Original Article

Anaesthetic Management of Awake Craniotomy for Tumour Resection

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Abstract

Introduction: Awake craniotomy allows accurate localisation of the eloquent brain, which is crucial during brain tumour resection in order to minimise risk of neurologic injury. The role of the anaesthesiologist is to provide adequate analgesia and sedation while maintaining ventilation and haemodynamic stability in an awake patient who needs to be cooperative during neurological testing. We reviewed the anaesthetic management of patients undergoing an awake craniotomy procedure. Materials and Methods: The records of all the patients who had an awake craniotomy at our institution from July 2004 till June 2006 were reviewed. The anaesthesia techniques and management were examined. The perioperative complications and the outcome of the patients were noted. Results: There were 17 procedures carried out during the study period. Local anaesthesia with moderate to deep sedation was the technique used in all the patients. Respiratory complications occurred in 24% of the patients. Hypertension was observed in 24% of the patients. All the complications were transient and easily treated. During cortical stimulation, motor function was assessed in 16 patients (94%). Three patients (16%) had lesions in the temporal-parietal region and speech was assessed intraoperatively. Postoperative motor weakness was seen in 1 patient despite uneventful intraoperative testing. No patient required intensive care unit stay. The median length of stay in the high dependency unit was 1 day and the median length of hospital stay was 9 days. There was no in-hospital mortality. Conclusion: Awake craniotomy for brain tumour excision can be successfully performed under good anaesthetic conditions with careful titration of sedation. Our series showed it to be a well-tolerated procedure with a low rate of complications. The benefits of maximal tumour excision can be achieved, leading to potentially better patient outcome.

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Key words: Brain neoplasm, Neurosurgery, Postoperative complications

Introduction

Historically, surgery for intractable epilepsy was performed with the patient awake for at least some part of the procedure to facilitate cortical mapping and satisfactory, safe excision of the epileptogenic focus. Awake craniotomy for resection of brain tumours is a less common but increasingly performed operation. While the availability of modern frameless stereotaxic and neuronavigational guidance systems has made intraoperative tumour localisation more precise, it cannot replace awake intraoperative neurological testing. By performing the resection with the patient awake, aggressive and potentially total gross tumour resection under the operating microscope may be possible and at the same time minimise damage to the eloquent cortex.

Anaesthetic techniques for awake craniotomy have evolved over the years and now include local anaesthesia and conscious sedation or general anaesthesia with intraoperative wake-up. The challenge of anaesthetic management in an awake craniotomy is to have the patient comfortable enough to remain immobile throughout the procedure and yet sufficiently alert and cooperative to comply with neurological testing during surgery. The availability of short-acting anaesthetic drugs has increased the armamentarium of neuroanaesthesiologists in the perioperative management of this challenging procedure.

We undertook a review of awake craniotomies for tumour resection in our institution to determine variations in

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anaesthetic management, intraoperative complications and postoperative outcome.

Materials and Methods

We reviewed the anaesthetic management of consecutive patients who had undergone awake craniotomy for tumour surgery in our institution over a 2-year period. Approval was sought and granted by our institution's domain-specific review board. Patients were identified from the neurosurgical operating room records. The medical records of these patients were examined. The patient's characteristics and histological diagnosis were recorded. The anaesthesia records, operation notes and the postoperative notes were also reviewed to determine the incidence of complications, recovery profile and outcome, including high-dependency or intensive care unit stay and length of hospital stay. Inadequate or excessive sedation, pain, nausea or vomiting, oxygen saturation <90%, airway obstruction and haemodynamic instability were classified as anaesthetic complications. Seizures, brain swelling and new neurological deficits were classified as neurological complications.

Results

During the study period from July 2004 till June 2006 (2 years), 17 patients underwent an awake craniotomy procedure for excision of brain tumour in our institution. The characteristics of the 17 patients are shown in Table 1. The complications are shown in Table 2. There were 8 male and 9 female patients, with a median age of 40 years (range, 19 to 74). The median duration of procedure was 240 minutes (range, 120 to 420).

All procedures were performed under local anaesthesia with conscious sedation. Non-invasive blood pressure, electrocardiography, pulse oximeter, respiratory rate using impedance plethysmography (AS2/3 M-NESTR Module, Datex-Ohmeda, Bromma, Sweden) or nasal canula CO_2 sampling were routinely monitored for all the patients. Supplemental oxygen was given during the procedure. Intraarterial blood pressure was monitored in 53% of the patients and urine output was measured in 42% of the patients. Midazolam was given for anxiolysis in 29% of the patients. Anti-convulsant therapy and dexamethasone were continued perioperatively. Propofol infusion (15 of 17 patients) was titrated to keep the patient comfortably sedated while maintaining spontaneous respiration. Small boluses of fentanyl (25 to 50 mcg aliquots) were administered before skin infiltration of 0.75% lignocaine with 0.25% bupivacaine and placement of head fixator pins. Remifentanil infusion (0.005 to 0.02 mcg/kg/min) was used concurrently in 13 of 17 patients. Infiltration of the scalp flap was achieved with 0.75% lignocaine (1:200,000 adrenaline) with or without 0.25% bupivacaine. The supraorbital nerve, zygomatico-temporal and auriculotemporal nerves were blocked in an anterior band block from the supraorbital ridge, along the zygomatic arch to the anterior of the tragus of the ear. The greater and lesser occipital nerves were blocked posteriorly in a band extending laterally from the depression lateral to the inion in the superior nuchal line to just behind the ear. During the raising of the scalp and bone flaps, frequent adjustment of the depth of sedation was necessary to ensure the patient's comfort. Depth of sedation was titrated to avoid upper airway obstruction or sonorous respiration as this carries a risk of hypoventilation, with subsequent hypercapnia, cerebral hyperaemia and a tense brain. The patients were allowed to awaken fully by stopping all infusions prior to neurological testing.

Table 1. Patient's Characteristics

Characteristic	No.	%
Gender		
Male	8	47
Female	9	53
Location		
Frontal	9	52
Fronto-parietal	3	18
Parietal	2	12
Temporal	3	18
Histology		
Astrocytoma (Grade 2)	1	6
Glioblastoma multiforme (Grade 4)	3	18
Oligodendrioglioma (Grade 2)	4	24
Pleomorphic xanthoastrocytoma (Grade 2)	2	12
Ependymoma (Grade 3)	1	6
Metastases	3	18
Others (abscess, haematoma, toxoplasmosis)	3	18
Patient's position during procedure		
Supine	13	76
Lateral	4	24
Arterial blood pressure monitoring		
Yes	9	53
No	8	47
Urinary catheterisation		
Yes	7	41
No	10	59
Use of mannitol		
Yes	11	65
No	6	35
Drugs used (alone or in combination)		
Fentanyl	12	71
Remifentanil	13	76
Propofol	15	88
Midazolam	5	29
Morphine	1	6

Table 2. Anaesthetic and Neurological Complications

Complication	No.	%
Anaesthetic complications		
Respiratory		
Oxygen desaturation (<90%)	3	18
Apnoea (>15 seconds)	1	6
Airway obstruction	0	0
Haemodynamic		
Hypertension (SBP >160 or DBP >90)	4	24
Hypotension (SBP <90)	0	0
Bradycardia (HR <60)	0	0
Tachycardia (HR >120)	0	0
Others		
Intraoperative pain	3	18
Restlessness	1	6
Intraoperative nausea/vomiting	1	6
Conversion to general anaesthesia	0	0
Postoperative		
Pain	7	41
Nausea/vomiting	2	12
Neurological complications		
Intraoperative		
Brain swelling	2	12
Seizure	0	0
Neurological deficits	0	0
Postoperative		
Haematoma	0	0
Seizure	2	12
Transient neurological deficits	5	29
Persistent neurological deficit	1	6

DBP: diastolic blood pressure; HR: heart rate; SBP: systolic blood pressure

Brain mapping was done after exposure of the pial surface and confirming the location of the lesion with a frameless stereotactic guidance system (Stealthstation Treon, Medtronics, Louisville, CO). The Ojemann stimulator was used for bipolar cortical stimulation (Radionics, Burlington, MA). During motor testing, the patients were assessed by the anaesthesiologists. Movements of the arm or legs were observed and communicated to the neurosurgeon and strength tested throughout the mapping procedure. Positive findings included the patient's inability to make specific movements when commanded or the presence of involuntary movements. Motor function was assessed in 16 (94%) patients where the lesions were deemed to be encroaching the motor areas. For lesions near the eloquent cortex essential for language, 3 patients (18%) were asked to count serially and to name the days of the week or lists of objects. Patients were observed for speech hesitation, arrest or dysnomia during cortical stimulation. After successful delineation of the vital cortical areas, depth of sedation was increased for patient comfort during the phase of tumour resection and wound closure. All the patients successfully completed the procedure under conscious sedation. No patient required a conversion to general anaesthesia during the procedure.

Documented oxygen desaturation (<90%) occurred in 3 patients (18%). One patient required assisted ventilation with a bag and mask when his oxygen saturation fell to 70%. Another patient required assisted ventilation with a bag and mask because of prolonged apnoea. His oxygen saturation, however, did not fall during that episode. Both occasions occurred immediately after small boluses of remifentanil (20 to 60 mcg) were given to the patients during the placement of the Mayfield head fixator. There was no documented airway obstruction in any of the patients and none required an airway adjunct.

Hypertension was a relatively common complication during the procedure. Four patients (24%) had systolic blood pressure above 160 mm Hg intraoperatively. Treatment with intravenous labetolol was needed in 3 patients. Hypotension was not encountered in this group of patients. Blood loss was not significant in any of the patients and none received blood transfusion. There was no documented bradycardia or tachycardia in the patients throughout the procedure. Other problems encountered in our patients included restlessness and confusion (one patient) and intraoperative pain requiring additional analgesia (3 patients). One patient developed nausea intraoperatively and was treated with intravenous ondansetron.

We were able to conduct neurological testing in all the patients. Resection of the tumour was stopped and some residual tumour was left behind in a patient who developed transient motor deficit during tumour resection. The brain was noted to be slightly swollen in 2 patients (12%) after lifting of the bone flap. This was treated with mannitol infusion (0.5 g/kg) but resection was not affected. There was no documented seizure during the procedure.

In the immediate postoperative period, 7 patients (41%) experienced mild to moderate pain. Two patients (12%) experienced nausea and were treated with intravenous ondansetron. Two patients had simple partial seizure that resolved spontaneously. Five patients (29%) had unilateral motor weakness contralateral to the side of the cortical lesion after the procedure despite uneventful intraoperative neurological testing. Persistent motor weakness was present in 1 patient (6%) upon discharge from hospital. There was no incidence of postoperative intracerebral haematoma in our series. Fourteen patients (82%) stayed in the high-dependency unit for 1 day whereas the other 3 patients (18%) were discharged to the general ward after routine observation in the post-anaesthesia care unit. The median length of hospital stay was 9 days (range, 3 to 77). One

patient had prolonged hospital stay of 18 days as a result of persistent unsteady gait. Another patient was hospitalised for 77 days following a diagnosis of a cerebral aneurysm that was subsequently clipped during the same admission. His late discharge was also partly due to the development of a urinary tract infection. There was no in-hospital mortality.

Discussion

Awake craniotomy for tumour surgery has recently become more popular.[1,2] It allows brain mapping and facilitates maximal tumour resection with decreased risk of neurological morbidity. Aggressive brain tumour resection offers many potential advantages, including increased probability of an accurate diagnosis, reduction of intracranial pressure, reduction of tumour burden as a prelude to adjuvant therapy and a decrease in the probability of de-differentiation of a lower grade tumour.[2] There has been data to suggest improved median survival time and later onset of recurrence.[2] However, this has to be balanced against the possibility of producing a life-altering neurological deficit. Resection of tumour close to the eloquent areas of the cortex can be most safely done in an awake patient, as this provides continuous feedback to the neurosurgeon on the integrity of neurological function. Continuous assessment of neurological function has also facilitated the excision of tumours that might otherwise be considered inoperable. There has been an increase in the number of awake craniotomy in our institution as well. During this study period of 2 years, 17 patients had undergone an awake craniotomy procedure. In comparison, for the preceding 5-year period from July 1999 till June 2004, only 6 such procedures were performed for brain tumour. However, ongoing developments in high-resolution functional magnetic resonance imaging (MRI), combined with advances in the intraoperative use of MRI, may reduce the need for awake craniotomy in the future.[3]

Preoperative Preparation

Provision of anaesthesia for awake craniotomy remains a challenge. Patient selection is important as not all patients will be able to tolerate an awake craniotomy. Confusion, decreased level of consciousness and communication difficulties (e.g., profound dysphasia or language barrier) and extreme anxiety are some contraindications to awake craniotomy. The average duration of the procedure was approximately 4 hours in our experience and hence the ability to lie still for a prolonged period of time must be considered. Patients with obstructive sleep apnoea, the morbidly obese and those with larger vascular tumours or tumours with significant dural involvement may pose additional challenges. Any pre-existing neurological deficits and medical problems should be identified during the preoperative visit. The patient should also be informed of the complexities and demands of an awake craniotomy. A good rapport should be established between the anaesthesiologist and the patient. The signs and symptoms that may indicate that the patient is experiencing a seizure should be noted. Medications such as steroids and anticonvulsants should be continued.

An awake craniotomy adds additional stress to the patient and the entire operating room team. All preparations should be completed before the patient arrives in the room. Staff should be aware of the presence of an awake patient by putting up signs on all entrances in the room and noise should be kept to a minimum. Staff movement should be restricted and a calm atmosphere maintained. Extra pillows, soft mattress and soft headrest should be available to ensure maximum patient comfort during positioning.

Routine monitoring of non-invasive blood pressure, electrocardiogram and pulse oximetry is essential. Capnography monitoring is also useful, primarily as a monitor of respiratory rate and overall adequacy of ventilation. Apnoea and airway obstruction may be detected by loss of the capnography trace. Invasive arterial blood pressure was monitored in 53% of our patients but with increased familiarity with the procedure, it is no longer routine to have an arterial blood pressure monitoring for the patient undergoing an awake craniotomy. Blood loss is generally not significant and the placement of a central venous catheter is not necessary. A urinary catheter is not routinely placed to minimise discomfort but should be considered at the onset if prolonged operation is anticipated or if there is a high probability of diuretic use intraoperatively. The intravenous catheter should be sited in the arm not used for neurological testing.

The use of neuronavigation necessitates the placement of patient's head in a rigid skull pin fixation system. Adequate local anaesthesia should be infiltrated prior to pin application. Supplemental intravenous analgesia and sedation is often required during local anaesthesia infiltration, as this can be very painful. Local anaesthesia infiltration and scalp blocks are usually performed by the neurosurgeon. Long-acting local anaesthetic agents such as bupivacaine with adrenaline are often used. Lignocaine may be given to areas that are still painful during the procedure, such as the dura. Successful use of ropivacaine has been described.[4]

Sedation Techniques

Many sedation techniques have been described for awake craniotomy. Unlike epilepsy surgery, intraoperative electrocorticography is not routinely done during tumour resection and hence there are fewer restrictions to the choice of anaesthetic agents use. The techniques of drug

administration and dosage requirements vary greatly and should be titrated to each patient's needs. Short-acting anaesthetic drugs that provide good conditions and ensure that the patient is alert for neurological assessment are preferred. Traditionally, intermittent boluses of fentanyl and droperidol were used.[5,6] Nowadays, a combination of propofol (continuous or target controlled infusion) and fentanyl or remifentanil is most commonly used.[7-10] Non-pharmacologic measures such as frequent reassurance and holding the patient's hand cannot be overemphasised. The sedation should be discontinued to ensure patient's cooperation for brain mapping.

Remifentanil, an ultra short-acting opioid, is becoming a popular choice.[8,9,11] Its rapid onset and short duration of action makes titration relatively easy and patients can be rapidly awakened for neurological testing. With careful titration, remifentanil provided a smoother haemodynamic profile.[8] A recent study compared the use of fentanyl with remifentanil in combination with propofol for awake craniotomy.[11] Both regimes provided effective sedation and control of pain. The main disadvantage of remifentanil was hypoventilation. Respiratory complications occurred in 18% of patients but these were usually brief and easily treated.[11] Overdosage of remifentanil is also associated with hypotension and bradycardia. Remifentanil infusion is increasingly being used for awake craniotomy in our institution (76%).

Dexmedetomidine is a selective $\alpha 2$ adrenoreceptor agonist. Unlike the opioids and propofol, dexmedetomidine has been shown to provide sedation and analgesia without significant respiratory depression. It also reduces the intraoperative and postoperative anaesthesia requirement. Patients sedated with dexmedetomidine typically appear to sleep comfortably but are easily arousable to verbal stimuli. It has been used successfully in patients undergoing awake craniotomy.[12-14] However, there were some concerns of impaired neurocognitive testing after stopping dexmedetomidine infusion.[14] Hypotension and bradycardia are common side effects of the drug. Dexmedetomidine is currently not used in our institution.

Asleep-awake-asleep Technique

An alternative technique involves the induction of general anaesthesia with airway control during the craniotomy and closure. With a secured airway, deep anaesthesia can be achieved without compromising the patient's safety. Excellent operating conditions can also be achieved with control of ventilation. The patient is fully awakened for intraoperative neurological evaluation. This technique is suitable for patients who are not able to tolerate craniotomy with sedation alone, especially the longer procedures. This technique has been used in paediatric patients.

Numerous combinations of drugs and airway adjuvant have been used for asleep-awake-asleep procedures. A combination of propofol and remifentanil infusion is currently popular as it is allows the levels of anaesthesia to be easily titrated and provide fast and reliable wake-up.[7] The use of target-controlled infusions and depth of anaesthesia monitoring have further improved the safety and effectiveness of this technique.[7] The laryngeal mask airway (LMA) is now most commonly used during the "asleep" phase of this technique.[7,15] Patients can either be breathing spontaneously or mechanically ventilated; the ProSeal LMA may be a better choice than the classic LMA in the latter case.[16] The drugs are stopped and the patients allowed to wake up after the initial craniotomy and dural opening. Neurological testing is performed once the patient is awake and cooperative. Following completion of the testing and resection of tumour, general anaesthesia is re-induced and the airway repositioned before wound closure. Other techniques of airway placement described include awake insertion of LMA under topical anaesthesia, the use of the fibreoptic bronchoscope to assist in LMA placement, fibreoptic-assisted endotrachael intubation and the use of cuffed oropharyngeal airway.[16,17] In our series, techniques involving sequential manipulation of the airway were not used.

Complications

Respiratory depression and airway obstruction are the inherent risks associated with sedation. Severe respiratory depression may lead to hypercapnia and brain swelling. Skucas and Artru[18] studied the complications in over 300 patients who had awake craniotomy for epilepsy surgery, and found that 5 patients (1.5%) had oxygen saturation of less than 90%. A body mass index >30 was cited as a risk factor for oxygen desaturation.[18] Patients placed in the lateral position are less likely to have airway obstruction. In our series, most of our patients were placed supine both for patient comfort as well as for surgical access. Three of our patients had transient desaturation. This is comparable to other series.[11] It is important to recognise airway obstruction as this can lead to oxygen desaturation, hypercapnia and brain swelling. Immediate management includes decreasing sedation, jaw thrust or use of an airway adjunct. Nasopharyngeal airway can be used early to relieve airway obstruction. Equipment for emergency airway control should be available throughout the procedure. Options include intubation under direct vision, blind nasal intubation, fibreoptic-assisted intubation and LMA insertion. This should be planned ahead of the procedure.

Haemodynamic instability was reported to be more common in awake craniotomy than craniotomy under general anaesthesia.[8,18] Hypertension was commonly reported during the application of the head fixator. However,

there were no negative sequelae to the patients from the haemodynamic changes. Additional analgesia and sedation may be given for pain. Occasionally, intravenous antihypertensive agents may be needed. Three patients in our series had intraoperative hypertension that required treatment with intravenous labetolol. Excessive blood loss and hypotension were uncommon.

Intraoperative seizures are a risk with this procedure. The incidence of intraoperative seizures has been quoted as 3% to18%.[7,18] The incidence of intraoperative seizure may be more frequent in patients with epilepsy than with brain tumour. Most seizures occurred during brain mapping or tumour resection, correlating with periods of cortical stimulation. None of the patients in our series developed seizures intraoperatively. For some patients, there may be a prodrome that precedes the onset of seizure; hence, it is useful for the patient to be primed preoperatively to alert the anaesthesiologist if this occurs. Immediate management to terminate the seizure includes cessation of cortical stimulation and irrigation of the brain surface with cold saline. Patient should be protected from injury. Supportive measures to maintain patent airway, assist ventilation and maintain cardiovascular stability should be instituted.

Patients undergoing a craniotomy frequently experience nausea and vomiting. Surgical stimulation including manipulation of the dura, the temporal lobe and the meningeal vessels may cause nausea and vomiting. Keifer et al[9] reported 8 patients out of 98 patients (8%) having nausea during an awake craniotomy. In our series, 1 patient (6%) complained of nausea during the procedure. In the postoperative period, 2 patients had nausea and required treatment with intravenous ondansetron. Manninen and Tan[19] reported the incidence of postoperative nausea and vomiting after awake craniotomy for tumour surgery to be less than that after general anaesthesia. They postulated that the use of propofol, which is an effective antiemetic, and the avoidance of high doses of opioids were contributory factors. Headache was a common complaint both intraoperatively as well as postoperatively. Three patients (18%) from our series experienced headache that required supplemental analgesia. Keifer et al[9] reported an incidence of 16% in their patients. Postoperatively, 7 (41%) patients in our series experienced pain that required treatment. Intravenous fentanyl was effective in treating postoperative pain.

Venous air embolism during awake craniotomy is an uncommon complication. Balki et al[20] reported an incidence of 0.64%. It is more likely to occur in circumstances when there is high negative intrathoracic pressure, including deep inspiration with or without airway obstruction, and in the upright position.[20] Presentation may be varied, including coughing, dysrhythmias, hypotension, chest pain, hypoxaemia and reduction in end-expiratory CO_2.[20] Diagnosis is generally less obvious as monitoring in awake patients tends to be less comprehensive. Early suspicion and treatment, including placing the patient in Trendelenburg's position, is essential.

Transient neurological deficit may occur after brain tumour resection due to oedema and inflammation around the operation site. Five patients developed neurological deficit after the operation and 4 completely recovered before discharge. One patient had persistent deficits. It should be noted that brain mapping may be less reliable in some patients, especially those with pre-existing neurological deficits.[1] Major neurological complications can still occur and vigilant postoperative observation must not be compromised. Other medical complications, including deep venous thrombosis, urinary tract infection and pneumonia, were infrequent but may be a cause of delayed discharge from hospital.

Conclusion

Awake craniotomy is a well-tolerated procedure with low rate of conversion to general anaesthesia and low rate of complications. Potential benefits to patient include avoidance of general anaesthesia and its attendant complications and potentially better neurological outcome. It also allows better resource utilisation; patients required fewer days in the high-dependency unit and had overall shorter hospital stays.[1,21] However, it is also important to recognise the potential problems in the anaesthetic management of awake craniotomy. Vigilant monitoring of the patient with frequent adjustments of the depth of moderate to deep sedation with adequate local anaesthesia to ensure patient safety and maximal comfort is crucial.

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