Anesthetized versus Awake Craniotomy

An essay

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List of Acronyms

ACTH	: Adrenocorticotrophic hormone
AEP	: Auditory evoked potential
ADH	: Antidiuretic hormone
AICA	: Anterior Inferior Cerebellar Artery
AVM	: Arteriovenous malformation
BBB	: Blood brain barrier
BIS	: Bispecrtal index
CBF	: Cerebral blood flow
CMR	: Cerebral metabolic rate
CNS	: Central nervous system
CO_2	: Carbon dioxide
COPD	: Chronic obstructive pulmonary disease
CSF	: Cerebrospinal fluid
CT	: Computed tomography
CVP	: Central venous pressure
DBS	: Deep brain stimulation
ECG	: Electrocardiogram
ECoG	: Electrocorticography
EEG	: Electroencephalogram
EMLA	: Eutectic mixture of local anesthetic
$ETCO_2$	: End-tidal Carbon dioxide
ETT	: Endotracheal tube
IABP	: Invasive arterial blood pressure

ICP	: Intracranial pressure
IM	: Intramuscular
IV	: Intravenous
LCD	: Liquid crystal display
LMA	: Laryngeal mask airway
MAC	: Minimum alveolar concentration
M.B.B.Ch.	: Medical Bachelor and Bachelor of Chirurgie
MEP	: Motor evoked potential
MRI	: Magnetic resonance imaging
N_2O	: Nitrous oxide
NMDA	: N-methyl-D-aspartate
NSAIDs	: Non-steroidal anti-inflammatory drugs
$PaCO_2$	: Arterial carbon dioxide tension
PABA	: Para-amino benzoic acid
PCA	: Patient controlled analgesia
PICA	: Posterior Inferior Cerebellar Artery
SpO_2	: Arterial oxygen saturation
SSEP	: Somatosensory Evoked Potential
TCI	: Target controlled infusion
TIVA	: Total intravenous anesthesia
TMS	: Transcranial magnetic stimulation
TMS-induced MEPs	: Transcranial magnetic stimulation induced motor evoked potential
VEP	: Visual evoked potential

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Abstract

Anesthesia for awake craniotomy is a unique clinical setting that requires the anesthetist to provide changing states of sedation and analgesia, to ensure optimal patient comfort without interfering with electrophysiologic monitoring and patient cooperation, but also to manipulate cerebral and systemic hemodynamic while guaranteeing adequate ventilation and airways safety. Awake craniotomy is the preferred approach for functional neurosurgery (including deep-brain stimulation for the treatment of Parkinson's disease, and, more recently, for epilepsy surgery) and for neurosurgical procedures requiring intraoperative monitoring of speech and motor functions to localize the area of surgical interest (including resection or biopsy of brain tumors in eloquent areas) since it allows wider tumor excision and lower perioperative morbidity, when compared to conventional craniotomy, in which any neurological dysfunction is discovered after the end of the procedure. Different anesthetic techniques for awake craniotomy have been described in the literature. Some have used conscious sedation, while others have used 'asleep-awake-asleep' technique.

Key words

Neuroanesthesia

Awake craniotomy

Local anesthetics

Scalp blockade

Brain mapping

Chapter 1

Introduction and Historical Background

• Introduction

It is not surprising that anesthesia for craniotomy presents special considerations. The brain is enclosed in a rigid skull and the majority of craniotomies are performed for the treatment of space occupying lesions. At the same time, the brain is a highly vascular organ presenting potential for massive perioperative hemorrhage. Tolerance of the brain to interruption of glucose and oxygen delivery is minimal. Anesthetics and physiologic factors controlled by the anesthetist have profound effects on the brain. Interactions between anesthesia and surgical outcome can be expected. (1)

Awake craniotomy techniques are widely used and offer many advantages in patients undergoing surgical management of epilepsy and other procedures in eloquent areas of the brain. Awake craniotomy literally means performing a craniotomy on an awake patient. It allows intraoperative assessment of the patient's neurological status. It is mainly used for mapping the resection margins during epilepsy surgery, accurate location of electrodes in surgery for movement disorders, and excision of tumors from eloquent areas of the cortex. Eloquent areas are specialized areas of brain which control important functions, like movement, sensation, speech etc. (2)

Intraoperative neurological testing allows optimal tumor resection with minimal postoperative neurological dysfunction. Different anesthetic techniques for awake craniotomy have been described in the literature. Some have used conscious sedation, while others have used 'asleep-awake-asleep' technique. (3 - 7)

The usual indication for the awake approach is to facilitate intraoperative electrocorticography (ECoG) and cortical mapping to accurately identify those areas of brain which control motor functions and speech. The same anesthetic techniques can also be useful for patients with tumor or arteriovenous malformation (AVM) near the speech or motor areas, or for patients in whom a general anesthetic may present an unnecessary risk. Indeed, there are frequent reports of the use of this technique for unusual tumor or epilepsy surgical cases. (8, 9)

Historical background about awake craniotomy

The evolution of brain mapping

The idea of awake craniotomy for tumor surgery arose from its use for epilepsy surgery. It is known from archeological findings that in ancient times, thousands of years ago, patients were treated for seizures by trepanation of the skull. [10, 11] Seizures are a common clinical presentation of brain tumor in adults; and therefore, some of these ancient trepanations must have been done in patients harboring brain tumors. The surgery was also done to correct morbid conditions of the skull like contusion or fracture, or to permit the escape of evil air. [12]

The first documentation of awake craniotomy in “modern” times to treat epilepsy was in the early 17th century. [11] The poor results of trepanation drove physicians and scientists to explore the brain and try to define the seizure source. Hughlings Jackson, who did an extensive study of focal epilepsy between 1864 and 1870, predicted that an area existed in the cerebral cortex that governed isolated movements. [13]

This was verified by Fritsch and Hitzig in 1870, who for the first time were able to elicit movements of the extremities in animals by means of electrical stimulation on the cerebral cortex. [14]

The first concept of brain mapping with electrical stimulation in humans was generated by Bartholow in 1874. [15] He used an electrode to stimulate the cerebral cortex through a skull defect resulting from the osseous infiltration of an epithelioma. A decade later in 1886, Horsley, whose studies of animals gave him an excellent understanding of the human cortex, and his colleague Jackson applied electrical stimulation to localize the thumb area and decided to excise the area because it was the source of the seizure. [16] Jackson demonstrated that in focal epilepsy an area could be found on the cerebral cortex, which would give rise to the seizure. The excision of this area, which he called the primary spasmic center, was usually followed by a cessation of the attacks. [17]

From that time on, electrical stimulation to localize the motor cortex and seizure foci became quite popular. In the late 1920s, Wilder Penfield was trying to treat patients with intractable epilepsy. [18] He also applied mild electric current to map the brain. Before an epileptic seizure, he knew patients experienced an aura, a warning that a seizure is about to occur. He thought that if he could provoke this aura with mild electric current on the brain, then he could locate the source of the seizure activity and could potentially remove or destroy that bit of tissue. While patients were fully conscious at craniotomy, he used a stimulator with unilateral or bipolar electrodes consisting of a platinum wire in a glass holder. [19, 20] He rigorously documented all his intraoperative findings. [21 - 23] He stated that the patient must be conscious and alert during the electrical stimulation so the patient could warn the surgeon about the aura, motor weakness, or sensory change. His technique was often successful and reproducible, becoming accepted worldwide for epilepsy surgery. He also applied awake craniotomy to some patients with brain tumors, notably his own sister. [18]

➢ Awake craniotomy for epilepsy

One of the first large studies describing the anesthetic experience with awake craniotomy was published by Archer et al in 1988. [24] They described their experience with 347 awake craniotomies for cortical resection for epilepsy, using local analgesia and intravenous (IV) fentanyl and droperidol. In 1992, Silbergeld et al introduced the use of propofol, which offers the advantages of being a short-acting sedative with anti-emetic and amnestic properties in sedative doses. [25 - 27] Now there is considerable variation in the anesthetic techniques for “awake craniotomy,” ranging from the “asleep-awake-asleep” technique, with or without the use of an airway, to those using monitored anesthesia care or conscious sedation. [5, 6, 7, 28, 29, 106]

Propofol and, more recently, remifentanil have been frequently used. [5, 28, 29] Midazolam is also popular because of its anxiolyic and amnestic properties. [30] Low doses of midazolam (0.075 mg/kg) do not affect the ventilatory response to carbon dioxide (CO_2), suggesting that clinically significant respiratory depression is unlikely at that dose range. [31] In addition, it raises seizure threshold, [32] and offers an extra margin of safety when local anesthetic is used. [17]

➢ Awake craniotomy for tumors

Many hemispheric glial and metastatic tumors are located within or adjacent to functional areas such as motor cortex, speech area, and sensory cortex. It has been shown that functional cortex and subcortical white matter may be located within the tumor or adjacent infiltrated brain.[33] Using brain mapping techniques for brain tumor surgery was a logical step from its use in epilepsy surgery and started to be more widely used for this purpose within the last two decades. (34) It was used to identify regions of language representation in the dominant cerebral hemisphere and the motor cortex in either hemisphere. This technique allows intraoperative mapping to delineate any eloquent cortex and its relationship with the tumor, and facilitates finding the safest transcortical route to the tumor, and more aggressive tumor resection while minimizing morbidity by preserving functional tissue. (35)

Another large series of patients treated with awake craniotomy for brain tumor surgery was published in 1999; 200 cases operated over seven years were reported. (36) The same group has recently described their experience in more than 600 tumor patients, (37) which is, to our knowledge, the largest such series in the literature. Useful data have arisen such as the observation that positive mapping was associated with a 5% risk of neurologic worsening, whereas negative mapping was associated with 1.8% incidence of patients sustaining neurologic worsening. At the same time, awake craniotomy for brain tumor also became more and more popular in other centers. (38, 39) For more than 20 years, this technique has been shown to be relatively safe, simple, and well-tolerated by patients. (17)

The avoidance of general anesthesia and its associated invasive monitoring could potentially decrease postoperative medical morbidity and shorten the length of hospital stay, so that recently, this technique has actually been used for outpatient craniotomy for brain tumor resection. (40 - 42) Of note is that one small randomized study actually reported higher blood loss, more neurologic deficit, and less degree of cytoreduction in patients undergoing awake craniotomy for tumors in eloquent cortex. (43)

Chapter 2

Anatomy

Anatomy of the scalp

- **Definition**

The soft tissue envelope of the cranial vault is called the scalp. The scalp extends from the external occipital protuberance and superior nuchal lines to the supraorbital margins.

- **Structure**

The scalp consists of five layers: the skin, connective tissue, epicranial aponeurosis, loose areolar tissue, and pericranium, shown below in Figure 1. The first three layers are bound together as a single unit. This single unit can move along the loose areolar tissue over the pericranium, which is adherent to the calvaria. [46, 47, 49, 50]

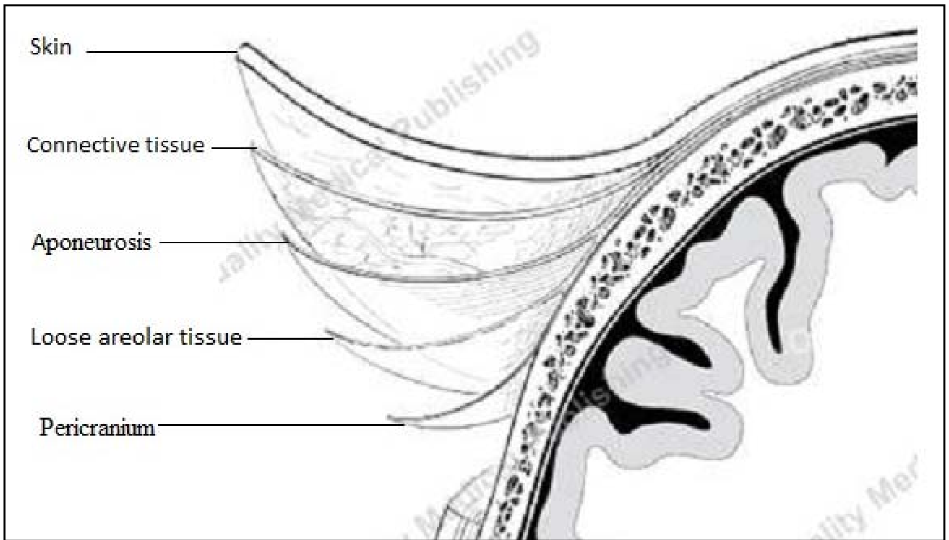

Figure 1: Layers of the scalp [45]

➢ **Skin**

The skin of the scalp is thick and hair bearing and contains numerous sebaceous glands. [48]

➢ **Connective tissue (superficial fascia)**

It provides a passageway for nerves and blood vessels. Blood vessels are attached to this fibrous connective tissue. If the vessels are cut, this attachment prevents vasospasm, which could lead to profuse bleeding after injury. [48]