Monitored Anesthesia Care in Awake Craniotomy for Brain Tumor Surgery

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Monitored anesthesia care during brain surgery was introduced more than 60 years ago for surgical treatment of epilepsy. The procedure was proposed mainly for patients whose pathology was located in the anterior temporal or frontal lobes, near motor, language, or memory areas of the brain [1]. Intraoperative cortical mapping during such "awake craniotomies" allows detection and sparing of these important brain regions. In recent years this technique of intraoperative brain mapping in the awake patient has been used more frequently, especially in patients undergoing surgery for resection of brain tumors located in close proximity to eloquent cortex [2–4].

Identification of cortical areas essential for motor or language functions can guide the surgeon during corticotomy and tumor resection and prevent significant functional disabilities. Moreover, identifying the functional brain regions may allow the resection of lesions that would otherwise be considered inoperable based on classical anatomical landmarks. Such landmarks have been shown to be inaccurate due to the variability in the anatomic location of brain functions and the displacement caused by the tumor mass itself. The cortical organization of language, for example, has been historically defined by correlating structural abnormalities caused by stroke or tumor, with resulting language deficits [5,6]. On this basis, Broca's area responsible for expressive aphasia was located in the posterior portion of the inferior frontal gyrus, and Wernicke's area responsible for receptive aphasia was located in the presilvian region in the temporoparietal cortex [7,8]. More recently, Ojemann et al. [9] used electrical stimulation mapping to demonstrate speech areas within 3 cm of the temporal lobe up in the superior and middle temporal gyri. No specific region of the temporal lobe cortex was found to be essential for language in more than 55% of 117 patients. Haglund et al. [10] found a similar variability in cortical language sites, and demonstrated that intraoperative mapping allowed for more extensive resection of gliomas.

Although this technique is beneficial, it requires a fully awake and cooperative patient during surgery and exposes the patient to several potential anesthetic hazards. While adequate analgesia and sedation are necessary during the painful initial stages of the procedure, the patient must be fully conscious and cooperative during the periods of brain mapping and tumor resection. Uncontrolled pain during head-frame positioning and craniotomy may lead to hemodynamic instability, emotional distress, and loss of cooperation on the part of the patient. Alternatively, excessive sedation may lead to hypoventilation and hypoxemia, both hazardous to the patient with intracranial pathology and increased intracranial pressure. Moreover, urgent endotracheal intubation for the management of airway, hypoventilation, or "tight brain" might be impossible in patients in the lateral position while the head holder tightly fixes the head. Other serious potential problems during surgery may include convulsions that may be caused by the cortical stimulation itself, nausea and vomiting, particularly associated with traction on the dura, and emotional distress leading to loss of control by the patient with an exposed brain.

One of the first reports describing anesthetic experience with awake craniotomy, and by far the one based on the largest experience, is the publication by Archer et al. [11]. In this article, the authors described retrospectively the experience with 347 procedures of awake craniotomy for cortical resection for epilepsy over a 7 year period. Anesthesia was based on local analgesia and intravenous fentanyl (1–2.4 μg/kg) and droperidol (0–40 mg). In addition, the majority of patients received methohexitone boluses to stimulate the cortical activity, and diazepam was used during closure of craniotomy in 42% of the patients. Despite the potential hazards, the authors reported a low incidence of major complications. The most common complications were seizures and nausea and vomiting, in 16% and 8% of the patients, respectively. Excessive sedation, sufficient to interfere with patient evaluation, occurred in 3% of the patients, local anesthetic toxicity in 2%, and "tight" brain in only 1.4%. Seven patients could not cooperate sufficiently

and anesthesia was converted to general anesthesia. Although no major complications occurred, this study is limited by the retrospective data collection, the non-invasive hemodynamic monitoring, and the fact that oxygen saturation and exhaled end-tidal carbon dioxide were not monitored.

In recent years, the development of new anesthetic drugs that offer easier titration between dose and effect, as well as a rapid and controlled recovery, has led to changes in the traditional opiate/droperidol-based sedation in patients undergoing awake craniotomy. The relatively new drug propofol was first suggested for this purpose in 1992 when Silbergeld et al. [12] published their experience in nine patients. Propofol offers the advantages of being a short-acting sedative with anti-emetic and amnestic properties in sedative doses [13,14], as well as its ability to reduce the incidence of intraoperative seizures without compromising the quality of electrocorticographic monitoring during awake craniotomy for seizures [15]. In another publication by Herrick et al. [16], propofol sedation in combination with fentanyl was compared to the more traditional fentanyl droperidol regimen in patients operated on for seizures. While levels of intraoperative sedation, patient satisfaction, and cognitive functions were similar in both groups, the incidence of transient hypoventilation was more frequent among the propofol-treated patients and intraoperative seizures were more common among the neuroleptic-treated patients.

Other groups studied the use of new opioids, characterized by a shorter duration of action, to replace fentanyl as part of the anesthetic protocol. Gignac and co-workers [17] compared fentanyl, sufentanil and alfentanil, in addition to droperidol during awake craniotomy for epilepsy. Although based on their pharmacokinetic and pharmacodynamic properties, the new opiates offer some theoretical advantages over fentanyl. The conditions for surgery, electrocorticography, and for stimulation testing were satisfactory in all patients. The main complications during this study were nausea and vomiting (15/30 patients), seizures (5/30 patients), oxygen saturation lower than 90% (3/30 patients), increase in end-tidal CO_2 above 45 mmHg (9/30 patients), and induction of general anesthesia (2/30 patients). None of the patients had a "tight" brain upon dural opening, and the conditions of the brain were satisfactory for surgery throughout the procedure in all patients [17].

Recently, Johnson and Talmage [18] described the use of the new short-acting opiate remifentanil in combination with propofol during awake craniotomy. Previous studies in patients undergoing surgery under local or regional anesthesia have demonstrated that remifentanil as compared to propofol provides similar intraoperative conditions and patient comfort at a lower sedation level [19,20]. In addition, when titrated to the same sedation level, remifentanil provided a smoother hemodynamic profile than propofol during regional anesthesia [21]. The main disadvantages of remifentanil in comparison to propofol are the higher incidence of hypoventilation [19–21] and the associated nausea and vomiting [20], complications that might be significant in patients undergoing brain surgery.

In our institution we have been performing awake craniot-

omy for brain tumor removal for the last 5 years at a rate of 15–20 patients a year (excluding patients undergoing awake stereotactic procedures or open brain biopsies). Based on the data published by others, mainly in patients undergoing surgery for epilepsy, and the experience gained with this type of surgery, a specific protocol has been developed and is now being implemented in all awake procedures. The protocol includes guidelines for the preoperative evaluation, as well as intraoperative management and postoperative care.

Preoperative evaluation

The decision to perform surgery for brain tumor removal with intraoperative mapping is made in cooperation between the surgeon and the anesthesiologist. The decision is based mainly on the location and the neurological deficits associated with the brain pathology. Lately, functional magnetic resonance imaging testing is performed in order to locate motor or speech areas and their anatomic relations to the brain pathology. Other factors influencing the decision are the patient's past medical history and his or her ability to cooperate during surgery. Medical conditions such as morbid obesity or obstructive lung disease may interfere with patient's ability to lie sedated for several hours without hypoxemia or hypercarbia. However, the balance between the possible benefits and risks is considered in each patient. In our experience, the advantages of intraoperative mapping in patients with selected brain pathologies are of such significance that most medical conditions are considered to be only relatively contraindicated, and surgery is performed with intraoperative mapping after preoperative evaluation and optimization of the patient's medical problems.

After a patient is found to be suitable for the procedure, and as part of the preoperative preparations, the patient is informed about the different stages of the procedure, and the different intraoperative cortical mapping tests for baseline measurements are introduced to the patient prior to surgery.

Premedication

Clonidine at a dose of 2–3 g/kg is given to the patient orally one hour before arrival at the operating room. Clonidine induces mild sedation, hemodynamic stability due to blunting of the adrenergic response, as well as analgesic and anti-emetic effects [22].

Oxygenation and ventilation

On admission to the operating room, and after sedation has begun, a nasal airway is inserted into the patient with proper local analgesia, and oxygen at a flow of 3 L/min is given nasally. Monitoring includes hemoglobin oxygen saturation measured by pulse oximetry, respiratory rate, and end-tidal carbon dioxide levels measured by capnography. A laryngeal mask airway, a laryngoscope, and an endotracheal tube are prepared routinely to be used in cases of significant hypoventilation or hypoxemia, or if there is a need to induce general anesthesia.

Hemodynamic monitoring

Electrocardiogram and invasive and non-invasive blood pressure measurements are done in all patients. Urinary catheter is used only for female patients; male patients usually complain about the discomfort caused by the catheter and prefer to use a bottle if necessary.

Sedation and analgesia

Intravenous propofol at an initial dose of 100 μg/kg/min is initiated on arrival at the operating room and titrated according to the patient's response. Remifentanil in an initial dose of 0.05 μg/kg/min is added to propofol 3–5 minutes before, and reduced to 0.01 μg/kg/min after placement of the head holder. Infusions of both propofol and remifentanil are adjusted by 25% increments in order to achieve a sedation score ⩾2, respiratory rate >8/min, and hemoglobin saturation ⩾95%. Before placement of the head holder and before skin incision, local analgesia is administered using bupivacaine 0.25% and lidocaine 1% with bicarbonate. Just before the dura incision, additional lidocaine is infiltrated along dural blood vessels to block pain perception within the dura.

Both remifentanil and propofol are discontinued before brain mapping is initiated, and are resumed at the beginning of closure of the dura. Propofol is resumed initially at a dose of 15 μg/kg/min, and remifentanil at an initial dose of 0.01 μg/kg/min is added only if the patient requires more than 25 μg/kg/min propofol.

Other medications

All patients are given preoperative antibiotics, dexamethasone, and anticonvulsants. Mannitol (0.25 g/kg) is administered during skull opening, and diclofenac (1 mg/kg) is given intramuscularly 30 minutes before the end of surgery. Labetalol in boluses of 5–10 mg is used to keep systolic blood pressure at a value lower than 150 mmHg with a heart rate of >50/min. Intravenous hydralazin is used when hypertension is concomitant with heart rate lower than 60/min.

Intraoperative brain mapping

No sedation is given during the phase of intraoperative cortical mapping. However, seizures may be evoked during electrical stimulation and these are handled with rapid irrigation of the cortex with ice water, which usually aborts seizure activity. If seizures persist, intravenous midazolam in 2 mg boluses is administered until seizure activity stops.

Other intraoperative considerations

Special care and attention are needed for patient positioning and draping for surgery, since the patient will need to stay awake in the same position for several hours when the head is rigidly held by pins. Moreover, the face needs to be in a position that allows the patient to look at pictures and objects during brain mapping, and is accessible for the treatment of airway and breathing emergencies. In order to improve the patient's cooperation special attention must be paid to the atmosphere in the operating room. Low temperatures are to be prevented and the patient should be actively heated; operating room personnel are instructed to speak only if necessary, and patients are allowed to drink small amount of water during surgery.

Postoperative management

At the completion of surgery, patients are routinely monitored for 2–3 hours in the recovery room and then in the neurosurgical intensive care unit for an additional period of 12–24 hours. Patients are usually discharged from the hospital on the 2nd to 3rd postoperative day.

Conclusion

Using this protocol, awake craniotomy for brain tumor removal is performed safely, as previously reported by others [2–4]. Hemodynamic and respiratory stability can be achieved, and the patient's cooperation permits the satisfactory completion of the procedure. Among all the patients operated in our hospital, in only one patient was general anesthesia and mechanical ventilation using laryngeal mask airway needed to control the patient's agitation, which led to over-sedation and hypoventilation. Nausea and vomiting, reported to be the most common complication (8–50%) in patients undergoing awake craniotomy for intractable epilepsy [4,5,8], were rare, most probably due to the anti-emetic properties of both propofol and clonidine. Seizures were a minor problem as well; induced by the electrical stimulation of the brain in most instances, they were early controlled with ice-water irrigation.

In summary, the anesthetic care during awake craniotomy for brain tumor removal allows for the safety and efficacy of the procedure without significant complications. Brain mapping during surgery can influence intraoperative decisions, guiding the place of corticotomy and the extent of tumor resection to achieve maximal tumor resection while minimizing the associated morbidity and the incidence of postoperative neurological deficits.

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