Acute Brain Swelling in the Patient Undergoing Awake Craniotomy

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OBJECTIVES

At the end of this discussion the participant will be able to:

1. Discuss indications for awake craniotomy and patient selection principles for this procedure.
2. Establish an optimal anesthetic plan for this procedure, including choice of regional techniques and intravenous agents for sedation and analgesia, and respiration management.
3. Discuss possible complications anticipated with this procedure and optional approaches to their management.
4. Discuss pharmacological profile of remifentanil and its use in spontaneously breathing patients.

STEM CASE - KEY QUESTIONS

A 43-year old male presents with episodic dysphasia, lasting less than 3 hours and associated with headache. Head CT and MRI reveal a well-defined posterior frontal/temporal lesion in the dominant hemisphere. The patient has a history of hypertension controlled by an ACE inhibitor and is otherwise healthy. He is scheduled for left temporal craniotomy with intraoperative cortical mapping and speech testing. The surgeon requests an anesthetic technique, which will allow the patient to be awake at the time of cortical mapping and the tumor resection.

· What are the indications for "awake" craniotomy?

· Which patients **should not** be considered for this technique from the anesthetic perspective? Discuss preoperative evaluation.

· What are the existing approaches to assure awake and responsive patient for intraoperative testing?

· Discuss optimal choice of anesthetic agents and airway management.

Preoperatively the patient is alert and oriented, without speech impairment. He is moderately overweight (BMI 27), with Class II airway, oxygen saturation 97-98 % on room air. He is currently receiving anti-convulsant therapy and intravenous corticosteroids. An anesthetic plan, consisting of scalp block combined with remifentanil/propofol sedation and standard anesthetic intraoperative monitoring for craniotomy, is proposed and agreed on with the neurosurgical and electrophysiology teams. Various aspects of intraoperative testing and anesthetic management are thoroughly explained to the patient. He displays high level of understanding and cooperativeness. On the day of surgery, after obtaining intravenous access and placing of standard monitors the patient is sedated with 100 mkg of fentanyl. Ondansetron 4mg is administered iv and right radial artery catheter is placed. At this stage sedation with remifentanil (0.25 μg/kg bolus and 0.05 μg/kg/min infusion) and propofol (50 μg/kg/min) begins. A few minutes later, when the patient is consciously sedated his nasal passages are lubricated with 4% viscous lidocaine and two nasopharyngeal airways are inserted. These airways are connected via a double-lumen endotracheal tube connector to a breathing circuit of an anesthesia machine. A good $ETCO_2$ waveform is obtained using a side-stream capnograph. After the patient comfort and responsiveness is confirmed the skull block is performed using a mixture of 40 ml 0.5% bupivacaine and 10 ml 1% lidocaine and epinephrine 1:400,000. About 20 ml of this mixture is used for additional skin infiltration at the incision site and at head clamp pins insertion sites.

· Which nerves innervate the scalp?

· What are the various approaches to provide reliable local anesthesia for craniotomy?

· What local anesthetic or their mixtures could be used for this purpose? Discuss advantages/disadvantages.

Following skin incision the patient is sedated but responsive and reports no pain. Patient is breathing 12-14 breaths a minutes with oxygen saturation of 99% on 50% air/oxygen mixture and $PaCO_2$ – 48 mmHg. At the time of bone flap elevation the patient reports mild discomfort and the rate of remifentanil infusion is increased to 0.075 μg/kg/min. The patient becomes more sedated and stops complaining. After raising the bone flap neurosurgeons inform the anesthesiologists that the brain is somewhat “tight” judging by the dural tension. The patient is asked to take a few deep breaths. At this time the patient is breathing 9-10 breaths a min and is stable otherwise. A few minutes later, during dural opening the patient ventilation rapidly slows down to 4-5 breaths a min and he becomes unresponsive. Oxygen saturation drops down to 92%. The brain rapidly swells.

· What are the likely causes of brain swelling in this patient?

· How this situation could have been prevented?

· What are your actions?

· Do you have to intubate this patient?

· At this stage remifentanil and propofol have been running for about 2 hours. What are their respective context-sensitive half times?

The inspired O_2 concentration is increased to 100%, remifentanil and propofol infusion are terminated and few assist ventilations are delivered via the nasopharyngeal airway assembly with the patient mouth closed. Saturation rapidly returns to 99% and within three minutes the patient becomes responsive. He is again asked to hyperventilate spontaneously by taking deep breaths repeatedly. $ETCO_2$ rapidly drops from 52 mmHg to levels below 40 mmHg, with subsequent brain relaxation in the next 10 minutes. At this stage the patient is awake, coherent and responsive enough to begin speech testing and cortical mapping. Remifentanil infusion is resumed at 0.02 μg/kg/min rate. With the patient comfortable and readily answering questions for speech assessment the cortical mapping and tumor resection are accomplished in under 90 minutes. The following flap closure is easily accomplished without further increases in remifentanil infusion rate.

· Would you consider this patient for PACU recovery from anesthesia, bypassing ICU?

· When this patient can be discharged home?

PROBLEM BASED LEARNING DISCUSSION

Indications for awake craniotomy.

Traditionally the awake craniotomy technique was used for epilepsy surgery. Recently its use has been also advocated for the resection of tumors (especially low grade tumors) located in the eloquent cortex or near it. Brain resection in this area can lead to a loss of motor or speech function as a result of surgery. Intraoperative neurological assessment in the awake patient provides an opportunity to minimize risk of such iatrogenic deficits and allow more complete resection of the tumor. In fact, recent evidence suggests that this approach lowers morbidity and minimizes hospitalization time[1]. An uncooperative patient is the only absolute contraindication to this technique. Relative contraindications include complicated airway, decreased pulmonary reserve, morbid obesity and severe acid reflux disease. However, these conditions significantly increase the risk of intraoperative complications and the decision to perform awake craniotomy must carefully considered.

Anesthetic techniques for craniotomy in the awake patient.

Despite the growing use of awake craniotomy there is no single ideal widely accepted approach to anesthetic management for this procedure. However, experience indicate that in order to succeed, following requirements need to be satisfied: (1) adequate analgesia and sedation/anesthesia to secure patient comfort and immobility, especially during painful part of the surgery; (2) full consciousness during cortical/subcortical mapping, intraoperative testing and tumor resection; (3) smooth transition between anesthesia and consciousness; (4) adequate ventilation. Pain, airway obstruction, nausea and vomiting, and intraoperative seizure are common problems associated with this procedure.

Various anesthetic techniques have been proposed to address the abovementioned challenges. These could be summarized as awake-asleep-awake technique, regional/local anesthesia combined with sedation, or a mixture of those approaches. Awake-asleep-awake technique typically involves fairly elaborate methods to secure the airway with an endotracheal tube or an LMA in the beginning and at the end of surgery, and extubation in the middle for the intraoperative testing [2]. This approach avoids hypoventilation associated with oversedation, and also protects the airway. The disadvantage of this approach is that it requires significant sedation, which may drastically prolong the time before the appropriate for intraoperative testing level of alertness is achieved.

Older techniques comprised of regional blockade and sedation with spontaneous ventilation and with an unprotected airway. Agents, such as midazolam, fentanyl, droperidol and propofol were used. These agents often resulted in failed or prolonged intraoperative testing, hypoventilation and airway obstruction. An infusion of a newer synthetic opioid remifentanil with a very short elimination half-time was successfully used in combination with light propofol sedation with a very low rate of respiratory or airway complications [3]. All of these approaches require premedication with antiemetics, e.g. ondansetron to avoid intraoperative nausea and vomiting.

Local Anesthesia for Awake Craniotomy.

A thorough and expert performance of scalp blocks is imperative for successful anesthesia for awake craniotomy. Various approaches to produce local anesthesia for awake craniotomy are used. It may be achieved by a field infiltration block of the incision area and directly under where the head clamp pins are placed. This approach requires large amounts of local anesthetic solutions in order to produce reliable anesthesia, thus creating a potential for local anesthetic toxicity. Blockade of the nerves that innervate the scalp uses anatomical approach and provides superior and more reliable analgesia with less overall amount of local anesthetic. These nerves include auriculotemporal, zygomaticotemporal, supratrochlear, supraorbital, greater auricular, and greater and lesser occipital nerves. More detailed instruction about how to identify and block these nerves can be found in the excellent review by Costello et al [3]. Sedation with propofol and opioid of choice should be initiated prior to skin injections to alleviate distress associated with it.

Long acting local anesthetics bupivacaine and ropivacaine (0.25 – 0.75%) have been successfully used for these blocks. Use of epinephrine in 1:200,000/400,000 dilution is recommended. Ropivacaine is less cardiotoxic and has been advocated by some as a local anesthetic of choice.

Intraoperative complications and their treatment.

Oversedation and hypoventilation are the most frequent and serious complications of awake craniotomy. This is often accompanied by airway obstruction and hypercapnia and hypoxia. This in turn is likely to cause increase in the cerebral blood flow and brain swelling. These problems should be anticipated and emergency plans for management of the compromised airway and hypoventilation during awake craniotomy made in advance. For example, emergent placement of laryngeal mask airway could be successfully accomplished in the majority of cases. In this patient an assembly made out of two nasopharyngeal airways connected to a double-lumen tube adaptor was placed before surgery. This airway could be easily tolerated following topicalization of nasal passages with lidocaine gel and do not interfere with speech. This assembly is easily connected to the anesthesia machine circuit allowing delivery of up to 100% oxygen and of positive pressure ventilation (if necessary).

Brain swelling in this patient was most likely caused by hypercapnia, which was confirmed by voluntary hyperventilation. However, other potential causes of acute brain swelling need to be ruled out, even when the explanation seems to be obvious. These include significant hypoxemia, severe hypotension or hypertension, impaired cerebral venous outflow, accidental overhydration, acute intracerebral bleeding.

Unique pharmacokinetic characteristics of remifentanil allowed rapid offset of sedation and respiratory depression in this patient. Remifentanil has very short onset and offset time at the effector site. This time is not dependent on the time of infusion. For example, context sensitive 50% and 80% decrement time after two and four hours of infusion does not change, staying less than 3.5 min and 10 min respectively. Propofol, conversely, does accumulate and its 80 % decrement time will increase dramatically during prolonged infusion. However, its context sensitive half-time is less affected by the duration of infusion and is less than 10 min after two hours of infusion. Therefore sedative effects of combined remifentanil/propofol infusion can be rapidly offset thus minimizing the deleterious effects of oversedation.

Postoperative management.

Most patients undergoing awake craniotomy are completely awake and hemodynamically stable at the end of surgery in no need of respiratory support. Neurological assessment is readily available in these patients. This creates a potential for minimizing ICU related expenses by accomplishing immediate postoperative recovery in the PACU. Indeed, in some centers uncomplicated awake craniotomy is followed by an early or even the same day discharge[1]. However caution is advised and selection criteria need to be stringent.

References

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3. Costello TG, Cormack JR. Anaesthesia for awake craniotomy: a modern approach. J Clin Neurosci. 2004;11:16-9.

Learning Summary

Discuss indications for awake craniotomy and patients selection criteria.
Establish an optimal anesthetic plan for this procedure, choice of regional anesthesia, intravenous agents for sedation and analgesia.
Discuss complications anticipated with this procedure, optional approaches to their management.
Discuss pharmacokinetics of remifentanil and its use in spontaneously breathing patients.