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Early institutional experiences of awake craniotomy with tumor removal at Chulabhorn Hospital, Thailand

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Abstract

Background & Objective: Brain tumors in eloquent regions pose major surgical challenges due to the high risk of neurological deficits with conventional resection. Awake craniotomy mitigates these risks through intraoperative neurophysiological monitoring that helps preserve eloquent function. Yet its adoption and documentation in Thailand, and Southeast Asia more broadly, remain limited. This study aims to address this gap and support regional advancement and benchmarking of the technique. *Methods*: We implemented a structured awake craniotomy program at Chulabhorn Hospital using a standardized asleep–awake–asleep (AAA) protocol with rigid skull fixation, informed in part by training from The Royal Melbourne Hospital. *Results:* Eight patients with intracranial tumors in eloquent cortical areas underwent surgery under this protocol. One intraoperative and one postoperative seizure occurred. Motor function was preserved or improved in nearly all cases, with only a single instance of postoperative weakness. Language outcomes were stable in five patients and improved in three. Gross total resection was achieved in five procedures, while three achieved subtotal resections. There was no perioperative mortality, surgical site infection, or need for reoperation.
Conclusions: These findings on one of the few documented series of awake craniotomy in Thailand demonstrate that this technique can be safely introduced and effectively performed within emerging neurosurgical centers in Southeast Asia. Our experience shows that a standardized AAA protocol is both safe and feasible for tumor resection in eloquent brain regions and provides an important foundational step toward expanding the technique and strengthening regional neurosurgical capacity.

Keywords: Craniotomy, conscious sedation, treatment outcome, brain neoplasm, intraoperative neurophysiological monitoring, Thailand

INTRODUCTION

Brain tumors situated in eloquent regions, such as motor and language cortices, often carry a poorer prognosis because of their proximity to critical neurological structures responsible for essential language and motor functions.[1] Given the vital importance of sparing all healthy tissue within these critical regions, it is extremely challenging to resect such tumors using conventional techniques, and there is a high risk of negative neurological outcomes and an increased mortality rate.[2]

Current evidence suggests that optimizing the extent of tumor resection while preserving critical brain functions is often associated with lower relapse rates, longer progression-free survival, and improved overall survival and neurological outcomes.[3-6] Thus, for tumors in eloquent regions, awake craniotomy is favored over conventional techniques, as it enables precise lesion resection with simultaneous intraoperative neurological

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monitoring through real-time patient feedback.[7] This enables the surgeon to precisely identify and preserve key brain areas involved in essential functions, particularly when a tumor is located nearby, through direct cortical stimulation.[8] Maximal tumor removal can then be achieved while minimizing postoperative neurological deficits, which enhances surgical outcomes, quality of life, and survival rates.[9]

Multiple institutions worldwide have developed standardized protocols for performing awake craniotomies, which are generally categorized into the asleep–awake–asleep (AAA) and awake–awake–awake techniques.[10-12] However, the procedure remains underutilized in Thailand and is performed at only a limited number of tertiary care centers. Notably, the first reported awake craniotomy in Southern Thailand occurred as recently as 2019.[13] This has resulted in limited data on the protocols used and the associated outcomes.[13,14] In support of this, a study from a major teaching hospital in Bangkok reported only 66 awake craniotomy cases collected over a 10-year period between 2006 and 2016.[15] Similarly, a study from a major center in Singapore reported 55 cases collected over a 5-year period between 2017 and 2022.[16] This scarcity of information might be due to the procedure being performed too infrequently to generate robust data, which may in turn be attributable to resource limitations that constrain the availability of the equipment and highly trained personnel needed to conduct this complex procedure.

Given this substantial gap in regional evidence, further studies are essential to clarify which awake craniotomy approaches provide the best outcomes for different tumor types within the Thai and Southeast Asian context. To contribute to this need, we evaluated the awake craniotomy protocol implemented at Chulabhorn Hospital, an emerging center with developing expertise in this field, with a focus on neurological outcomes and the feasibility of integrating a standardized AAA workflow into a growing neurosurgical program.

METHODS

Participant selection

All patients who underwent an awake craniotomy with tumor removal at Chulabhorn Hospital between 2021 and 2025 were screened for eligibility. At Chulabhorn Hospital, awake craniotomy is routinely considered for patients with intracranial tumors located in or adjacent to eloquent regions of the dominant hemisphere, where surgical intervention carries a high risk of postoperative speech or motor deficits.[1] Patients were selected for surgery provided there were no contraindications, including inability to cooperate or follow commands, severe cognitive impairment or dementia, severe aphasia, or a high risk of aspiration. Patients with relative contraindications, such as language or communication barriers, significant anxiety, or patient preference, were also excluded at the discretion of the multidisciplinary team. A total of eight patients met the inclusion criteria and were therefore included in this study. All underwent awake craniotomy for tumor resection involving an eloquent brain region.

Inclusion and exclusion criteria

Patients were eligible for inclusion if they met the following criteria: (1) underwent awake craniotomy with tumor resection at Chulabhorn Hospital between 2021 and 2025; (2) were aged ≥18 years; (3) had complete documentation of the surgical procedure; (4) provided written informed consent; and (5) had complete medical records available for review.

Patients were excluded if they were initially planned for awake craniotomy but subsequently underwent non-awake surgery, including those diagnosed with psychiatric or neurological disorders that could interfere with intraoperative cooperation or outcome assessment; those who declined or withdrew from awake surgery; those with incomplete medical records; or those who withdrew consent to participate in the study.

Data collection

Patient data were collected from electronic health records and by taking a medical history at Chulabhorn Hospital. Data were collected on the following characteristics: sex, age, underlying diseases (e.g., hypertension, diabetes, and dyslipidemia), lifestyle factors (e.g., smoking and alcohol consumption), weight, height, and body mass index. Information on each patient's presenting symptoms was also collected, such as the Glasgow Coma Scale (GCS) score, motor weakness or sensory losses in the upper and lower extremities, facial palsy, dysarthria, diplopia, and other noteworthy symptoms.

Surgical information was documented, including the procedure, surgery date, duration, estimated blood loss, and nerve stimulation or neurological monitoring techniques used. Additionally, the anesthesia method, patient's position during surgery, final diagnosis, brain lesion location, and pathological findings were recorded. Postoperative complications were assessed during follow-up visits and documented according to the time at which they were observed: immediately after surgery, at 90 days, and at 180 days postoperatively. These included neurological issues (e.g., early, transient, or permanent seizures, bleeding, or infection), while indicators of local neurological capacity were also monitored (e.g., GCS score, motor power, sensory perception, and presence of aphasia). Clinical data were collected at the following time points: pre-surgery, post-surgery, and 90 and 180 days post-surgery.

Radiological images, including computed tomography scans (with and without contrast) and magnetic resonance imaging scans (with and without gadolinium), were generated and reviewed pre- and post-surgery. All medications used, including antiplatelet agents, anticoagulants, and antihypertensive drugs, were also recorded. Additionally, photos taken and video recorded during the surgery were obtained to illustrate the utilized protocol, with the patient's consent.

Patient positioning

Each patient was positioned according to the specific surgical approach to be applied. Specifically, for patients with a temporal mass, the lateral decubitus position was used. The patients with a frontotemporal mass were positioned supine with their head tilted laterally on a soft, elastic, donut-shaped pillow. Patients with a parietal mass were placed in a park-bench position. Three-point rigid skull fixation was employed for some cases to avoid any movement during the surgery. In these cases, local anesthesia with 2% xylocaine containing adrenaline was administered to minimize intraoperative and postoperative pain and bleeding. A single large drape was used to maintain the sterile field, while an opening between the anesthesiologist and the patient was preserved to allow continuous communication throughout the procedure (Figure 1).

Intraoperative procedures

The AAA technique was used. The patients were deeply sedated during the initial phase, awakened for the cortical mapping, and then re-sedated after the mapping. A standardized low-frequency bipolar direct cortical stimulation protocol was used in all cases.

Anesthesia

All patients were evaluated preoperatively by a neuroanesthesiologist. To reduce the risk of postoperative nausea, 8 mg of ondansetron was administered preoperatively. When the patient

Figure 1. An example of the intraoperative set-up showing the patient positioning during awake craniotomy. A large sterile drape is used to separate the surgical field from the anesthesiology team. Visual and verbal access to the patient is maintained for continuous neurological monitoring and cortical mapping.

arrived at the operating room, conscious sedation to deep sedation was initiated, including sedation with propofol using a target-controlled infusion and infusion of fentanyl at approximately 0.5 µg/kg/h. The propofol concentration was adjusted in increments of 0.5 µg/mL and kept within the range of 2 to 5 µg/mL throughout the procedure. A radial artery catheter was inserted for continuous arterial pressure monitoring. The scalp block was performed by injecting 20 mL of 0.5% bupivacaine with 1:200,000 epinephrine using the landmark technique. A weight-based maximum local anesthetic dose was calculated and communicated to the surgical team. Standard American Society of Anesthesiologists monitoring was used, which included monitoring end-tidal carbon dioxide ($EtCO_2$) via a nasal cannula. The concentration of propofol was adjusted to maintain anesthetic depth, with the aim of achieving a bispectral index of 40–60 and mean arterial pressure within ±20% of the preoperative value. A multimodal pain relief regimen was started intraoperatively. The patient received 1 g of intravenous acetaminophen at the start of the operation, followed by doses every 6 hours, not exceeding a total of 4 g per day. The propofol and fentanyl infusions were discontinued for about 15 min before the brain mapping and resumed at the beginning of the dura closure, continuing until the completion of the operation.

Cortical mapping

Once the cranium was removed and the surgical area was identified, the patient was awakened and cortical mapping was performed. The electrical stimulator was calibrated prior to mapping. Bipolar direct cortical stimulation with a frequency of 50 Hz was applied, initially at 2.0 mA, after which the current was incrementally increased by 1.0 mA until a positive response was observed. The maximum stimulation threshold was 15.0 mA. Motor and language baselines were established prior to tumor resection. The motor power of the proximal and distal upper and lower extremities was assessed when applicable. Language baselines were obtained by instructing the patient to complete a series of tasks, which included word repetition, comprehension, and recall tasks. Areas associated with motor or language functions, as identified by cortical stimulation, were meticulously noted and avoided during resection. Intraoperative navigation was also performed to aid in the identification of eloquent regions (Figure 2).

RESULTS

Characteristics of patients undergoing awake craniotomy with tumor removal

Eight patients were included in this study: five males and three females. They were between 34

Figure 2. A representative intraoperative view of the surgical team utilizing intraoperative navigation during cortical mapping. Real-time images are displayed on the monitor to support precise anatomical localization and safe tumor resection while preserving the eloquent cortex.

and 70 years of age (mean: 50.6 years). Most (n = 6) tumors were located in the left hemisphere, particularly in the precentral frontal/parietal and insular regions, while two were located in the right hemisphere. The final histopathological diagnoses were as follows: four cases of brain metastases (all from primary lung cancer), two cases of WHO Grade II isocitrate dehydrogenase-mutant astrocytoma, one case of low-grade (WHO Grade II) insular glioma, and one case of high-grade (WHO Grade IV) glioma (Table 1).

Operative characteristics

The operative time ranged from 90 to 420 min, with a mean of 211 min. The longest surgery involved the removal of a large insular glioma (Case 4), while the shortest involved reoperation for recurrent glioma (Case 7). The estimated blood loss ranged from 100 (Case 8) to 500 mL (Case 4) (mean: 231 mL) (Table 1). All procedures were completed using the AAA protocol. There was no need for intraoperative conversion to general anesthesia, intubation, or termination of the AAA protocol. Intraoperative motor and language mapping was performed in all cases.

Neurological outcomes following awake craniotomy

Four patients had a history of seizures prior to surgery. Specifically, two had experienced generalized tonic–clonic seizures (Cases 3 and 5) and two had experienced focal motor seizures (Cases 6 and 7). Among these four patients, Case 3 developed a seizure intraoperatively, and Case 7 experienced a recurrent focal seizure postoperatively (Table 2). However, none experienced seizures by the 90- or 180-day follow-up.

The patients' GCS scores were maintained at Eye 4, Verbal 5, and Motor 6 (E4V5M6) throughout the perioperative and follow-up periods in all cases (Table 2). There were no instances of altered consciousness or delayed awakening. Sensory function, assessed via pinprick and temperature discrimination, remained symmetrical and intact in all patients across all time points (Table 2).

Motor function was maintained or improved in six patients (Cases 1–5 and 8) throughout the follow-up period. One patient (Case 7) showed partial improvement in preoperative right-sided weakness (Grade II to III) by 180 days postoperatively but continued to have right upper motor neuron facial palsy. Another patient (Case 6) experienced mild left facial weakness and left upper motor weakness preoperatively, and his symptoms worsened postoperatively (Grade IV to III) (Table 2).

Language function was preserved or improved in all cases. Two patients had preoperative motor aphasia (Cases 4 and 7), and one had preoperative mixed aphasia (Case 1). The aphasia observed in

Table 1: Characteristics of patients undergoing awake craniotomy with tumor removal and operative characteristics

Case	Pathology	Lateralization	Operation time (min)	EBL (mL)	Intraoperative complications
1	BMLC	Lt.	120	150	None
2	BMLC	Lt.	180	400	None
3	Astrocytoma Grade II	Lt.	300	200	GTC seizure
4	LGG	Lt.	420	500	None
5	Astrocytoma Grade II	Rt.	180	200	None
6	BMLC	Rt.	120	100	Venous drainage compromised
7	HGG Grade IV	Lt.	90	200	None
8	BMLC	Lt.	180	100	None

Abbreviations: BMLC, brain metastasis from lung cancer; LGG, low-grade glioma; HGG, high-grade glioma; Lt., left; Rt., right; EBL, estimated blood loss; GTC, generalized tonic–clonic

Note: Operation time, recorded in minutes, indicates the duration from incision to closure; intraoperative complications include any adverse events noted during or immediately after the time of surgery.

Table 2: Neurological and radiological outcomes following awake craniotomy

Case	Seizure	GCS	Sensory	Motor Power	Aphasia	EOR
1	None	Intact	Intact	Intact	Improved mixed	GTR
2	None	Intact	Intact	Intact	Intact	NTR
3	GTC improved	Intact	Intact	III Rt. LE improved	Intact	GTR
4	None	Intact	Intact	Intact	Improved motor	NTR
5	GTC improved	Intact	Intact	Intact	Intact	GTR
6	FTC at left face improved	Intact	Intact	IV Lt. UE to III Lt. UE	Intact	GTR
7	FTC at right hand improved	Intact	Intact	II Rt. UE, III Rt. LE, and Rt. UMN facial palsy remained	Improved motor	NTR
8	None	Intact	Intact	Intact	Intact	GTR

Abbreviations: GTC, generalized tonic–clonic; FTC, focal tonic–clonic; GCS, Glasgow Coma Scale; Rt., right; Lt., left; LE, lower extremities; UE, upper extremities; UMN, upper motor neuron; EOR, extent of resection; GTR, gross total resection; NTR, near-total resection

Note: Phrases such as "improved" and "to" denote changes between preoperative and postoperative evaluations. "Intact" denotes a GCS score of 15 (normal consciousness), no sensory or motor neurological deficits, or no aphasia. Roman numerals I–V represent motor power grading (I–V). "Mixed" indicates mixed aphasia, and "motor" indicates motor aphasia.

Cases 1 and 4 was fully resolved by day 90 of follow-up. Case 7's motor aphasia had improved by day 180; however, full resolution was not achieved (Table 2).

Radiological outcomes following awake craniotomy

The postoperative radiological findings confirmed that gross total resection was achieved in five patients (Cases 1, 3, 5, 6, and 8). In the remaining three patients, subtotal resection was performed due to the tumors extending into eloquent areas or indistinct margins. Expected postoperative findings were evident in radiological images, including the presence of residual perilesional vasogenic edema and small areas of enhancement compatible with surgical cavities. In most cases (Cases 1–3 and 5–8), the preoperative mass effect and midline shift were improved. Case 4 had significant postoperative findings, including cytotoxic edema, a midline shift, and uncal herniation. These findings were consistent with this patient undergoing a subtotal resection of a complex tumor and the relatively long operative time (420 min) (Table 2). No major surgical complications, such as intracranial hemorrhage, infection, or cerebrospinal fluid leak, were observed.

Overall, the awake craniotomy procedure was well tolerated and resulted in good seizure control, preserved neurological function, and favorable oncological outcomes in this early case series.

DISCUSSION

This case series details the early institutional experience of performing awake craniotomies at Chulabhorn Hospital, Bangkok, Thailand. The results show that it is safe and feasible to perform this procedure in patients with intracranial tumors located in eloquent brain areas and that good neurological and oncological outcomes can be achieved at this institution.

Standardized protocol at Chulabhorn Hospital

In this case series, motor and language mapping was successfully performed in all cases. In addition, our AAA protocol was well tolerated by all patients. These findings demonstrate that it is feasible to effectively resect intracranial lesions using simultaneous neurological monitoring via this protocol in newly established awake craniotomy programs.

Our protocol was developed in part by neurosurgeons trained at The Royal Melbourne Hospital. As previously described, it employs the AAA technique with rigid skull fixation. A similar approach has been implemented at the Mayo Clinic Florida, where the AAA protocol is performed under general anesthesia during the asleep phases, with airway management via a laryngeal mask airway and headpins used for cranial immobilization.[12] At another center, Stony Brook University Hospital, the AAA technique is also utilized with minimal airway management and stereotactic navigation; however, that approach does not involve rigid skull fixation, which may reduce patient discomfort during and after surgery. Nonetheless, this decreased rigidity may lead to increased movement and interference during cortical mapping[11]

Although the AAA protocol offers advantages in terms of stable cranial fixation, secure airway management, and reliable cortical mapping, it is associated with potential drawbacks, particularly patient discomfort. To address this, some centers have adopted alternative methods, such as the awake–awake–awake protocol or conscious sedation.[10,12]

Neurological and radiological outcomes of awake craniotomy

Seizure control is a recognized challenge during awake craniotomy.[17] In our study, 50% of patients had seizures preoperatively (Table 2). All intraoperative and postoperative seizures occurred in patients who had also previously experienced them, indicating an increased intraoperative risk for this group, consistent with previous reports. The intraoperative seizure rate (12.5%) aligns with published data.[18,19] The intraoperative seizure was transient and managed using copious cold lactated Ringer's solution applied over the surface of the brain parenchyma and intravenous phenytoin at a dose of 250 mg administered over 40 min, reflecting the effectiveness of the anesthetic and mapping protocols.

Promising neurological outcomes were achieved in our case series. Motor function was preserved or improved in nearly all patients, with only one of eight cases demonstrating increased weakness at 180 days (12.5%). Notably, this patient (Case 6) had compromised intraoperative venous drainage, as reported by the surgical team, which may have contributed to the neurological deficit. Overall, this rate is consistent with previous studies reporting postoperative motor deficits in 4%–17% of awake craniotomy cases.[8]

Language outcomes were similarly favorable, although three patients in our cohort had preexisting aphasia prior to surgery. All of the other patients maintained intact language function postoperatively, whereas those with preexisting aphasia demonstrated improvement at the 90-day follow-up (Table 2). These findings are consistent with a previous study,[7] which reported that postoperative language deficits, although relatively common in the immediate period (9.3%), are rarely permanent (1.6%).

In terms of the radiological outcomes, gross total resection was achieved in five of the eight cases (Table 2), and subtotal resection was achieved in the other cases due to proximity to the functional cortex or other structures such as major cerebral arteries and sinuses. The radiological findings confirmed that most cases exhibited stable or improved midline shifts and edema postoperatively, which further supported the efficacy of our surgical and anesthetic protocols. The extent of resection must be balanced against the need for functional preservation, and there is evidence that subtotal resection with preserved neurological function can improve the quality of life and progression-free survival of selected patients.[4,6,20]

Importantly, no perioperative mortality, surgical infections, or debilitating postoperative complications requiring reoperation were recorded in this case series. This attests to the safety of awake craniotomy when conducted by an appropriate multidisciplinary team.

Several limitations of this study should be acknowledged. First, the small sample size reflects the early institutional experience and the limited number of patients eligible for awake craniotomy during the study period, which restricts statistical power and limits the generalizability of the findings. Second, the absence of a comparison group, such as patients undergoing tumor resection under general anesthesia, precludes direct comparative evaluation of neurological and oncological outcomes between awake and non-awake techniques. Third, potential selection bias must be considered, as candidates for awake craniotomy were carefully screened and excluded if they had contraindications such as impaired cooperation, communication barriers, or significant anxiety, potentially resulting in a cohort with more favorable baseline characteristics. Additionally, the retrospective nature of data collection and incomplete long-term follow-up in some patients limit the robustness of outcome assessment.

Future studies should incorporate psychosocial assessments such as pain scale and postoperative questionnaire to allow more comprehensive analysis of the benefits of awake craniotomy with tumor removal, not only in terms of neurological or oncological outcome, but also patient discomfort.[21] Moreover, evaluating long-term oncological outcomes, such as progression-free and overall survival, was beyond the scope of this study; however, it is essential to assess such outcomes in future longitudinal research.

Nonetheless, our findings provide a strong foundation for future longitudinal studies designed to fully elucidate the benefits of awake craniotomy with tumor removal.

In conclusion, our findings demonstrate that awake craniotomy is a safe and feasible option for the resection of intracranial tumors in eloquent regions at Chulabhorn Hospital. Importantly, this series adds to the limited but expanding body of literature documenting awake craniotomy within Thailand and the broader Southeast Asian region, underscoring that this advanced neurosurgical technique can be successfully established in resource-variable settings when supported by appropriate training, preparation, and patient selection.[13,14] Given the substantial burden of gliomas and metastatic tumors involving the eloquent cortex,[22,23] integrating awake craniotomy into regional neurosurgical practice holds significant potential for improving both oncological and functional outcomes.

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DISCLOSURE

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