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Awake craniotomy for brain tumors: Indications, benefits, types of anesthesia and surgical techniques

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Abstract: Background: Awake brain surgery is used to treat brain tumors and epileptic seizures near areas that control language, movement or cognition, movement disorder, and recently during neurovascular surgery.

Methods: Preoperative airway evaluation should be performed in all patients. There are two commonly used anesthetic methods for awake craniotomy: monitored anesthesia care (MAC) and asleep-awake-asleep (AAA) technique, after the tumor resection, sedation is often sufficient until completion of the surgery. In our institution at Mount Lebanon hospital-Balamand university hospital, the combination of propofol and remifentanil has been considered as the standard protocol for sedation during the first stage of awake craniotomy because of the ease of use and reliability. The application of neuro-navigation, and intraoperative electrical mapping are a reliable method to minimize the risk of permanent deficit during surgery for brain tumors in eloquent areas.

Results: Whether sedation or an asleep-awake-asleep technique is chosen, it is crucial to apply adequate local anaesthesia on the skin incision what we call elliptic block using combinations of lidocaine and bupivacaine with epinephrine. If we perform awake-asleep-awake anesthesia type than similar to the pre-awake phase, one can also choose awake, spontaneous ventilation under light or deep sedation, or GA with airway control. Sedation often suffices. The patient usually requires lower rates of sedative infusions during the postawake phase than during the pre-awake phase as patients are often fatigued, and there is a lower level of painful stimuli during skull closure.

Conclusion: Patients receiving awake craniotomy have better outcomes in many aspects. The improvements in anesthetic agents and techniques, the application of neuro-navigation, and intraoperative electrical mapping are a reliable method to minimize the risk of permanent deficit during surgery. Appropriate patient selection, perioperative psychological support, and proper anesthetic management for individual patients in each stage of surgery are crucial for procedural safety, success, and patient satisfaction.

Keywords: Brain tumors; Awake craniotomy; Monitored anesthesia care.

1. Introduction

Awake craniotomy can be defined as a neurosurgical procedure performed while the patient is awake and alert during surgery. Awake brain surgery is used to treat brain tumors, epileptic seizures near areas that control language, movement or cognition, movement disorder, and recently during neurovascular surgery [1]. When the patient is alert, we can ask questions and request specific movements or responses from the patient so we can monitor brain performance as we operate; this can help ensure the brain remains safe while the tumor is removed.

Early in its history, awake Craniotomy was used to treat epilepsy. The modern era of awake craniotomies began in the late 1920s when Wilder Penfield was attempting to treat patients with intractable epilepsy; Archer, in 1988 first surgeon who performed awake Craniotomy for brain tumors [2,3]. This procedure has become increasingly popular with broader indications prompted by evidence that patients receiving awake Craniotomy have better outcomes in many aspects.

The improvements in anesthetic agents and techniques, the application of neuro-navigation, and intraoperative electrical mapping are reliable methods to minimize the risk of the permanent deficit during surgery for brain tumors in eloquent areas [3].

2. Indications and contraindications

There are many indications for awake craniotomy. For neuro-oncology, the resection of any intra-axial masses that are near eloquent areas can benefit from awake surgery, as the patient monitoring and the brain mapping that we perform in these surgeries enable us to resect more of the tumor without injuring the cortical centers and subcortical tracts with less risk of post-operative neurological morbidities when we compare it to general anesthesia [4,5]. Furthermore, as the extent of resection of the lesions in neuro-oncological surgeries is directly correlated to the survival and quality of life in many tumors, awake craniotomy can be superior to classical surgeries. In particular cases, in patients with specific skills like musicians, we perform functional MRI to localize the musical perception area and the relation with the tumor to resect the lesion without disturbing the musical ability. It is an individually tailored mapping.

In epilepsy surgeries, in the case of drug-resistant seizures where the foci are extra temporal, resection becomes difficult, as they are closer to the eloquent cortex in most cases. These cases benefit from awake craniotomy as mapping the cortex before resection protects the critical areas and makes the surgery safer.

Also, the utility of awake surgeries in some neuro-vascular procedures, awake surgery during aneurysm clipping to prevent ischemic episodes during temporary clipping [1], and endarterectomies, where the frequent examination of the patient while clamping the diseases carotid to perform the surgery can show the examiner the dependency of the patient on that particular vascular axis, and help the surgeon chose the proper surgical technique (shunting vs no shunting). Another benefit that can push the surgeon to go for awake surgery to prevent the risks of general anesthesia may prevent extended hospitalization and ICU stay. Also, it will help the anesthesiologists use less invasive methods and catheters to monitor the patients.

On the other hand, there are many factors that contra-indicate awake surgeries. The most important one is patient cooperation, as cases of agitation or non-cooperation while performing the surgery can lead to dangerous outcomes and injuries. This makes patient selection very important. No clear consensus on the proper age for awake surgeries, as they were performed on pediatric and geriatric patients. Patients with difficulty talking, who are somnolent or confused due to some tumor, may not benefit from awake surgery even if its location is ideal due to the impossibility of performing pre-op examinations. Furthermore, long surgeries with heavy blood losses and uncomfortable positions make a relative contra-indication to awake surgery as they can lead to agitation and non-cooperation. Obesity, sleep apnea, and other conditions that can lead to insecure airway stability can cause a relative contra-anesthesia in Awake craniotomy

3. Preoperative preparation

Awake craniotomy requires a highly cooperative patient and an expert surgical team. Preoperative airway evaluation should be performed in all patients. Control of preoperative anxiety before awake craniotomy is important and can be relieved by proper preoperative counseling about the anesthetic and surgical procedures. Therefore preoperative consultation by an anesthesiologist is a necessary process. The anesthesiologist should outline the overall awake craniotomy procedures, including positioning, scalp nerve block, possible discomfort, and the motor and language test. A good anesthesiologist-patient relationship is essential, and the anesthesiologist should attempt to alleviate the anxiety and discomfort of the patient.

4. Anesthetic approaches for awake craniotomy

Various anesthetic techniques may be helpful for awake craniotomy. Among them are two commonly used anesthetic methods for awake craniotomy: monitored anesthesia care (MAC) and the asleep-awake-asleep (AAA) technique. The anesthesiologists should provide sufficient sedation and analgesia during the initial craniotomy; rapid and smooth emergence of patients is required for the intraoperative neurophysiologic test, including motor and language tests and brain mapping.

After the tumor resection, sedation is often sufficient until the completion of the surgery. The sedation profile during the first stage of awake craniotomy, from scalp incision to dura opening, plays a pivotal role in the quality of intraoperative consciousness. The anesthesiologist should restore the patient's consciousness to the preoperative state for neurophysiologic tests and brain mapping to be performed successfully.

In our institution at Mount Lebanon hospital-Balamand university hospital, the combination of propofol and remifentanil has been considered the standard protocol for sedation during the first stage of awake craniotomy because of the ease of use and reliability. The propofol and remifentanil-based AAA technique allow a smooth emergence and rapid recovery of consciousness for intraoperative neurophysiologic testing. The propofol and remifentanil-based MAC technique is associated with dose-dependent respiratory depression, which can produce hypercapnia and subsequent brain edema. Therefore, achieving the optimal sedation level for an individual is crucial. Meanwhile, light sedation risks causing accidental patient movement, and anxiety is likely. Generally, drowsiness but readily responsive state is considered the optimal sedation in awake craniotomy, and experienced anesthesiologists are required to accomplish this balance in the complex setting.

Dexmedetomidine, an alternative to propofol for the MAC technique during awake craniotomy, can also be used. It is a selective alpha-2 agonist with sedative, analgesic, anxiolytic, and sympatholytic properties. The advantageous effects of dexmedetomidine, such as minimal effect on neurophysiologic monitoring, stable hemodynamics, and minimal respiratory depression, make it suitable for sedation during awake craniotomy. Dexmedetomidine and the scalp nerve block were used successfully in awake craniotomy, but it can cause bradycardia, that's why it needs good dose monitoring techniques.

Anesthesia for awake craniotomy is one of the most challenging fields for anesthesiologists. The MAC and AAA techniques are feasible and safe anesthetic techniques for awake craniotomy, and an adequate regional block is required for effective intraoperative pain control and better patient satisfaction. Appropriate patient selection, perioperative psychological support, and proper anesthetic management for individual patients in each stage of surgery are crucial for procedural safety, success, and patient satisfaction.

5. Pre-operative planning

The neuro-onology multi-disciplinary team meeting should discuss most awake craniotomies for brain tumor resection. Good radiological imaging should be done for surgical planning, including diffuse tensor imaging (DTI) if the tumor. In addition, a formal speech and motor power assessment evaluation is usually carried out up to 2 days before surgery (baseline) and repeated intra-operatively to identify errors during stimulation. Although fMRI is increasingly being adopted as a practical preoperative planning tool for brain tumor resection, there remains a substantial discrepancy about its current use and presumed utility.

In a comprehensive neuropsychological evaluation, a patient's emotional state and ability to cooperate during awake surgery are usually assessed, and meeting the team before surgery is crucial as well. Indication, and so a proper evaluation by the anesthesiologist pre-op should be performed.

Surgical Technique As with any awake technique, delays and technical problems in the operating theatre should be avoided. The team should be aware of the presence of an awake patient by a sign on the entrance of the operating room, and noise should be kept to a minimum. The operating theatre becomes crowded, staff movement should be restricted, and a calm atmosphere should be maintained at all times. Patient comfort is essential. We should ask the patient if they are comfortable, the operating table should be adequately padded, and attention should be paid to head and limb positioning. That should be double-checked before draping the patient. It is usually preferable to allow the patient to position themselves on the operating table before the institution of sedation or anaesthesia to lie in the most comfortable position. If a Mayfield head fixator is used, adequate local anaesthesia should be applied prior to application of the pins. Surgical drapes should be positioned, allowing the anaesthetist constant and unimpeded access to the airway while preserving a sterile field. The use of transparent drapes reduces the feelings of claustrophobia.

Whether sedation or an asleep-awake-asleep technique is chosen, it is crucial to apply adequate local anaesthesia on the skin incision called elliptic block, using combinations of lidocaine and bupivacaine with epinephrine. The skin, scalp, pericranium, and periosteum of the outer table of the skull are all innervated by cutaneous nerves arising from branches of the trigeminal nerve; subcutaneous infiltration with local anaesthesia in the manner of a field block or over specific sensory nerve branches blocks afferent input from all layers of the scalp.

The skull can be drilled and opened without pain or discomfort to the patient since there is no sensory innervation. However, the dura is innervated by branches from all three divisions of the trigeminal nerve, the recurrent meningeal branch of the vagus, and branches of the upper cervical roots [1]. Usually, in most brain tumor surgery, we use neuro-navigation to minimize the incision size and identify the vascular anatomy and cortical anatomy.

Functional neuroimaging has improved the pre-planning of surgery in eloquent cortical areas but remains unable to map white matter. Thus, tumor resection in functional subcortical regions still presents a high risk of sequelae. The authors successfully used intraoperative electrical stimulations to perform subcortical language pathway mapping to avoid a definitive postoperative deficit. They correlated these functional findings with the anatomical location of the eloquent bundles detected using postoperative MRI [4,5].

6. Awake phase

The goal is to transition smoothly and rapidly without agitation, confusion, or drowsiness from sedation or anesthesia to an awake patient. The patient needs to be engaged, cooperative, pain-free, and comfortable for mapping and tumor resection. All agents are stopped; I prefer to keep the patient awake. Pain should be managed with supplemental Local aesthesia. Non-pharmacological intraoperative management should be used to reduce fear and anxiety. Empathy, handholding, reassurance, ongoing encouragement, coaching, and conversation are all useful and important. A sponge soaked with ice-cold water can be used to wet the patient's lips and mouth for comfort. The patient can be allowed to move limbs and hips at appropriate times. An air blanket is used to provide either warm or cool air to maintain a comfortable temperature [6–8].

7. Physiological test

8. Motor and sensory pathways

Awake surgery accurately maps both cortical and subcortical pathways of the limbs, face, and mouth. Mapping can elicit or inhibit movements. Responses of orofacial musculature, laryngeal activity, and vocalizations can be recorded as tingling or movement, for example, withdrawal of protruded tongue or speech arrest [6,9]. Similarly, tingling, twitching, or movement in the limbs may be elicited, most commonly in arms and hands [8,10]. The anesthesiologist should observe the patient and report every movement to the surgeon. That is why the anesthesia team should examine the patient before surgery, and the patient should also be instructed to report any abnormal movement or sensation. The stimulation mapping not only delineates the cortical areas but also allows the surgeon to stimulate and monitor subcortical tracts.

9. Language

It is not easy to localize speech areas based on anatomical landmarks. To assess speech, the Visual Object Naming Test is frequently used. The Boston Naming Test consists of 60 drawings of everyday objects graded in difficulty, for example, window, car, dog, and guitar [11]. In addition, language functions can be studied with more terrific refinement and complexity. Bilingual patients need to be tested in both languages, as the anatomical areas may not entirely overlap. Classic models of language organization posited that separate motor and sensory language foci existed in the inferior frontal gyrus (Broca's area) and superior temporal gyrus (Wernicke's area), respectively, and that connections between these sites (arcuate fasciculus) allowed for auditory-motor interaction. These theories have predominated for more than a century, but advances in neuroimaging and stimulation mapping have provided a more detailed description of the functional neuroanatomy of language. New insights have shaped modern network-based models of speech processing composed of parallel and interconnected streams involving both cortical and subcortical areas. Recent models emphasis-size processing in "dorsal" and "ventral" pathways, mediating phonological and semantic processing, respectively; phonological processing occurs along a dorsal pathway, from the posterosuperior temporal to the inferior frontal cortices. On the other hand, semantic information is carried in a ventral pathway that runs from the temporal pole to the basal occipitotemporal cortex, with anterior connections.

10. Visual

Intraoperative brain mapping of the cortical visual cortex with subcortical mapping of visual tracts may be useful to minimize the risk of permanent hemianopia in tumors located in the parieto-occipital area. Identifying optic radiations by direct subcortical electrostimulation is a dependable method to reduce permanent injury in surgery for gliomas involving visual pathways [11,12]. In addition, methods to identify other functions, such as memory and counting, are of interest and are being developed.

11. Challenges during the awake phase

The main challenges during awake craniotomy include: hypertension, seizures, somnolence, agitation, oxygen desaturation, tight brain, and shivering.

(1) Hypertension: This is most commonly secondary to pain, agitation, and anxiety. However, other causes should also be sought such as hypoxia, hypercapnia, and dexmedetomidine (DEX) associated [5,6,9,13]. Treatment should focus on managing the cause. Labetalol or esmolol may sometimes be necessary.
(2) Seizures: Seizure incidence is 3% to 16% and happens during cortical and subcortical stimulation mapping [14,15]. If the surgeon avoids stimulating an area twice in rapid succession, the incidence is less. Continuous monitoring of electrocorticography for spikes or sharp waves within 5 seconds after each stimulation allows early detection [16]. Patients with a history of seizure and younger patients, especially with tumors of the frontal lobe, are more prone to seizures [17]. Intraoperative seizures have a higher incidence of transient motor deterioration, and longer hospitals stay [11,16]. First-line treatment of stimulation-evoked seizures is irrigation of the cortex with a cold crystalloid solution, which can be repeated as often as necessary.
(3) Emergence agitation and delirium may occur if the pre-awake phase is with GA or deep sedation. Contributing factors include older age; pain; disorientation; inappropriate use of naloxone, flumazenil, neostigmine, and atropine; oxygen desaturation; hypercapnia; urethral stimulation, and bladder distention. It can be tough to manage, and there is no consensus on the best approach. An approach is to reinduce anesthesia with a propofol bolus, then administer a dexmedetomidine bolus before the second wake-up attempt [10,18].
(4) Somnolence: This usually reflects residual anesthetic effects or from anti-consultants. The best strategy is prevention by early termination of DEX and propofol, and the avoidance of large doses of midazolam or longer acting opioids.
(5) Nausea and vomiting: These are most commonly associated with opioids; other common associated factors are age, gender, and anxiety. The incidence is much lower with the common use of propofol. Management includes empathy, ondansetron, and small dose of propofol
(6) Hypothermia and shivering: These should be prevented by the use of blankets, warm air devices, and appropriate room temperature. Tramadol or meperidine may be effective [6]. Post-awake and post operative care.

Suppose we perform an awake-asleep-awake anesthesia type similar to the pre-awake phase. In that case, one can also choose awake, spontaneous ventilation under light or deep sedation, or GA with airway control. Sedation often suffices. The patient usually requires lower rates of sedative infusions during the post-awake phase than during the pre-awake phase, as patients are often fatigued, and there is a lower level of painful stimuli during skull closure. The patient should initially require to be admitted to the neurosurgical intensive care unit, with hourly neuro observation for the first 24 hours. Pain management can be achieved intravenously with small doses of opioids, including with patient-controlled analgesia, and oral opioids combined with anti-inflammatory drugs.

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