Anaesthesia for awake craniotomy is safe and well-tolerated

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ABSTRACT

INTRODUCTION: Awake craniotomy for tumour resection has been performed at Glostrup Hospital since 2004. We describe and discuss the various anaesthetic approaches for such surgery and retrospectively analyse the 44 planned awake craniotomies performed at Glostrup Hospital. The surgery falls into four phases: craniotomy, mapping, tumour resection and closing. Three methods are being used: monitored anaesthetic care, asleep-awake-asleep and asleep-awake (AA).

MATERIAL AND METHODS: Anaesthesia is induced and maintained with propofol and remifentanil. A laryngeal mask (LM) is used as an airway during the craniotomy phase. In the AA method, patients are mapped and the tumour is resected while the patient is awake.

RESULTS: A total of 41 of 44 planned AA craniotomies were performed. Three had to be converted into general anaesthesia (GA) due to tight brain, leaking LM and tumour haemorrhage, respectively. The following complications were observed: bradycardia 10%, leaking LM 5%, nausea 10%, vomiting 5%, focal seizures 28%, generalized seizures 10%, hypoxia 2%, hypotension 5% and hypertension 2%.

DISCUSSION: Our results comply well with the international literature in terms of complications related to haemodynamics, respiration, seizures, vomiting and nausea and in terms of patient satisfaction. Awake craniotomy is a well-tolerated procedure with potential benefits. More prospective randomized studies are required.

In awake craniotomy, the patient remains awake during part of or the entire surgery. Hersley performed awake craniotomy in local anaesthesia as early as 1886. In Denmark, awake craniotomy for epilepsy surgery has been performed for many years. Since 2004, this technique has also been applied at Glostrup Hospital for tumours situated near eloquent areas of the brain. Prior to resection of such tumours, the function of the brain cortex is mapped – usually by magnetic resonance imaging or positron emission tomography. In spite of their rapid development and precision, these methods may not be as good and precise as the peroperative mapping of cortical functions in the awake patient. During such mapping, the neurosurgeon applies electrical stimulation to the exposed brain cortex of the awake patient which allows the surgeon to monitor any sensory, motor and speech effects as well as any effects on more complex cognitive functions. Such mapping can also be performed during resection of the tumour, thereby allowing for maximal tumour resection whilst minimizing neurologic deficits (the resection is stopped if symptoms emerge). This gives the patient better postoperative quality of life. In addition, there is growing evidence that the degree of tumour resection correlates with survival and with tumour progression-free life expectancy [1]. We describe and discuss the different anaesthetic approaches in awake craniotomy, and retrospectively analyse the first 44 cases of planned surgery performed at Glostrup Hospital.

MATERIAL AND METHODS

Awake craniotomy comprises four phases

Phase one: Local anaesthetic (LA) is injected at the rigid pin fixation insertion sites as well as at the skin incision site. Relevant scalp nerves are blocked, and the patient is placed in the head holder. Subsequently, the craniotomy and opening of the dura are performed.

Phase two: Mapping of cortex in the awake patient.

Phase three: Tumour resection in the either (re-) anaesthetized or awake patient.

Phase four: Closing of the cranium and scalp in the either (re-)anaesthetized or awake patient.

Several anaesthetic methods can be used for awake craniotomy

Monitored anaesthesia care (MAC): The patient is sedated and remains spontaneously breathing throughout the entire procedure whereby risks related to general anaesthesia (GA), e.g. airway issues, are avoided [2]. The disadvantage of this approach is patient discomfort, especially in the first phase of the operation, despite relatively deep sedation. Heavy sedation can lead to airway obstruction, which is a serious complication because it is of paramount importance to avoid hypoxia and/or hypercapnia in these patients.

Asleep-awake-asleep (AAA) technique: The patient is anaesthetized during phase one. A laryngeal mask (LM) or an endotracheal tube (ET) is used for ventilation. During phase two, the patient is awakened and the LM

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TABLE 1

Background data.

Patients, n	44
Not awakened, n	3
Age, years, mean (range) Male, %	43 (19-69) 66
Female, %	34
Frontal, %	5
Temporal, %	17
Fronto-temporal, %	5
Parietal, %	17
Midazolam as premedication, %	5
Patients receiving remifentanil when necessary during the awake phase, %	85
Patients needing supplemental local anaesthetic, %	15
Max. remifentanil infusion during awake phase, microgram/kg/min., mean (range)	0.06 (0-0.42)
Average remifentanil infusion during awake phase, microgram/kg/min., mean (range)	0.03 (0-0.08)
General anaesthesia time, min., mean (range)	147 (75-312)
Awake time, min., mean (range)	166 (75-320)
Awake end-tidal CO_2, mmHg, mean (range)	5.19 (2.7-6.2)

TABLE 2

Complications.

Bradycardia, %	10
Leaking laryngeal mask, %	5
Nausea, %	10
Vomiting, %	5
Focal seizures, %	28
General seizures during the awake phase, %	10
Hypoxia, %	2
Hypotension, %	5
Hypertension, %	2

or the ET is removed. Mapping is performed while the patient remains awake. Upon mapping, the patient is re-anaesthetized and the LM or ET is reinserted [3]. The advantage of this technique is that the heavy sedation and the related airway problems during phase one are avoided. The LM or ET, however, must be replaced under difficult circumstances as the head is fixated and partly covered with sterile draping. Coughing and stress upon removal of LM or ET can increase the intracranial pressure or lead to protrusion of the brain. Additional mapping or monitoring of the neurological status during tumour resection is not possible.

Asleep-awake (AA) method: This method has been described in detail by Olsen [4] and is still being used at Glostrup Hospital. Potential candidates for awake craniotomy include those who have eloquent brain areas near the tumour. Once the neurosurgeon has identified a candidate, the patient is informed about the method and its benefits and risks. A thorough neuropsychological and pre-anaesthetic examination is performed. It is essential that patients are well-selected and prepared. Psychologically stable, well-cooperating patients are offered an awake craniotomy

Sedatives are rarely used as premedication because sedation may interfere with the mapping. The anaesthesia is induced and maintained with infusion of remifentanil and propofol. A LM is used as an airway. Antiemetics and paracetamol are administered after the induction of the anaesthesia. Often mannitol and methylprednisolon are given to reduce the risk of brain oedema. If there is a history of seizures, the patient is loaded with phosphenytoin.

Oxygen saturation, electrocardiography, end-tidal CO_2, invasive arterial blood pressure and diuresis are monitored. Hypotension is treated by means of ephedrine and phenylephrine. After anaesthesia induction, LA is performed. Next, the craniotomy is performed, the patient is awakened and the LM removed. Nasal prongs are placed to administer oxygen and monitor end-tidal CO_2. An infusion of a small dose of remifentanil is started if the patient feels any discomfort. The cortex is mapped by the neurosurgeon in close co-operation with the neuropsychologist. Subsequently, tumour resection is carried out, guided by further intermittent mapping. If the patient develops neurological deficits, the tumour resection is terminated or redirected. This option is a major advantage of the AA technique compared to the AAA technique. It is only occasionally necessary to re-anaesthetize the patient during closure, thus reducing airway management compared to AAA. After the surgery, the patient stays at the intensive care department, typically for 24 hours. We retrospectively analyzed the 44 patients who were anaesthesized with the AA method from May 2004 to March 2009 at Glostrup Hospital. Background data are provided in **Table 1**.

RESULTS

Three procedures were converted into GA. In one (obese) patient, it was impossible to obtain a tight LM (and the patient was eventually intubated). The second patient had respiratory depression during the final part of the awakening phase (causing protrusion of the brain and bradycardia) and the LM was therefore not removed. The third patient developed excessive bleeding from the tumour immediately after the craniotomy, and the operation was carried out in GA. There was one more case of a leaking LM, but the procedure was continued as an AA using an ET. Only in one case was mask ventilation necessary after the removal of the LM (due to respiratory depression late in phase four). We experi-

enced no clinical signs of LA toxicity. In postoperative interviews performed by the neuropsychologist, all the patients expressed satisfaction with the procedure and stated that they would be willing to go through the same procedure again, if necessary. The patients were generally satisfied with the procedure. Complications are listed in **Table 2**.

DISCUSSION

Craniotomy for a cerebral tumour aims to maximize tumour resection with as few side-effects on motor, sensory, language and cognitive functions as possible. A number of different anaesthetic approaches have been proposed for performing awake brain tumour surgery. The most frequently used anaesthesias in Europe for AAA and AA are propofol and remifentanil [5]. The rapid onset and fast removal of both drugs and the antiemetic properties of propofol make these drugs well-suited for awake craniotomy. A study comparing fentanyl plus propofol with remifentanil plus propofol found that patient satisfaction levels were similar in the two groups, but respiratory complications were twice as many as in a fentanyl group[6]. A comparison of the three opiates fentanyl, sufentanil and alfentanil administered with droperidol revealed no differences between them in terms of patient satisfaction or complications [7].

Airway management may present problems. When the patient is sedated and therefore at risk of respiratory depression, it may be difficult to mask ventilate or insert a LM or an ET because the head is fixated in the head frame. In procedures where the MAC method is used, these problems primarily arise in phase one where heavy sedation is often necessary because the patient is in much pain. The incidence of airway obstruction has been found to range from 0% to 20% and desaturation from 0% to 28% [6, 8]. In comparison, airway obstruction in the AAA and AA procedures was seen in 0-7% of cases, whereas desaturation was not reported [3, 9]. The incidence of respiratory complications decreased with increasing experience of the anaesthetic team [10, 11]. The most frequently used airway device for AAA and AA is the LM [12]. One study reported the incidence of leaking LM to be 4% [11]. Another technique has also been described in which a fibreoptic oral or nasal ET is applied during sedation equipped with a preformed tube with a special catheter around the cuff for the administration of LA. The tube can then be retracted from trachea during phase two to permit the surgeon to map speech, and the patient can be re-intubated using a tube exchanger or fibrescope for phase three [3]. Nasal bilevel positive airway pressure [13] or a cuffed oropharyngeal airway [14] have also been used successfully for this procedure.

The frequency of acute conversions from the awake phase to GA has been found to range from 0% to 6%. The most common cause of conversion was generalised seizures, but also tight brain, vomiting, agitation and prolonged apnoea have been shown to make GA necessary. There was a tendency towards more conversions to GA in the MAC studies, and towards fewer conversions as the experience of the anaesthetic team improved [3, 8-11, 15].

In a sedated patient whose head is fixated and who has no safe airway, nausea and vomiting during the operation may be problematic. The incidence of nausea has been estimated at 0-6% with a lower incidence when using propofol as compared to neurolept anaesthesia [6, 16, 17]. The incidence of vomiting was not registered in the majority of the studies reported here. Two studies reported the incidence to be 1.2-7%, the highest being Conte's AA study [11, 16].

Patient interviews show that pain in relation to cerebral surgery primarily derives from skin incision, craniotomy and pin insertion [18]. Thus, with respect to pain, the AA or the AAA seem both to be rational approaches.

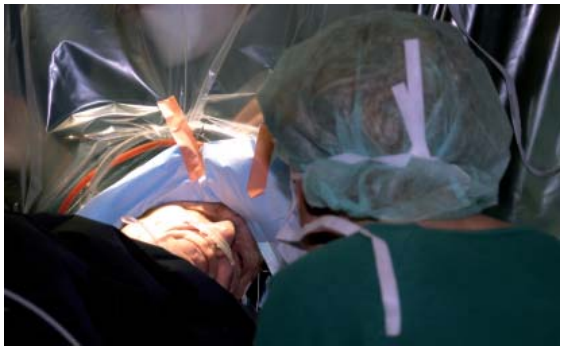
The incidence of preoperative epileptic seizures has been found to range from 0% to 32% [8, 11, 12, 16], with a tendency towards fewer seizures when using propofol than when using neurolept anaesthesia [19]. Irrigating the cerebrum with cold saline often causes seizures to subside. Five of our patients had an insufficient effect of this approach, and it was necessary to administer intravenous propofol or thiopental and, subsequently, phosphenytoin.

We encountered no problems with agitation. In the literature, the highest incidences have been reported for the MAC method (4-20%) [6, 8, 10], whereas the corresponding incidence rates for the AA and the AAA methods were 5-6% [9, 11]. The reason for this may be the use of GA during the painful phase one.

Haemodynamic instability as well as hypoxia and hypercapnia may cause protrusion of the brain through the craniotomy, which will complicate the surgical procedure. We observed only one such case. An explanation for this low incidence could be that 85% of our patients received mannitol. In MAC-based studies, the incidence of cerebral protrusion was 0-12%, whereas this phenomenon is not mentioned in the AA and the AAA studies [8-11, 17]. Thus, another explanation for this difference could be a relative hypoventilation in the sedated MAC patients.

Hypertension during the operation was found to be between 0% and 24% in MAC studies [6, 10, 17] and ranged from 0% to 27% in the AA and the AAA studies [9, 11]. Hypotension is reported with an incidence of 0-10% in MAC, AA and AAA studies.

In general, our complication rate is comparable with those reported in international studies published during the past decade.



An awake patient who is being tested by the neuropsychologist during tumour resection.

Two large Canadian studies with 200 and 610 patients, respectively, showed a one-month mortality of 0.5-1% and a morbidity, including neurological deficits, of 14.8-16.5% [2, 15]. Conte et al prospectively compared AA in a group of patients needing speech mapping with GA (intubated) in a group undergoing motor mapping. They found a tendency towards more anaesthetic complications in the AA group. On the other hand, fewer epileptic seizures were seen in the AA group. Neuro logical outcome was not registered [11]. The only prospective randomised study comparing awake craniotomy with GA included 53 patients. In the GA group, a surprising tendency was found towards better neurological outcome, shorter operation time and shorter hospital stay, and a statistically significantly shorter operation room time was observed. The steep learning curve for the team involved in awake craniotomy and the lack of mapping were considered possible reasons for this result [20]. Bearing this in mind, there is no other way to test language function besides awake surgery.

Most studies conclude that awake craniotomy is a generally well-tolerated procedure [6, 19, 21]. These findings are in accordance with our experience.

A large Canadian study comprising 200 patients undergoing surgery over a six-year period showed that with growing experience, the total hospital stay could be reduced from four days to a single day, the number of patients admitted to intensive care postoperatively could be reduced from 80% to 10%, and the mean surgery time could be reduced from 4.25 to 3.25 hours [2]. This seems to be in accordance with the findings by Gupta mentioned above [20].

The selective α-2-receptor agonist dexmedetomidine seems promising in relation to awake brain surgery, its unique properties being sedation, anxiolysis and analgesia without causing respiratory depression. It has yet to be approved in Europe.

In conclusion, when carried out by trained specialists, awake craniotomy for tumour surgery is generally a safe procedure. There are several potential advantages, e.g. maximum tumour resection with few side-effects and minimal drain on resources with reduced hospital stay and fewer intensive care unit admissions. Patients generally find the method acceptable and the patients are willing to go through it again if necessary. There is a need for large randomised studies that compare different forms of awake craniotomy (MAC, AAA, AA) with craniotomy carried out in GA.

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