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Original article

Pain during awake craniotomy for brain tumor resection. Incidence, causes, consequences and management

D. Fontaine[a,b,*], F. Almairac[a]

[a] *Service de neurochirurgie, hôpital Pasteur, CHU de Nice, 30, avenue de la Voie-Romaine, 06000 Nice, France*
[b] *Fédération hospitalo-universitaire Inovpain, 06000 Nice, France*

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ABSTRACT

Introduction. – Awake craniotomy for brain tumor resection is usually well-tolerated and most of the patients are satisfied. However, in studies reporting the patients' postoperative perception of the awake craniotomy procedure, about half of them have experienced some degree of intraoperative pain. Pain was mild (intensity between 1 and 2 on the visual analogical score) short lasting in most cases, and did not challenge the procedure. Pain was reported as moderate in about 25% and exceptionally severe.
Methods. – We conducted a preliminary survey among French centers ($n = 9$) routinely performing awake craniotomy.
Results. – Neurosurgeons' opinions were concordant with patient's reports. Intraoperative pain exceptionally challenged the awake craniotomy procedure or led to changes in the resection strategy. For neurosurgeons, the most challenging causes of intraoperative pain were the patient's inadequate installation, the contact of surgical tools with pain-sensitive intracranial structures, especially the dura mater of the skull base, falx cerebri, and the leptomeninges of the lateral fissure and neighboring sulci.
Conclusion. – Strategies to deal with these causes included focusing the patient on the intraoperative functional tests to distract their attention away from the pain, and avoiding contacts with the pain-sensitive intracranial structures during the awake phase. Adequate preoperative patient information and preparation, trained anesthesiologists and application of recommendations for awake craniotomy procedures as well as adaptation of surgical technique to avoid contact with pain-sensitive intracranial structures are key factors to prevent intraoperative pain and ensure patient's postoperative satisfaction.

1. Introduction

Awake surgery (under local anesthesia) with cortical and subcortical direct electrostimulation is now considered the gold standard method for brain tumor resection in the so-called "eloquent" regions, especially for gliomas [1,2].

Intuitively, pain is a main preoperative concern for patients envisioning an awake cranial surgery for brain tumor resection [3]. However, the entire concept of awake craniotomy (AWC) with intraoperative brain functional mapping is based on the principle that this surgery is not painful, and that the absence of pain warrants the complete cooperation of the patient, and therefore the possibility to evaluate high level functions. Published studies from experienced centers reporting large series of patients operated under AWC do not mention intraoperative pain as a complication, rarely as a source of "discomfort", and never as a limit for functional-based tumor resection [4–6]. It is difficult to determine if such results reflect the reality, or reflect an experience-based refined pain management with reduction of the potential sources of intraoperative pain, or if intraoperative pain is just a taboo. In fact, these results contrast with several patient's reports describing some degree of intraoperative pain [7], and the observations of less experimented surgeons who had to deal with intraoperative pain during AWC.

2. Methods

In order to clarify this point, we analyzed the literature reporting the physicians and the patient's experiences, and we conducted a short survey in 9 voluntary French neurosurgical centers, performing at least 10 AWC procedures per year (mean 23.5 procedures/year; range 12–50) for many years (range: 3–20 years).

* Corresponding author.
E-mail address: fontaine.d@chu-nice.fr (D. Fontaine).

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2.1. Incidence of intraoperative pain

In previous studies investigating patient's responses to AWC, the rate of patients reporting intraoperative pain ranged from 43–56% [8,9]. Pain was reported as moderate by 20–24% of the patients [8–11] and severe by 5% [9]. These rates seemed higher in studies using an awake-awake procedure than in studies using an asleep-awake-asleep procedure [7]. However, in absence of a comparative study, no conclusion can be made on this specific point. In our survey, the only center using an awake-awake procedure did not report a higher incidence or severity of intraoperative pain. The occurrence of a post-traumatic stress disorder (PTSD) related to intraoperative pain or to the global AWC procedure is exceptional, although symptoms of PTSD may occur in 12% of the patients [7,12].

Recently, Beez et al. performed a prospective postoperative survey, asking 105 patients (mostly operated under asleep-awake-asleep procedure) to report their perceptions about intraoperative pain, discomfort and anxiety [11]. Pain intensity was estimated on a visual analog scale (VAS) from 0 (no pain) to 10 (maximal pain imaginable). Twenty-five patients out of 105 (23.8%) reported a pain exceeding 3/10 on the VAS. Global pain levels were 1.3 (range: 0–8) at the beginning, 1.9 (range: 0–10) in the middle, and 2.1 (range: 0–10) at the end of the awake phase.

However, all these estimations rely on the postoperative patient's impressions (from 1 day to 1 month after the surgery), which are subject to discussion considering that 2/3 of them have incomplete or no recollection of the intraoperative time afterwards [11]. As regards the neurosurgeon's point of view (who is at the same time a more reliable but biased witness), the first question of our survey was: "do your patients frequently complain of pain during AWC?". Three centers out of 9 answered "yes". The next question was: "what is the proportion of patients complaining from a significant/important pain during AWC?". The mean estimated proportion was 26.7% (range: 5–90%; median 25%), the variations possibly resulting from different surgical techniques and analgesic protocols used across centers.

Globally, these data suggest that, although AWC is well tolerated, pain may occur during the procedure, moderate in about one patient out of 4, and exceptionally severe [9]. How long this pain may last and how it would interfere with the surgical procedure was not reported in the literature.

2.2. Causes of intraoperative pain

Potential sources of intraoperative pain are numerous. In the patients' impressions, pain and/or discomfort resulted from head fixation (6%), from painful position on the operating table (12%), or from a painful surgical procedure (10%) [11,13]. In awake-awake patients, head fixation in the Mayfield head frame, administration of local anesthesia and scalp incisions were additional sources of pain [7]. About half of these patients remembered the craniotomy as the worst experience during the whole operation [3].

For neurosurgeons answering our survey, pain related to head fixation, skin incision and flap, manipulation of the dura mater of the calvaria were rare, mostly mild and easily fixed by additional injection of local anesthetics. The most frequent, severe and annoying causes of intraoperative pain were related to the patient's position (mean estimated intensity: 3.7 on a 10-point scale; range: 1 to 9/10), and related to the stretching or touching of painful intracranial structures (mean intensity: 6.5/10; range: 3–10) (Tables 1 and 2). The intracranial structures whose handling/touching may cause pain, cited by interviewed neurosurgeons, were the pachymeninges of the skull base (mean intensity: 7.9/10; range: 0–10) – especially the temporal base frequently interested during resections of temporal tumors – or the falx cerebri and tentorium (mean intensity: 4.2; range: 0–9),

Table 1
French neurosurgical survey. Replies from interviewed neurosurgeons to the following question: "among these potential causes of intraoperative pain, what are the most frequently involved? Please provide a score from 0 (never) to 10 (very frequent)".

Centre	1	2	3	4	5	6	7	8	9
Head fixation	0	0	4	2	0	3	1	0	1
Patient's installation	2	1	3	2	5	9	1	8	2
Skin incision	0	0	2	0	0	0	0	0	0
Skin flap	0	0	2	1	2	0	2	0	2
External dural convexity	0	0	2	0	0	0	0	0	0
Internal dural convexity	0	0	2	3	0	0	0	0	0
Dura of the skull base	4	10	6	9	10	9	6	0	8
Dura of the falx/tentorium	1	8	2	7	0	0	5	0	8
Perisylvian meninges	3	8	2	6	10	9	8	0	8
Non perisylvian structures	0	0	0	1	0	0	0	0	0

Table 2
French neurosurgical survey. Replies from interviewed neurosurgeons to the following question: "among these potential causes of intraoperative pain, what are the most painful? Please provide a score from 0 (not painful) to 10 (extremely painful)".

Centre	1	2	3	4	5	6	7	8	9
Head fixation	0	0	4	5	0	5	2	0	2
Patient's installation	3	1	3	2	3	9	2	8	2
Skin incision	0	0	2	0	0	3	0	0	0
Skin flap	0	0	2	2	5	0	2	0	3
External dural convexity	0	0	2	0	0	0	0	0	0
Internal dural convexity	0	0	2	5	0	2	0	0	0
Dura of the skull base	10	10	4	10	10	9	8	0	8
Dura of the falx/tentorium	6	5	2	9	0	3	5	0	8
Perisylvian meninges	9	2	1	8	10	9	10	0	8
Non perisylvian structures	0	0	0	1	0	2	0	0	0

but also the perisylvian leptomeninges, either within the lateral fissure or in the perisylvian sulci (mean intensity: 6.6; range: 0–10). Pain elicited by touching these structures was described as sharp, acute, intense and brief, disappearing when touching stopped, but usually recurring when touching them again.

Our knowledge about intracranial pain-sensitive structures in humans is partial and comes from initial observations from the pioneers of awake craniotomy and from animal headache models [14,15]. In 1940, Ray and Wolff described in 46 patients that electrical stimulation of the dura mater and the carotid arteries, but neither the brain parenchyma nor pia-arachnoid of the calvaria, evoked the perception of pain, referred in trigeminal V1 and occipital territories. Observations collected in our survey suggest that pia-mater or smaller vessels located in sulci close or distant to the lateral fissure, and even choroid plexus, may also be pain-sensitive in some patients, as suggested by recent models of migraine pathophysiology [15].

Consequently, in our survey, resections of temporo-insular and temporo-basal tumors, as well as tumors in contact with the falx cerebri (i.e. the supplementary motor area region for example) were more likely to induce pain than parietal or temporo-parietal tumors. The use of ultrasonic aspirator, especially with high power and close to the dura, was reported as an influencing factor on intraoperative pain.

2.3. Consequences and management of intraoperative pain

Although relatively frequent, intraoperative pain has not been reported as a cause of failure of the awake procedure in large series [4–6,16]. In most cases, reported pain was mild or easily fixed during the surgery. Prevention, experienced anesthesiologists and careful preoperative patient information and preparation appear to be key factors in reducing intraoperative pain and anxiety. The anesthetic protocol for asleep-awake-asleep procedure has been extensively described [16–18] and prevents pain related to skin

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