4 (7.7)    | 5 (11.4)   | 0.539   |
| Diabetes Mellitus, n (%)      | 1 (1.9)    | 1 (2.3)    | 0.905   |
| Cardiovascular Disease, n (%) | 1 (1.9)    | 1 (2.3)    | 0.905   |
| Chronic Lung Disease, n (%)   | 0 (0)      | 1 (2.3)    | 0.274   |
| Smoking, n (%)                | 6 (11.5)   | 7 (15.9)   | 0.533   |
| Drinking, n (%)               | 3 (5.8)    | 8 (18.2)   | 0.057   |
| White blood cells (10⁹/L)     | 5.8 ± 1.9  | 7.3 ± 4.0  | 0.002   |
| Platelet count (10⁹/L)        | 157 ± 44   | 170 ± 48   | 0.798   |
| Hemoglobin (g/L)              | 138 ± 15   | 138 ± 21   | 0.106   |
| PT (s)                        | 12.6 ± 1.0 | 12.4 ± 0.9 | 0.906   |
| APTT (s)                      | 32.1 ± 3.7 | 34.4 ± 5.7 | 0.027   |
| Albumin (g/L)                 | 40.4 ± 3.1 | 42.3 ± 4.1 | 0.280   |
| PNI                           | 40.4 ± 3.1 | 42.3 ± 4.1 | 0.281   |
| Tumor Size (cm)               | 5.0 ± 1.5  | 5.0 ± 1.5  | 0.735   |
| Tumor Location, n (%)         |            |            | 0.935   |
| Frontal                       | 22 (42.3)  | 16 (36.4)  |         |
| Temporal                      | 8 (15.4)   | 9 (20.5)   |         |
| Parietal                      | 4 (7.7)    | 2 (4.5)    |         |
| Occipital                     | 1 (1.9)    | 1 (2.3)    |         |
| Thalamus                      | 15 (28.8)  | 13 (29.5)  |         |
| Multiple location             | 1 (1.9)    | 1 (2.3)    |         |
| Infratentorial                | 1 (1.9)    | 2 (4.5)    |         |
| Tumor Grade, n (%)            |            |            | 0.422   |
| WHO I                         | 4 (7.7)    | 1 (2.3)    |         |
| WHO II                        | 23 (44.2)  | 18 (40.9)  |         |
| WHO III                       | 18 (34.6)  | 21 (47.7)  |         |
| WHO IV                        | 7 (13.5)   | 4 (9.1)    |         |
Eleven patients exhibited low KPS scores; six of these patients were admitted with tumor-related hemorrhagic stroke (Table 2). The incidence of tumor-related stroke was higher in these patients than in those with high KPS scores ($p < 0.001$). Despite some differences in albumin levels and PNI, patients in the low and high KPS groups had comparable BMI, systemic disease incidence, and tumor characteristics (tumor location and grade). Four patients underwent emergency tumor resection because of tumor-related hemorrhagic grade). Four patients underwent emergency tumor resection classified by KPS.

Table 4 Comparison of complications in patients received repeated surgery classified by KPS.

| Complications       | KPS ≤ 70 (n = 11) | KPS > 70 (n = 85) | $p$ value |
|---------------------|-------------------|-------------------|-----------|
| Emergency surgery   | 4 (36.4)          | 4 (47.7)          | $< 0.001$ |
| Operation Duration (h) | 3.6 ± 1.0          | 4.6 ± 1.9         | 0.143     |
| Blood-loss (mL)     | 639 ± 326         | 567 ± 448         | 0.590     |
| Extent of resection, n (%) | 0.779             |                   |           |
| GTR                 | 9 (81.8)          | 70 (82.4)         |           |
| STR                 | 2 (18.2)          | 12 (14.1)         |           |
| PR                  | 0 (0)             | 3 (3.5)           |           |
| NICU duration(days) | 2 ± 1             | 4 ± 7             | 0.313     |
| Death within 30 days | 0 (0)             | 5 (5.9)           | 0.409     |
| Re-operation, n (%) | 0 (0)             | 1 (1.2)           | 0.718     |
| Hemorrhage, n (%)   | 0 (0)             | 4 (4.7)           | 0.462     |
| Severe edema, n (%) | 0 (0)             | 3 (3.5)           | 0.527     |
| Hydrocephalus, n (%)| 0 (0)             | 1 (1.2)           | 0.718     |
| Neurological deficit, n (%) | 3 (27.3)      | 16 (18.8)         | 0.508     |
| Intracranial infection, n (%) | 4 (36.4)       | 22 (25.9)         | 0.462     |
| Seizure, n (%)      | 2 (18.2)          | 11 (12.9)         | 0.633     |
| Systemic infection, n (%) | 0.936            |                   |           |
| Pulmonary infection, n (%) | 1 (9.1)          | 8 (9.4)           |           |
| Urinary infection, n (%) | 0 (0)           | 1 (1.2)           |           |

(Continued)

| Complications       | KPS ≤ 70 (n = 11) | KPS > 70 (n = 85) | $p$ value |
|---------------------|-------------------|-------------------|-----------|
| Venous thrombosis, n (%) | 0 (0)             | 0 (0)             | 0.001     |
| CSF leak, n (%)     | 1(9.1)            | 20 (23.5)         | 0.276     |
| Porencephalia, n (%)| 0 (0)             | 3 (3.1)           | 0.527     |
| Severe complication, n (%) | 0 (0)            | 7 (8.2)           | 0.323     |
| CNS complication, n (%) | 5 (45.5)         | 49 (57.6)         | 0.443     |
| Systemic complication, n (%) | 1 (9.1)          | 9 (10.6)          | 0.878     |
| Total complication, n (%) | 5 (45.5)         | 55 (64.7)         | 0.215     |

Table 5 Comparison of complications between ASA score 1~2 and 3~4.

| Complications       | ASA = 1~2 (n = 52) | ASA = 3~4 (n = 44) | $p$ value |
|---------------------|-------------------|-------------------|-----------|
| Emergency surgery   | 1 (1.9)           | 7 (15.9)          | 0.013     |
| Operation Duration (h) | 4.7 ± 1.8         | 4.4 ± 2           | 0.824     |
| Blood-loss (mL)     | 545 ± 458         | 611 ± 409         | 0.990     |
| Extent of resection, n (%) | 0.041             |                   |           |
| GTR                 | 47 (90.4)         | 32 (72.7)         |           |
| STR                 | 5 (9.6)           | 9 (20.5)          |           |
| PR                  | 0 (0)             | 3 (6.8)           |           |
| NICU duration(days) | 4 ± 8             | 4 ± 6             | 0.829     |
| Death within 30 days | 2 (3.8)           | 3 (6.8)           | 0.514     |
| Re-operation, n (%) | 0 (0)             | 1 (2.3)           | 0.274     |
| Hemorrhage, n (%)   | 1 (1.9)           | 3 (6.8)           | 0.232     |
| Severe edema, n (%) | 1 (1.9)           | 2 (4.5)           | 0.462     |
| Hydrocephalus, n (%)| 0 (0)             | 1 (2.3)           | 0.274     |
| Neurological deficit, n (%) | 9 (17.3)        | 10 (22.7)         | 0.507     |
| Intracranial infection, n (%) | 15 (28.8)      | 11 (25.0)         | 0.673     |
| Seizure, n (%)      | 6 (11.5)          | 7 (15.9)          | 0.533     |
| Systemic infection, n (%) | 0.445            |                   |           |
| Pulmonary infection, n (%) | 4 (7.7)          | 5 (11.4)          |           |
| Urinary infection, n (%) | 0 (0)            | 1 (2.3)           |           |
| Venous thrombosis, n (%) | 0 (0)            | 0 (0)             |           |
| CSF leak, n (%)     | 11 (21.2)         | 10 (22.7)         | 0.853     |
| Porencephalia, n (%)| 0 (0)             | 3 (6.8)           | 0.056     |
| Severe complication, n (%) | 2 (3.8)          | 5 (11.4)          | 0.158     |
| CNS complication, n (%) | 29 (55.8)        | 25 (56.8)         | 0.918     |
| Systemic complication, n (%) | 4 (7.7)          | 6 (13.6)          | 0.342     |
| Total complication, n (%) | 32 (61.5)        | 28 (63.6)         | 0.832     |
The rate of tumor-related stroke was significantly higher in patients with high ASA scores than in those with low ASA scores \((p = 0.019)\) (Table 3); thus, the former underwent emergency surgery and had a significantly lower extent of tumor resection than the latter \((p = 0.041)\) (Table 5). Despite these differences, the incidence of perioperative complications was still comparable between the two groups (Table 5).

Nonetheless, we found that low PNI was a risk factor for total complications, which has not been previously reported in patients undergoing craniotomy. On multivariate analysis, neither low KPS nor high ASA score was found to be independently associated with a high incidence of severe complications, CNS complications, or total complications. Unexpectedly and interestingly, the multivariate analysis in the present study showed that women had a higher hazard rate of CNS complications and total complications than men (Table 6).

### 4 Discussion

In the present study, we assessed the impact of preoperative KPS and ASA scores on perioperative complications in patients undergoing repeated glioma resection. In contrast with the results reported in the literature for patients with newly diagnosed glioma undergoing primary craniotomy [4, 9–11], we did not find any significant correlation between low KPS or high ASA score and perioperative complications, including severe complications (death within 30 days or unplanned reoperation within 7 days), CNS complications, and total complications.

Five patients (5.2%) died within 30 days of the repeated operation; this rate is comparable to that reported in previous studies (2.2%–16%) [2, 3]. The most frequent complications were CSF leakage and intracranial infection, and the incidence of these complications was similar to

| Variable                  | Severe complications | CNS complications | Total complications |
|---------------------------|----------------------|-------------------|---------------------|
|                           | Univariate analysis  |       | Univariate analysis  |       | Univariate analysis  |       |
|                           | HR (95% CI)          | \(p\) | HR (95% CI)          | \(p\) | HR (95% CI)          | \(p\) |
| Sex (Male)                | 0.482 (0.043–5.331)  | 0.551 | 2.630 (0.948–7.292)  | \textbf{0.063} | 2.540 (0.851–7.584)  | \textbf{0.095} |
| Age (≥ 65)                | 0.998                |       | 0.671 (0.041–10.852) | 0.778 | 0.790 (0.047–13.288) | 0.870 |
| KPS (< 70)                | 0.998                |       | 1.878 (0.353–10.006) | 0.460 | 1.112 (0.393–3.148)  | 0.842 |
| ASA score (ASA 3–4)       | 0.221 (0.023–2.137)  | 0.192 | 1.112 (0.416–2.972)  | 0.833 | 1.112 (0.393–3.148)  | 0.842 |
| BMI                       | 0.858 (0.576–1.279)  | 0.452 | 1.057 (0.891–1.255)  | 0.522 | 0.996 (0.836–1.186)  | 0.965 |
| PNI                       | 1.159 (0.853–1.575)  | 0.346 | 1.088 (0.957–1.238)  | 0.197 | 1.175 (1.021–1.353)  | \textbf{0.025} |
| Hypertension (Yes)        | 0.999                |       | 0.236 (0.029–1.899)  | 0.175 | 0.200 (0.022–1.854)  | 0.157 |
| Diabetes (Yes)            | 0.999                |       | 0.999                |       | 0.999                |       |
| Smoking (Yes)             | 0.541 (0.035–8.305)  | 0.660 | 1.686 (0.394–7.224)  | 0.481 | 1.540 (0.351–6.753)  | 0.567 |
| Tumor size (≥ 5cm)        | 0.153 (0.015–1.532)  | 0.110 | 0.484 (0.176–1.331)  | 0.160 | 0.453 (0.154–1.338)  | 0.152 |
| Location (Supratentorial) | 14.073 (0.650–332.616) | \textbf{0.091} | 1.525 (0.110–21.228) | 0.754 | 1.033 (0.053–20.033) | 0.983 |
| Tumor stroke (Yes)        | 0.998                |       | 3.020 (0.277–32.984) | 0.365 | 3.848 (0.313–47.242) | 0.292 |
| Emergency (Yes)           | 0.998                |       | 0.848 (0.051–14.099) | 0.909 | 1.033 (0.053–20.033) | 0.983 |
that reported in previous studies (2.1%~35%) [20, 21]. The surgical pathway for the repeated operation was usually primary skin and skull incisions and a similar or same pathway to decrease damage, which was one of the risk factors for wound-related complications, including CSF leakage and intracranial infections [2].

In the literature, low KPS is one of the established risk factors for perioperative complications in patients with glioma who undergo craniotomy [4, 9–11]. However, most of these studies focused on primary gliomas or gliomas without clarification of recurrence status. The present study did not find significant correlations between perioperative complications and KPS in this cohort of patients undergoing repeated operation. This result is surprising and suggests that repeated operation itself is an independent risk factor for perioperative complications [2].

Increased risk of perioperative complications has been reported in surgeries such as brain tumor craniotomy [12–17]. Reportedly, the length of hospital day after tumor resection is significantly longer in patients with high ASA scores than in those with low ASA scores [12]. Reponen et al. reported that high ASA scores are associated with increased systemic and infectious complications [17]. A more recent study has confirmed that high ASA scores are one of the independent risk factors for surgical site infection after craniotomy [18]. In the present study, the rate of systemic infections was higher in the high ASA than in the low ASA group, but the difference was not significant. These results imply that the impact of low KPS and high ASA scores on perioperative complications is weaker than the impact of repeated operation itself.

The present study is subject to several limitations. First, it is a retrospective study with its inherent limitations. As mentioned above, the small study sample obtained from a single center is another limitation, and it was difficult to include sufficient patients in the low KPS group. In addition, KPS and ASA scores were determined by multiple neurosurgeons and anesthesiologists; thus, there is a possibility of interobserver variability.

Notwithstanding these limitations, the present study did not find a significant impact of KPS and ASA scores on perioperative complications in patients undergoing repeated craniotomy for glioma. Further studies are needed to identify the risk factors associated with repeated glioma resection.

**Author contributions**

The authors ZD, CWD and MDW contributed for study concept and design. The authors ZD, HY, AW, and NW contributed for data collection. The authors ZD, JW, HY and TW contributed for data analysis. The authors ZD, TW and CWD drafted the manuscript. The authors JW, HY and MDW contributed for critical revision. The author MDW was the supervisor.

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**Conflict of interests**

The authors declare they have no conflict of interests.

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