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Factors Influencing Delayed Extubation Following Infratentorial Surgery for Tumor Resection: a 5-years Retrospective Study

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Abstract

Background: Infratentorial brain tumor resection presents specific challenges in airway management due to its proximity to vital neurological structures. Postoperative extubation must be carefully timed, as delayed extubation may reflect underlying risk and influence clinical outcomes. The primary aim of this study was to identify perioperative factors independently associated with delayed extubation after elective infratentorial tumor surgery. Secondary aims included determining the incidence of delayed extubation and comparing clinical outcomes between early and delayed extubation groups.

Methods: This retrospective cohort study was conducted in adult patients who underwent elective infratentorial tumor resection at a tertiary academic center between January 2018 and December 2022. Patients were categorized based on whether extubation was performed in the operating room (early) or after transfer to others unit (delayed). Demographic, anesthetic, surgical, and outcome data were collected. Multivariable logistic regression was used to identify independent predictors of delayed extubation.

Results: Of 210 eligible patients, 84 (40%) underwent delayed extubation. Factors independently associated with delayed extubation included preoperative hydrocephalus, high intraoperative opioid dose, opioid administration within one hour before surgery end, neuromonitoring without muscle relaxants, large-volume fluid resuscitation, and surgery completed after working hours. Patients with delayed extubation had longer ICU and hospital stays and higher rates of neurological complications.

Conclusion: Multiple modifiable perioperative factors were associated with delayed extubation following infratentorial tumor resection. Awareness of these factors may assist anesthesiologists and neurosurgeons in perioperative planning and optimizing postoperative outcomes.

Keywords: delayed extubation, infratentorial surgery, neurosurgical patients, tumor resection

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Introduction

Surgical resection of infratentorial brain tumors presents unique anesthetic and perioperative challenges due to the close proximity of vital structures such as the brainstem, cranial nerves, and cardiorespiratory centers. Even minimal postoperative edema or hemorrhage in this region can lead to life-threatening neurological compromise. As a result, perioperative airway management, particularly the timing of extubation, plays a crucial role in patient safety and outcome optimization. Early extubation following neurosurgical procedures allows for immediate neurological evaluation[1] and may reduce the risk of ventilator-associated pneumonia and airway trauma.[2-4] However, in infratentorial surgeries, concerns such as impaired consciousness, reduced protective airway reflexes, and intraoperative brainstem manipulation often necessitate delayed extubation.[5] Although delaying extubation is sometimes used as a precaution, it is also associated with worse functional outcomes, including prolonged ICU and hospital stays[6], increased sedation requirements, and higher rates of postoperative complications.[7]

A prior study conducted in 2010 identified several factors associated with delayed extubation after infratentorial tumor surgery, including lower cranial nerve dysfunction, hydrocephalus, surgery duration ≥ 6 h, brainstem tumor location, and blood loss ≥ 1,000 mL.[8] However, given the significant advancements in neurosurgical techniques, intraoperative neuromonitoring, and anesthetic practices over the past decade, the applicability of those findings to current practice may be limited. At our institution, intraoperative electromyography (EMG) monitoring has been routinely implemented since 2003, and surgical navigation systems have been increasingly utilized since 2006, particularly over the past five years. These technological advancements may have influenced anesthetic management strategies compared to earlier eras, particularly in minimizing the use of neuromuscular blocking agents and optimizing anesthetic depth to prevent intraoperative movement during neuromonitoring.[9,10] These developments have altered perioperative management and may influence extubation practices in contemporary neurosurgical care.

This retrospective cohort study was conducted to investigate perioperative factors associated with delayed extubation in patients who underwent elective infratentorial tumor surgery between 2018 and 2022.

The primary objective was to identify independent perioperative risk factors for delayed extubation.The secondary objectives were to determine the incidence of delayed extubation in this patient population and to compare postoperative outcomes including ICU stay, hospital stay, and complication rates between early and delayed extubation groups.

Methods

This retrospective cohort study was conducted at the Department of Anesthesiology, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand. After receiving approval from the institutional ethics

committee (COA.MURA2022/517), we reviewed medical records of adult patients (aged ≥ 18 years) who underwent intracranial surgery between January 1, 2018, and December 31, 2022. Patients were excluded if they underwent emergency surgery, had a pre-existing tracheostomy, or had incomplete documentation of perioperative variables relevant to this study. Only patients undergoing elective infratentorial tumor resection were included in the final analysis.

Patients were classified into two groups based on the timing and location of extubation. The early extubation group included patients who were extubated in the operating room immediately after surgery. The delayed extubation group included patients who remained intubated postoperatively and were extubated later in the ICU or other recovery units. The decision to delay extubation was based on clinical judgment by the attending anesthesiologist and neurosurgeon, taking into account factors such as depressed consciousness, inadequate respiratory effort, absent protective airway reflexes, or anticipated neurological complications.

Perioperative data were extracted from electronic medical records and anesthesia charts. Variables included in this study were selected based on prior literature reporting risk factors for delayed extubation after neurosurgical procedures, particularly infratentorial tumor resection, as well as clinical plausibility and availability in routine perioperative records.[6-8] Collected variables encompassed patient demographics, comorbidities, and American Society of Anesthesiologists (ASA) physical status classification. Preoperative assessments included the Glasgow Coma Scale (GCS) score and cranial nerve examination performed by the neurosurgical team. Dysfunction of at least one lower cranial nerve (cranial nerves IX, X, XI, or XII) was classified as lower cranial nerve dysfunction.

Tumor characteristics, including size and location, as well as the presence of hydrocephalus and cerebellar tonsillar herniation, were assessed using preoperative brain computed tomography or magnetic resonance imaging. The primary source of radiological information was the official report issued by the Department of Radiology. In cases where an official report was unavailable, findings documented in the neurosurgical assessment within the medical record were used. Tumor location was classified based on anatomical site as identified on preoperative neuroimaging. This classification was selected to reflect the surgical approach and proximity to brainstem and cranial nerves, which are clinically relevant to perioperative airway risk and extubation planning.[8]

Intraoperative variables included the presence of a neuroanesthesiologist, use of bispectral index (BIS) monitoring, intraoperative fentanyl dose, timing of the last opioid administration, total propofol dosage, and inhalational anesthetic type (none, desflurane, or sevoflurane). The last opioid dose was defined as the time interval (min) between the final dose and the end of surgery. The use of intraoperative neuromonitoring, particularly EMG, was recorded. Additional intraoperative factors included patient positioning, surgical end time (during or after

regular working hours), total operative time, anesthesia duration, estimated blood loss, vasopressor infusion, core temperature at the end of surgery, urine output, total intravenous fluid administration (including crystalloid, colloid), and intraoperative blood transfusion.

Postoperative outcomes assessed included ICU and hospital length of stay (LOS), Glasgow Outcome Scale (GOS) score, airway status at discharge, postoperative complications, and 30-day mortality. Complications were categorized as surgical (reoperation), reintubation within 48 h, pulmonary, or non-pulmonary in nature. Reintubation was analyzed as a postoperative complication and not as a delayed extubation event. Pulmonary complications included conditions such as hypoxemia, hypoventilation, and pneumonia, and were the leading causes of reintubation. Non-pulmonary complications referred to adverse events unrelated to surgical site or respiratory function, such as myocardial infarction, fever, or renal impairment. An unfavorable neurological outcome was defined as a GOS score of 1-3. Missing data were handled using complete-case analysis. Only patients with complete data for variables used in regression modeling were included in the final analysis. The proportion of missing data was less than 5% and was not expected to affect model performance.

Statistical analysis

The sample size for this study was estimated based on a previous investigation[8] that reported several significant predictors of delayed extubation after infratentorial surgery, including prolonged surgical duration ≥ 6 h (OR 3.518, 95% CI 2.466-5.019), tumor location at the brainstem (OR 40.029, 95% CI 16.138-99.288), and preoperative lower cranial nerve dysfunction (OR 2.925, 95% CI 1.868-4.581). The reported incidence of delayed extubation was 32.1%. Using logistic regression for a binary outcome, with $\alpha = 0.05$, $R^2 = 0.2$, and power of 80%, the minimum required sample size was calculated to be 209 patients. All data were analyzed using SPSS version 18.0 (SPSS Inc., PASW Statistics for Windows, Chicago, USA) and Stata V.17 (Stata Corp, College Station, Texas, USA). Continuous variables were tested for normality using the Kolmogorov-Smirnov test. Normally distributed variables were summarized as mean and standard deviation, while non-normally distributed variables were expressed as median with interquartile range. Categorical variables were presented as frequencies and percentages. For group comparisons, the Student's t-test was used for normally distributed continuous variables and the Mann-Whitney U test for non-normally distributed data. Pearson's chi-squared test or Fisher's exact test was applied for categorical data as appropriate.

Cut-off values for intraoperative variables were selected based on a combination of data distribution and clinical relevance. A fentanyl dose > 300 mcg was used to dichotomize intraoperative opioid exposure. This threshold was derived post hoc, corresponding to the median fentanyl dose in the delayed extubation group (IQR 225-410 mcg), and was considered clinically meaningful. It also approximated an average infusion rate of 50 mcg/h over 6 h, a value previously reported as relevant in neurosurgical populations.[11] Operation time

≥ 300 min and anesthetic time > 6 h were selected based on the 75th percentile values of the dataset, representing the upper range of prolonged procedures in our cohort. Operation time was defined as the interval from skin incision to wound closure, whereas anesthetic time encompassed the entire period from induction to tracheal extubation. The 300-min operation threshold was also supported by previous literature identified this cut-off as an independent predictor of delayed extubation in pediatric craniotomy patients.[12] The anesthetic time threshold reflected prolonged drug exposure, with a median of 480 min in the delayed group, and was consistent with durations reported in comparable neurosurgical studies.[11]

Univariate analysis was first conducted to identify candidate variables associated with delayed extubation; variables with a *P*-value less than 0.10 were then entered into a multivariable logistic regression model using a forward stepwise method to determine independent predictors of delayed extubation. Adjusted odds ratios (AORs) and 95% confidence intervals were reported. To assess potential linear relationships between predictor variables considered for the model, pairwise correlations were examined using a correlation matrix; high correlations (|r| ≥ 0.7) were investigated to mitigate potential multicollinearity issues. The predictive ability and calibration of the final binary regression model were evaluated using receiver operating characteristic (ROC) curve analysis and the Hosmer-Lemeshow goodness-of-fit test, respectively. The final model's discriminative ability was summarized using the area under the ROC curve (AUC). In addition, Kaplan-Meier survival analysis with log-rank testing was employed to compare ICU and hospital length of stay between early and delayed extubation groups, with censoring applied to patients who died or were discharged early. A two-tailed *P*-value of less than 0.05 was considered statistically significant for all tests.

Results

A total of 1,517 patients underwent craniotomy during the 5-year study period. Of these, 210 patients met the inclusion criteria for elective infratentorial tumor resection. Among them, 84 patients (40%) were extubated outside the operating room and classified into the delayed extubation group, while 126 patients (60%) were extubated in the operating room and classified into the early extubation group. The patient selection process is illustrated in Figure 1.

Baseline characteristics are shown in Table 1, they were generally similar between the two groups. However, patients in the delayed extubation group were more likely to have ASA physical status III-IV, preoperative hydrocephalus, and larger tumor size. Intraoperative variables are summarized in Table 2. Patients in the delayed extubation group received significantly higher doses of fentanyl compared to the early extubation group, with 48.8% receiving > 300 mcg. Opioid administration within the last 60 min before surgery end was also more frequent in the delayed group (P = 0.003). Total propofol dose was notably higher in the delayed group than in the early group (P < 0.001), and 73.8% of delayed patients

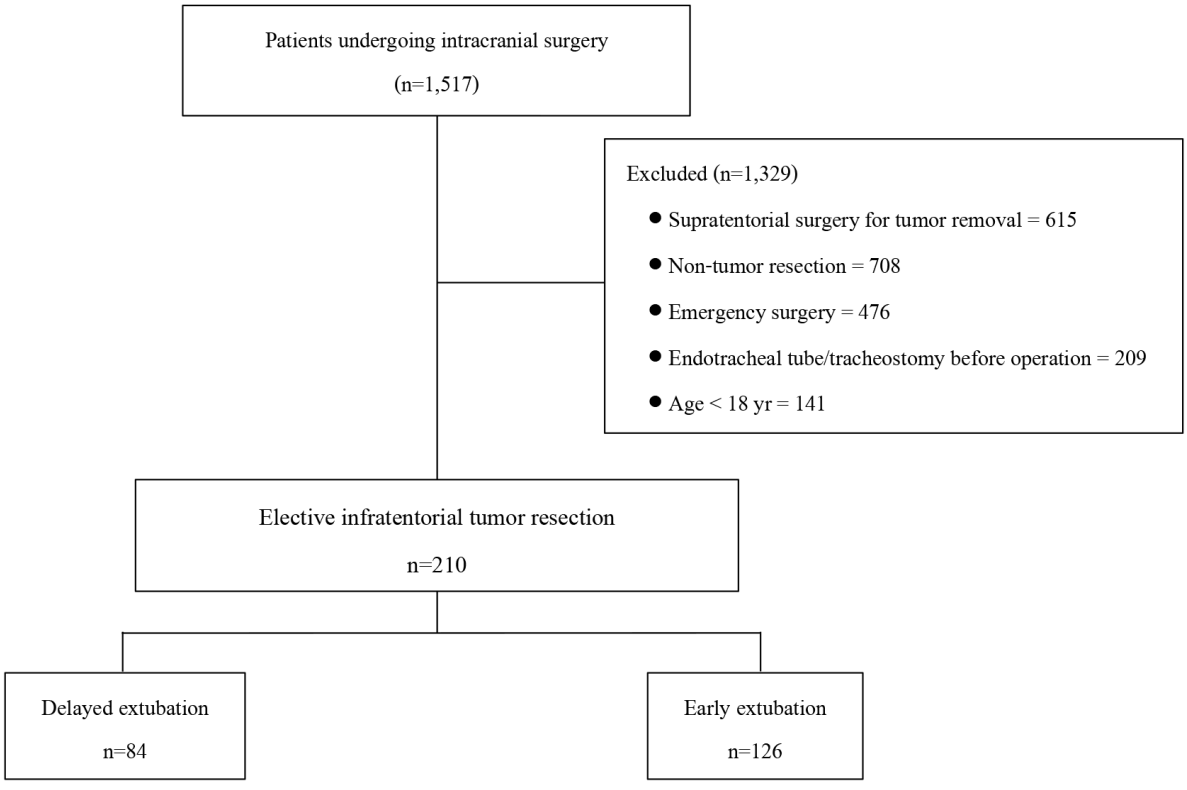


Figure 1 Flow diagram of patient selection

received more than 1,000 mg. EMG monitoring was more commonly used in the delayed group. Surgical end time after working hours was markedly associated with delayed extubation, as was longer anesthesia duration, operation time > 300 min, and blood loss > 1,000 mL. Crystalloid fluid administration was also significantly higher, with 77.4% of delayed patients receiving more than 3,000 mL. Blood transfusion was required in 50% of delayed patients compared to 15.9% in the early group ($P < 0.001$).

Multivariable logistic regression analysis identified seven independent predictors of delayed extubation, as shown in Table 3. Preoperative hydrocephalus was the strongest predictor. Other significant predictors included intraoperative fentanyl dose > 300 mcg, last opioid dose administered within 60 min before the end of surgery, use of intraoperative EMG monitoring, end of surgery after regular working hours, crystalloid infusion > 3,000 mL, and intraoperative blood transfusion. The final model demonstrated good discrimination, with an area under the ROC curve of 0.861 ($P < 0.001$), indicating strong predictive performance. Additionally, the Hosmer-Lemeshow goodness-of-fit test yielded a non-significant result, indicating that the model was well calibrated and adequately fit the observed data.

Postoperative outcomes are summarized in Table 4. The delayed extubation group had significantly worse functional recovery, with

Table 1 Baseline characteristics

	All (n=210)	Delayed extubation (n=84)	Early extubation (n=126)	*P*-value
Age (yr), median (IQR)	54.0 (42.0-64.0)	51.0 (40.5-62.0)	55.5 (45.0-65.0)	0.083
Sex, n (%)				
Male	66 (31.4)	33 (39.3)	33 (26.2)	0.045*
Female	144 (68.6)	51 (60.7)	93 (73.8)	
Body mass index (kg/m^2), median (IQR)	24.1 (21.8-26.8)	24.7 (22.1-27.2)	23.7 (21.8-26.2)	0.097
ASA physical status, n (%)				0.023*
I-II	77 (36.7)	23 (27.4)	54 (42.9)	
III-IV	133 (63.3)	61 (72.6)	72 (57.1)	
COPD/Asthma, n (%)	6 (2.9)	0	6 (4.8)	0.083
Obstructive sleep apnea, n (%)	5 (2.4)	4 (4.8)	1 (0.8)	0.084
Smoking, n (%)	6 (2.9)	3 (3.6)	3 (2.4)	0.685
Hypertension, n (%)	81 (38.6)	35 (41.7)	46 (36.5)	0.452
Coronary artery disease, n (%)	6 (2.9)	3 (3.6)	3 (2.4)	0.685
Arrhythmia/cardiac pacemaker, n (%)	10 (4.8)	6 (7.1)	4 (3.2)	0.203
Renal disease, n (%)	9 (4.3)	3 (3.6)	6 (4.8)	0.744
Preoperative GCS, n (%)				0.010*
15	205 (97.6)	79 (94.1)	126 (100.0)	-
≤ 14	5 (2.4)	5 (5.9)	0	
Range (min-max)	9-15	9-15	15	
Lower cranial nerve dysfunction (CN IX, X, XI, XII), n (%)	20 (9.5)	12 (14.3)	8 (6.4)	0.055
Cerebellar tonsillar herniation, n (%)	28 (13.3)	14 (16.7)	14 (11.1)	0.246
Hydrocephalus, n (%)	69 (32.9)	45 (53.6)	24 (19.1)	<0.001*
Tumor size, median (IQR)	3.5 (2.7-4.5)	4.15 (3.2-5.0)	3.1 (2.5-3.9)	<0.001*
≥ 4 cm, n (%)	75 (35.7)	47 (56.0)	28 (22.2)	<0.001*
Tumor location, n (%)	19 (9.1)	9 (10.7)	10 (7.9)	0.394
Tentorial or pineal region tumors	43 (20.5)	12 (14.3)	31 (24.6)	
Cerebellar tumors	3 (1.4)	1 (1.2)	2 (1.6)	
Intramedullary brainstem tumors	138 (65.7)	58 (69.1)	80 (63.5)	
Extramedullary brainstem tumors	7 (3.3)	4 (4.8)	3 (2.4)	
Upper cervical spinal tumors				

* Statistically significant

Table 1 Baseline characteristics *(cont.)*

	All (n=210)	Delayed extubation (n=84)	Early extubation (n=126)	*P*-value
BIS monitoring, n (%)	22 (10.5)	11 (13.1)	11 (8.7)	0.312
Fentanyl dosage (mcg), median (IQR)	250 (200-325)	300 (225-410)	225 (190-300)	<0.001*
> 300, n (%)	61 (29.1)	41 (48.8)	20 (15.9)	<0.001*
Last dose opioid (min), median (IQR)	100 (60-140)	90 (57.5-135)	102.5 (75-150)	0.099
≤ 60, n (%)	59 (28.1)	33 (39.3)	26 (20.6)	0.003*
Propofol dosage (mg), median (IQR)	1110 (580-1800)	1800 (990-2740)	935 (500-1300)	<0.001*
> 1,000, n (%)	119 (56.7)	62 (73.8)	57 (45.2)	<0.001*
Inhalation anesthetic use, n (%)				0.218
No	1 (0.5)	1 (1.2)	0	
Desflurane	54 (25.7)	18 (21.4)	36 (28.6)	
Sevoflurane	155 (73.8)	65 (77.4)	90 (71.4)	
Neuromonitoring, n (%)	140 (66.7)	62 (73.8)	78 (61.9)	0.073
EMG monitoring	137 (65.2)	62 (73.8)	75 (59.5)	0.033*
Positioning, n (%)				0.808
Prone	38 (18.1)	17 (20.2)	21 (16.7)	
Park bench	104 (49.5)	41 (48.8)	63 (50.0)	
3-quarter prone	13 (6.2)	6 (7.1)	7 (5.6)	
Lateral	29 (13.8)	9 (10.7)	20 (15.9)	
Supine	26 (12.4)	11 (13.1)	15 (11.9)	
End of operation, n (%)				<0.001*
During working hours	82 (39.1)	15 (17.9)	67 (53.2)	
After working hours	128 (60.9)	69 (82.1)	59 (46.8)	
Operative time (min), median (IQR)	265 (205-380)	380 (260-502)	232.5 (180-290)	<0.001*
> 300, n (%)	81 (38.6)	56 (66.7)	25 (19.8)	<0.001*
Anesthetic time (min), median (IQR)	345 (270-480)	480 (330-600)	315 (255-365)	<0.001*
> 6 h, n (%)	89 (42.4)	57 (67.9)	32 (25.4)	<0.001*
Crystalloid fluid administration, median (IQR)	3100 (2150-4360)	4400 (3125-6300)	2600 (2000-3450)	< 0.001*
Blood loss (ml), median (IQR)	300 (200-600)	575 (300-950)	200 (100-500)	<0.001*
> 1,000, n (%)	23 (11.0)	20 (23.8)	3 (2.4)	<0.001*
Vasopressor infusion, n (%)	18 (8.6)	10 (11.9)	8 (6.4)	0.159
Temperature at end of operation (°C), median (IQR)	36.4 (36.0-36.7)	36.6 (36.1-36.9)	36.3 (35.8-36.7)	<0.001*
< 36, n (%)	52 (24.8)	14 (16.7)	38 (30.2)	0.026*
Urine output (ml/kg/h), median (IQR)	2.8 (1.7-4.7)	2.8 (1.8-5.0)	2.8 (1.6-4.4)	0.431
< 0.5, n (%)	5 (2.4)	1 (1.2)	4 (3.2)	0.650

* Statistically significant

Table 2 Intraoperative management and events

	Delayed extubation (n=84)	Early extubation (n=126)	Unadjusted Odds ratio (95% CI)	*P*-value	Adjusted Odds ratio (95% CI)	*P*-value
Male, n (%)	33 (39.3)	33 (26.2)	1.82 (1.01-3.29)	0.046*	-	NS
ASA physical status III-IV, n (%)	61 (72.6)	72 (57.1)	1.99 (1.10-3.61)	0.024*	-	NS
Preoperative GCS ≤ 14, n (%)	5 (6.0)	0	-	NS	-	NS
Hydrocephalus, n (%)	45 (53.6)	24 (19.1)	4.90 (2.64-9.09)	<0.001*	6.12 (2.60-14.41)	<0.001*
Tumor size ≥ 4 cm, n (%)	47 (56.0)	28 (22.2)	4.45 (2.44-8.11)	<0.001*	-	NS
Fentanyl dosage > 300 mcg, n (%)	41 (48.8)	20 (15.9)	5.05 (2.66-9.60)	<0.001*	2.70 (1.19-6.12)	0.017*
Last Opioid ≤ 60 min, n (%)	33 (39.3)	26 (20.6)	2.49 (1.35-4.60)	0.004*	3.27 (1.36-7.89)	0.008*
Propofol dosage > 1,000 mg, n (%)	62 (73.8)	57 (45.2)	3.41 (1.87-6.21)	<0.001*	-	NS
EMG monitoring, n (%)	62 (73.8)	75 (59.5)	1.92 (1.05-3.50)	0.034*	3.43 (1.38-8.57)	0.008*
End of operation after 4 pm, n (%)	69 (82.1)	59 (46.8)	5.22 (2.70-10.10)	<0.001*	3.23 (1.43-7.31)	0.005*
Anesthetic time > 6 h, n (%)	57 (67.9)	32 (25.4)	6.20 (3.37-11.40)	<0.001*	-	NS
Blood loss > 1,000 ml, n (%)	20 (23.8)	3 (2.4)	12.81 (3.67-44.74)	<0.001*	-	NS
Temperature < 36°C, n (%)	14 (16.7)	38 (30.2)	0.46 (0.23-0.92)	0.028*	-	NS
Crystalloid fluid > 3,000 ml, n (%)	65 (77.4)	43 (34.1)	6.60 (3.52-12.40)	<0.001*	2.94 (1.34-6.46)	0.007*
Blood transfusion, n (%)	42 (50.0)	20 (15.9)	5.30 (2.79-10.06)	<0.001*	2.66 (1.15-6.13)	0.022*

lower median Glasgow Outcome Scale (GOS) scores and a higher rate of unfavorable neurological outcomes. Postoperative GCS was also significantly lower in the delayed group, with only 88.1% achieving GCS 15 compared to 98.4% in the early group. ICU length of stay (LOS) was significantly longer in the delayed extubation group, with a median of 40 h versus 20 h in the early group ($P < 0.001$). Prolonged ICU stay was more common in the delayed group, both for durations over 24 and 48 h. Similarly, total hospital LOS was significantly longer in the delayed group. Overall postoperative complications tended to be more frequent in the delayed group, although the difference was not statistically significant. The incidence of reintubation within 48 h, reoperation, and pulmonary complications did not differ significantly. However, non-pulmonary complications, such as myocardial infarction, fever, or renal impairment, were significantly more common in the delayed group.

Table 4 Clinical outcome compared between early and delayed extubation

	All (n=210)	Delayed extubation (n=84)	Early extubation (n=126)	*P*-value
GOS, median (IQR)	5 (4-5)	4 (4-5)	5 (4-5)	<0.001*
Unfavorable neurological outcome (GOS 1-3), n (%)	16 (7.6)	13 (15.5)	3 (2.4)	<0.001*
Postoperative GCS, n (%)				0.004*
15	98 (94.3)	74 (88.1)	124 (98.4)	
≤ 14	12 (5.7)	10 (11.9)	2 (1.6)	
Range of GCS, min-max	3-15	3-15	10-15	
ICU LOS (h), median (IQR)	24 (17-46)	40 (27.5-83.5)	20 (15-39)	<0.001*
> 24, n (%)	102 (48.6)	64 (76.2)	38 (30.2)	<0.001*
> 48, n (%)	48 (22.9)	31 (36.9)	17 (13.5)	<0.001*
LOS (h), median (IQR)	164 (122-259)	201.5 (144.5-332.5)	144 (119-193)	<0.001*
Postoperative complications, n (%)	40 (19.1)	21 (25.0)	19 (15.1)	0.073
Re-operation	15 (7.1)	7 (8.3)	8 (6.4)	0.584
Reintubation within 48 h	7 (3.3)	4 (4.8)	3 (2.4)	0.441
Pulmonary complications	5 (2.4)	4 (4.8)	1 (0.8)	0.084
Non-pulmonary complications	26 (12.4)	15 (17.9)	11 (8.7)	0.049*

* Statistically significant

The final model demonstrated good discrimination, with an area under the receiver operating characteristic (ROC) curve of 0.861 ($P < 0.001$), indicating strong predictive performance. Additionally, the Hosmer-Lemeshow goodness-of-fit test yielded a non-significant result, indicating that the model was well calibrated and adequately fit the observed data.

As shown in Figure 2, Kaplan-Meier survival analyses were conducted to compare time to

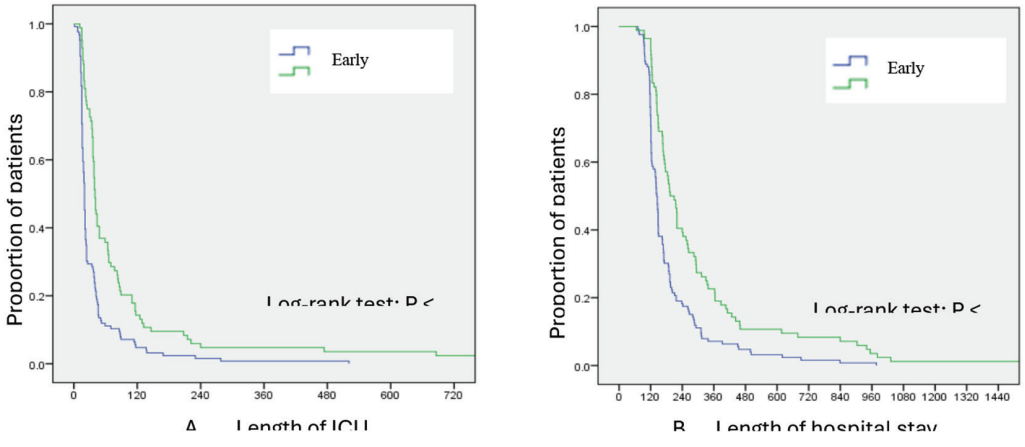


Figure 2 Kaplan-Meier curve shows A: Length of ICU stays, B: Length of hospital stays

ICU discharge and hospital discharge between the early and delayed extubation groups. The survival curves demonstrated significantly longer ICU and hospital stays in the delayed extubation group, with both comparisons yielding log-rank $P < 0.001$. The median ICU length of stay was 40 h in the delayed group and 20 h in the early group. At 24 h-post-operatively, the probability of remaining in the ICU was 83% for the delayed group and 39% for the early group. In both analyses, the survival curves for delayed extubation were clearly shifted to the right, indicating a lower probability of discharge at any given time point. These time-to-event findings support the association between delayed extubation and prolonged postoperative recovery following infratentorial tumor surgery.

Discussion

Carefully planned anesthetic management that facilitates smooth emergence and early neurological assessment is essential after brain surgery. When patients regain consciousness promptly and can follow commands, neuro-surgeons are better able to detect early post-operative complications, which may contribute to reduced morbidity and mortality. However, infratentorial surgery is inherently high-risk, and the decision to extubate early must be made with caution. Inappropriate early extubation may lead to failed extubation, reintubation, or worse functional outcomes.[13] As a result, attending anesthesiologists often rely on multiple perioperative parameters to guide extubation decisions and sometimes choose to maintain intubation when uncertainty exists. Nonetheless, prolonged intubation also carries well-recognized risks, including pneumonia, tracheostomy, increased morbidity and mortality, extended ICU stays, and higher healthcare costs.[1-4] Thus, finding the optimal timing for extubation remains a delicate balance between minimizing airway-related complications and avoiding the consequences of unnecessary mechanical ventilation.

This study aimed to identify factors associated with delayed extubation in patients undergoing elective infratentorial tumor surgery. We found that delayed extubation occurred in 40% of cases, which falls within the range reported in previous studies (10.0-49.8%).[8,14,15] Delayed extubation was significantly associated with multiple perioperative factors, including preoperative hydrocephalus, high-dose intra-operative opioid use, opioid administration close to the end of surgery, use of intraoperative electromyography (EMG) monitoring, surgery ending after working hours, large-volume crystalloid infusion, and intraoperative blood transfusion. Patients in the delayed extubation group experienced longer ICU and hospital stays and had higher rates of neurological complica-tions and unfavorable outcomes.

Preoperative hydrocephalus was the most significant predictor of delayed extubation in our model, with more than sixfold increased odds. Hydrocephalus may elevate intracranial pressure and distort brainstem anatomy, leading to impaired consciousness and suppression of protective airway reflexes.[5] These physiological changes increase the risk of poor neurological recovery and compromised respiratory function,

prompting clinicians to adopt a more cautious postoperative strategy, including prolonged mechanical ventilation and delayed extubation to ensure patient safety.

High intraoperative fentanyl doses (> 300 mcg) and administration of opioids within 60 min before the end of surgery were both independently associated with delayed extubation. These findings are consistent with the sedative and respiratory depressant effects of opioids, particularly when administered in high cumulative doses or close to the end of surgery. Without the use of ultra-short-acting agents like remifentanil, fentanyl may lead to residual sedation, reduced respiratory drive, or impaired airway reflexes[16,17], making early extubation less safe and increasing the likelihood of prolonged postoperative ventilation and ICU monitoring. In our study, the 300 mcg cut-off used for analysis was based on the median total fentanyl dose observed in the delayed extubation group, representing a relatively high dose in this population. Conceptually, this aligns with previously cited rates, such as 50 mcg/h over 6 h.[11] These findings suggest that limiting total fentanyl dose and avoiding opioid administration near the end of surgery especially in long-duration cases may help reduce the risk of delayed extubation.

Infratentorial tumor surgery poses a high risk of cranial nerve injury due to the close proximity of multiple nerves (CN V-XII) within the posterior fossa. Among these, CN IX, X, and XII are particularly critical for airway protection and swallowing. Intraoperative EMG monitoring is often employed to preserve nerve function, but it typically necessitates avoiding neuromuscular blockade, which may require deeper anesthesia and, in some cases, higher opioid doses. This, in turn, may delay emergence from anesthesia.[18,19] More importantly, injury to CN IX, X, or XII during surgery may not be clinically apparent until extubation is attempted, at which point impaired airway reflexes or swallowing dysfunction could result in aspiration, hypoventilation, or the need for urgent reintubation.[20] In such situations, when the extent of nerve involvement or brainstem edema remains uncertain, it is common practice to defer extubation postoperatively to allow for more thorough neurological assessment. In our study, the use of intraoperative EMG monitoring was independently associated with delayed extubation. This likely reflects both the anesthetic implications such as the occasional need for increased anesthetic or opioid administration due to the avoidance of neuromuscular blockade and the intrinsic surgical complexity of procedures where EMG is indicated, particularly those involving critical cranial nerve pathways.

Surgeries that concluded after 4:00 PM were also significantly associated with delayed extubation. In our cohort, 82.1% of patients in the delayed extubation group had surgery ending after this time, compared to 46.8% in the early extubation group. While this may partly reflect logistical considerations such as reduced ICU staffing or limited senior coverage during off-hours, it is also likely that procedures extending beyond regular hours were more complex and prolonged in nature. These features are common in infratentorial tumor cases that involve meticulous cranial nerve

dissection and require EMG monitoring. In such high-risk scenarios, particularly late in the day when immediate postoperative evaluation may be limited, clinicians may prefer to maintain airway protection and delay extubation until a more controlled reassessment is feasible.

In a previous study, preoperative lower cranial nerve dysfunction, hydrocephalus, duration of surgery ≥ 6 h, and estimated blood loss ≥ 1000 mL were identified as independent factors associated with delayed extubation.[8] In our study, anesthetic time > 6 h and blood loss > 1000 mL were also significantly associated with delayed extubation in the univariate analysis. However, these factors did not remain statistically significant in the multivariable model. Instead, we found that crystalloid fluid administration > 3000 mL and intraoperative blood transfusion were more robust independent predictors. These variables likely reflect the combined effects of hemodynamic instability, surgical complexity, and fluid-shift dynamics. Excessive crystalloid infusion may contribute not only to airway edema or pulmonary congestion[21] but also to cerebral edema, particularly in neurosurgical patients with disrupted blood-brain barrier integrity.[22] Similarly, transfusion may indicate significant blood loss and physiological stress, both of which can delay recovery and readiness for extubation. Such intraoperative findings may also influence the clinical judgment of anesthesiologists when deciding whether to proceed with extubation.

Although delayed extubation was associated with worse clinical outcomes in this study, it is important to recognize that it may not be the direct cause of those outcomes. Rather, delayed extubation may serve as a clinical indicator of underlying severity. In most cases, extubation is postponed because patients are judged to be neurologically unstable, have inadequate respiratory effort, or are at high risk for complications. Therefore, the relationship between delayed extubation and poor outcomes likely reflects shared underlying conditions rather than a direct causal effect. In some situations, extubation may be postponed by on-call staff who are less familiar with neuroanesthesia or by providers making pragmatic decisions to facilitate overnight case management, particularly during off-hours when experienced personnel and resources may be limited. These non-clinical considerations may partly explain why surgeries finishing after regular working hours were more frequently associated with delayed extubation in our study population.

Conversely, early extubation carries its own risks. If the patient's neurological status is overestimated or deteriorates unexpectedly, reintubation may become necessary. This can be technically challenging, especially in the presence of airway edema or limited access, and is associated with increased risks of aspiration, airway trauma, and further neurological injury. In this study, the reintubation rate within 48 h after early extubation in the operating room was 2.4%, compared to 4.8% in the delayed extubation group. Although this difference was not statistically significant, it underscores the need for careful patient selection and monitoring in both groups.

Patients in the delayed extubation group

had significantly worse clinical outcomes compared to those who were extubated early. Postoperative GCS scores were lower in the delayed group. Similarly, unfavorable neurological outcomes, defined as GOS scores of 1-3, were more frequent in the delayed extubation group. These findings highlight the association between delayed extubation and poor neurological recovery. In terms of postoperative care utilization, delayed extubation was associated with significantly longer ICU and hospital stays. The median ICU-LOS was 40 h in the delayed group compared to 20 h in the early group ($P < 0.001$), with over 75% of delayed extubation patients requiring ICU care beyond 24 h. Likewise, the total hospital LOS was significantly longer.

These findings were further supported by Kaplan–Meier survival analysis, which demonstrated clear separation of discharge curves between groups. These results are consistent with previous studies reporting that delayed extubation is associated with prolonged hospital utilization and adverse postoperative outcomes.[8,23] While causality cannot be determined from this observational study, delayed extubation may serve as both a consequence and a marker of greater illness severity. Although the overall rate of post-operative complications was not statistically different between the groups, non-pulmonary complications occurred more frequently in the delayed group. These included issues such as postoperative delirium, renal impairment, and other systemic complications. Pulmonary complications and reintubation rates were numerically higher in the delayed group but did not reach statistical significance. Notably, airway status at discharge was similar between groups, with nearly all patients ultimately extubated and discharged without tracheostomy.

The relationship between delayed extubation and postoperative neurological complications warrants careful consideration. In our study, non-pulmonary complications occurred more frequently in the delayed group, and delirium was one of the most common events observed. According to a systematic review by Kappen and colleagues, the incidence of postoperative delirium after intracranial surgery is approximately 19%, with reported rates ranging from 12% to 26% depending on surgical type and patient characteristics.[24] Furthermore, evidence from Moran and coworkers suggests that the risk of postoperative delirium increases with longer durations of mechanical ventilation.[25] Postoperative delirium has also been identified as an independent risk factor for prolonged ICU and hospital stays, greater dependency in personal activities of daily living, reduced quality of life, and increased mortality.[23,26] Taken together, these findings raise concern that delayed extubation, if not clinically justified, may inadvertently contribute to poorer cognitive outcomes. Therefore, when no clear indication exists, unnecessary prolongation of intubation should be avoided to reduce the risk of delirium and promote earlier neurological recovery.

Several limitations should be acknowledged. As a retrospective, single-center study, the findings may not be generalizable to other

institutions. The absence of a standardized protocol for extubation may have introduced variability in clinical decision-making. In addition, certain relevant variables such as depth of anesthesia, detailed neuromonitoring data, and brainstem imaging were not consistently recorded and thus excluded from analysis. Although missing data were minimal and managed using complete-case analysis, this approach may have introduced selection bias. Lastly, due to the observational nature of the study, causal relationships cannot be established.

Conclusion

In this retrospective cohort study of patients undergoing elective infratentorial tumor surgery, delayed extubation occurred in 40% of cases and was significantly associated with both patient-related and intraoperative factors, including preoperative hydrocephalus, high-dose opioid use, intraoperative neuromonitoring, large fluid or blood volume administration, and procedures ending after working hours. Although delayed extubation was associated with prolonged ICU and hospital stays, it may reflect the severity of underlying conditions rather than serve as a direct cause of poor outcomes. Awareness of these risk factors can support anesthesiologists and neurosurgeons in identifying high-risk patients, guiding extubation decisions, and optimizing postoperative care pathways to improve recovery and resource utilization.

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Ethics approval

This study was approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University. The reference number was COA. MURA2022/517, and the date of approval was September 15, 2022

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รายงานผู้ป่วย • Case Report

Catastrophic Internal Carotid Artery Injury in Endoscopic Transsphenoidal Surgery: a Case Report

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Abstract

Internal carotid artery (ICA) injury during endoscopic transsphenoidal surgery (ETSS) is a rare but critical complication. A 69-year-old man underwent ETSS for a nonfunctioning pituitary macroadenoma. He had intraoperatively severe bleeding that occurred from a suspected rupture of the right paraclinoid ICA, resulting in 3500 ml of blood loss and hypotension. After controlled bleeding, he was transferred to the angiographic suite, where cerebral angiography confirmed the injury. Definitive management involved ICA balloon sacrifice to stop the bleeding. Postoperatively, the patient was sedated in the intensive care unit for three days to ensure vascular stability. Sedation was managed with propofol. The patient was extubated on the third day with no significant neurological deficits except for right visual field loss. This case shows the critical role of a coordinated multidisciplinary approach in managing ICA injury during ETSS, demonstrating how prompt action can minimize complications.

Keywords: anesthetic management, endoscopic transsphenoidal surgery, internal carotid artery injury

Introduction

Endoscopic transsphenoidal surgery (ETSS) is commonly used to treat pituitary tumors and other skull base conditions.[1] ICA injury during ETSS, though rare, is a catastrophic event that can occur unpredictably. The incidence of ICA injury during TSS ranged from 0.34-2.6%.[2] It can cause significant problems, such as stroke or death, with a reported mortality rate of around 10%.[3]

A 69-year-old Thai man with an incidental nonfunctioning pituitary macroadenoma underwent elective ETSS. He has the underlying disease of hypertension and a history of amaurosis fugax. This patient was under general anesthesia with standard monitoring, including an arterial line for real-time blood pressure and blood sampling. We had a large bore intravenous line in place and had booked the ICU postop with one unit of group match blood component as usual.

During the removal of the sphenoid septum, brisk arterial bleeding occurred, leading to a sudden blood loss of 3500 milliliters

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and episodes of hypotension. The bleeding was suspected to result from a rupture of the right paraclinoid ICA. Hemorrhage control was achieved using crushed muscle from the right upper thigh. When the unexpected occurred, we had to request more blood due to arterial bleeding and establish additional intravenous lines. Blood components and fluids were rapidly administered. Initially, one unit of packed red blood cells (PRC) was ordered preoperatively. Following massive intraoperative blood loss, an emergency request was made for four additional units of PRC and four units of fresh frozen plasma (FFP). Upon arrival, four units of PRC were rapidly warmed and transfused. Concurrently, the patient received 2,800 mL of crystalloid and 1,500 mL of colloid fluids. Five PRC and four FFP units were administered, with the remaining FFP transfused in the interventional radiology unit. Throughout the intraoperative period, the patient's systolic and diastolic blood pressures remained within the range of 100-110 mmHg and 50-60 mmHg, respectively, with a mean arterial pressure (MAP) of approximately 70-80 mmHg. Heart rate was stable at 70-75 beats/min, and other vital signs remained within normal limits. Ephedrine (total 9 mg IV) was intermittently administered to maintain MAP above 65 mmHg.

The interventionist was alerted, and meanwhile, the anesthesiology team prepared for patient transfer. Once stabilized, the patient was moved to the angiographic suite. A cerebral angiogram was performed under general anesthesia, with blood pressure controlled to ensure adequate cerebral perfusion pressure. After a discussion between the interventionist and neurosurgeon, ICA balloon sacrifice was deemed necessary to secure the bleeding at the right proximal ICA. Complete occlusion of the proximal right ICA and the meningo-ophthalmic anastomosis was achieved.

The patient remained intubated and sedated in the intensive care unit (ICU) as planned, with immobilization maintained for three days to protect the repaired ICA. Sedation was stopped, and the patient was successfully extubated on postoperative day three, as originally planned. Neurological assessments were limited to minimizing movement, with pupil reactions being the only available evaluation method. Propofol infusion and bispectral index (BIS) monitoring were chosen for sedation management.

On the first night, more than 100 mcg/kg/min of propofol was administered, keeping the BIS between 30-50. On post-operative day (POD) 1, the propofol requirement was reduced to approximately 80 mcg/kg/min. The pupils, measuring 2 mm, showed slight reactions to light in both eyes. Vital signs and laboratory results were within normal ranges. On POD 2, sedation with propofol was continued, and the patient's vital signs remained stable. Tracheal extubation was performed on POD 3, and the patient exhibited no other neurological deficits except for a loss of vision in the right visual field, which was the new deficit.

Discussion

ICA injury during ESS, though rare, is a catastrophic event that can occur unpredictably. The incidence of ICA injury during TSS ranged

from 0.34-2.6%.[2] The arterial bleeding was massive, and the operation field was minimal, making it extremely difficult to identify the bleeding lesion. There is still no consensus on the best management for ICA injuries.[4] Upon the occurrence of the arterial bleeding, the surgeon decided to control the bleeding lesion by crushing muscle from the right upper thigh. This decision effectively controlled the bleeding. Our multidisciplinary team's experience and our instruments' readiness were crucial in this situation.

During the event, the blood pressure quickly fell due to the unidentified arterial bleeding. With the patient in a state of massive hypovolemic shock, our primary goal was to maintain stable hemodynamics to ensure adequate organ perfusion, including cerebral perfusion pressure. Once the bleeding was secured, we were able to maintain normal blood pressure to ensure adequate CPP throughout the intraoperative and interventional neuroradiology period.[4-6]

At ICU, the patient was planned to lay still on the bed to prevent rebleeding for three days. The only way to check a neurological exam is by checking pupil reactivity. So, an anesthesiologist was consulted for sedation and paralysis if we needed to. On the first night, the propofol requirement is significant. We discussed the risk of propofol infusion syndrome with the surgeon due to the potential for over-infusion, and muscle relaxants were considered only, if necessary, since neuromuscular blocking drugs do not impact the pupillary light reflex. For the rest of the recovery period, he proceeded as planned.

ICA injury during transsphenoidal surgery can have serious consequences. Managing ICA injuries during surgery is very difficult due to the small surgical area and the arterial bleeding require quick decisions and multidisciplinary with interventional radiology and intensive care. Some patients may suffer fatal brainstem failure and multiple cerebral infarcts despite active postoperative management, while others may experience only transient or no neurological deficits.[2] These variations show the unpredictable and potentially severe nature of ICA injuries, emphasizing the importance of rapid intervention and a multidisciplinary approach to optimize patient outcomes.

Conclusion

During this critical event, the prompt actions of an experienced team were crucial in reducing morbidity and mortality, leading to a successful outcome.

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