British Journal of Neurosurgery, June 2011; 25(3): 391–400

informa
healthcare

ORIGINAL ARTICLE

The experience of patients undergoing awake craniotomy for intracranial masses: expectations, recall, satisfaction and functional outcome

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Abstract

Introduction. Awake craniotomy is a well-established neurosurgical technique for lesions involving eloquent cortex, however, there is little information regarding patients' subjective experience with this type of surgery. Here we explore the expectations, recall, satisfaction and functional outcome of patients undergoing awake craniotomy.

Methods. Three semi-structured interviews using closed- and open-ended questions were conducted with each of 26 consecutive patients (17 males, 9 females; aged 16–78 years) who underwent their first awake craniotomy between 2007 and 2009. Seven patients were interviewed retrospectively, 19 prospectively. Clinical data are included.

Results. The following themes emerged from this study: (1) most patients demonstrated a good understanding of the rationale behind awake craniotomy; (2) patients felt the asleep–awake–asleep anaesthetic protocol used in this series was appropriate; (3) patients' confidence and preparedness for surgery was high, attributed to preparation by the surgical team. Seven of 26 (27%) patients had no recollection of being awake. Most patients had a positive anaesthetic and surgical experience, while a minority of patients reported experiencing more than slight pain (2/26; 8%) and discomfort (3/26; 12%), fear (4/26; 15%) or claustrophobia (1/26; 4%) intra-operatively. At follow-up (6 weeks post-operatively), most patients were functionally unimpaired; there was only one permanent neurological complication of surgery. We found that 24/26 (92%) patients were satisfied with their experience; one patient had no opinion and another one was unsatisfied. Five of 26 (19%) patients still reported more than slight discomfort, and 3/26 (12%) reported more than slight pain attributable to the surgery. A summary of the English peer-reviewed literature on the patient experience of awake craniotomy is also incorporated.

Conclusions. This study confirms that awake craniotomy using the 'asleep–awake–asleep' anaesthetic protocol is a generally safe and well-tolerated procedure associated overall with satisfactory patients' experiences and neurological outcomes.

Key words: *Awake craniotomy, brain tumour, cerebrovascular disease, outcome, patient experience.*

Abbreviations: *AKPS, Australia-modified Karnofsky performance status, DT, diffusion tractography, DTI, diffusion tensor imaging, DVT, deep venous thrombosis, fMRI, functional magnetic resonance imaging; MR, magnetic resonance; MRS, magnetic resonance spectroscopy; TIVA, total intravenous anaesthesia; WHO, World Health Organisation.*

1. Introduction

'Awake craniotomy' is a safe and well-established procedure used during surgery for intracranial masses that involve or abut eloquent brain regions. As the term implies, the patient is conscious and functionally testable during the procedure. The key advantage of awake craniotomy over its traditional 'asleep' counterpart is that it may allow the surgeon to minimise the risk of permanent neurological complications through real-time neurological testing as the resection proceeds[1–4]. Thus many lesions that would otherwise be deemed 'higher risk' of permanent deficit owing to their location may be more amenable to surgical resection using this approach (Fig. 1). Based on the findings of a retrospective cohort-matched comparison of awake versus asleep craniotomies that favoured the awake cohort[4], it has recently been proposed that a prospective randomised clinical trial be carried out to compare variables such as length of hospital stay, overall hospital cost and perioperative morbidity between awake and asleep craniotomy patient groups.[4]

While awake intracranial surgery has been performed for over 50 years[5] and is regarded as being generally well-tolerated by patients,[6–8] few studies

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Received for publication 1 September 2010. Accepted 27 February 2011.

ISSN 0268-8697 print/ISSN 1360-046X online © 2011 The Neurosurgical Foundation
DOI: 10.3109/02688697.2011.568640

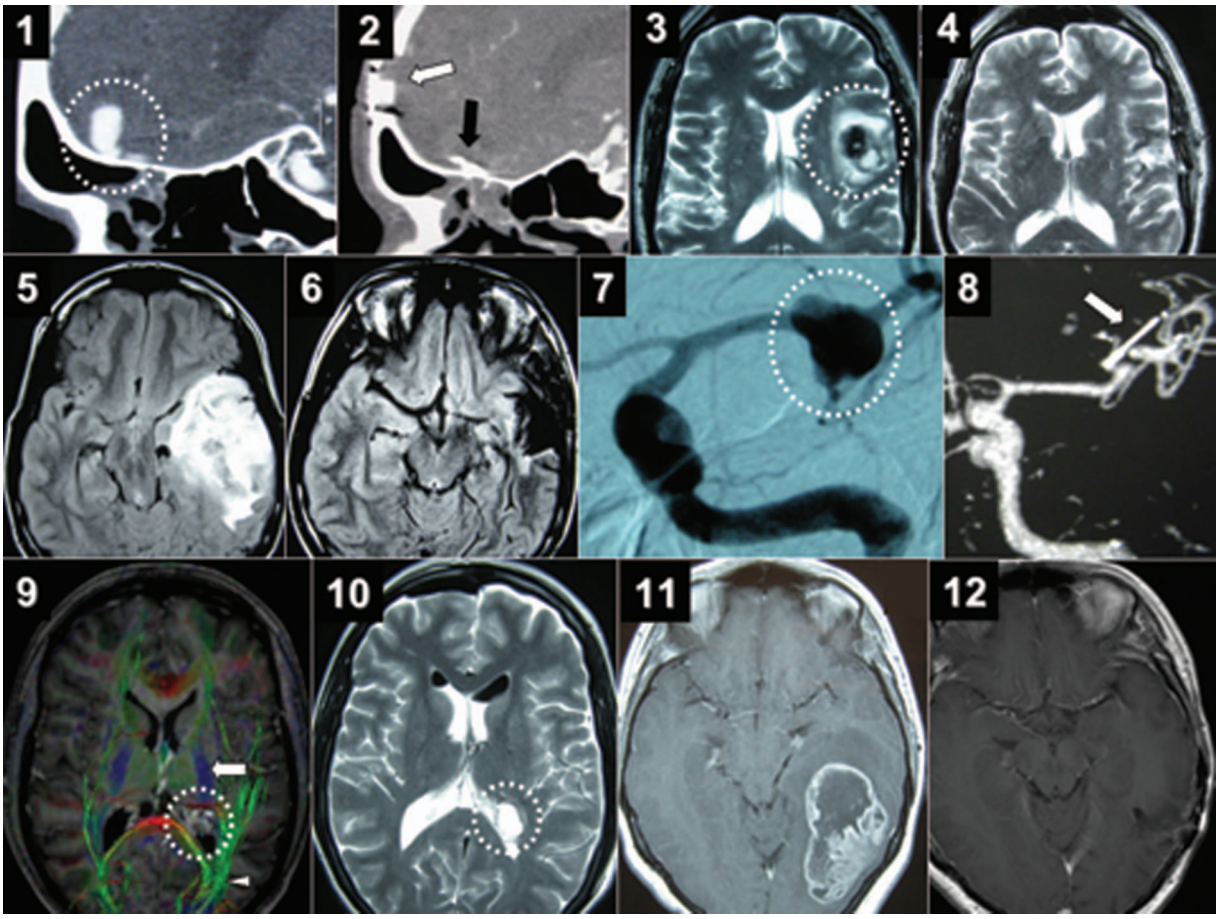

FIG. 1. Collage of paired pre- and post-operative images representing a variety of pathologies surgically treated with patients awake in this series (Patients 1, 4, 12, 14, 15 and 16, respectively, in Table I). Patient 1 – awake for vision: Orbitofrontal dural arteriovenous fistula threatening vision pre-operatively. Pre-operative sagittal CT angiogram (1) shows fistula vessels and venous aneurysm in circle. Post-operative CT angiogram (2) shows frontal mini-craniotomy (white arrow) and surgical clips (black arrow). Patient 4 – awake for language: Broca area cavernoma presenting with progressive dysphasia. Pre-operative (3) and post-operative (4) axial T2 MRI. Patient 12 – awake for language and movement: insula anaplastic oligodendroglioma with recent impending herniation. Pre-operative (5) and post-operative (6) axial FLAIR MRI. Patient 14 – awake for language and movement: Fusiform middle cerebral artery aneurysm presenting with thromboembolic events. Pre-operative (7) catheter angiogram and post-operative (8) CT angiogram (white arrow shows aneurysm clips). Patient 15 – awake for vision and movement: Left atrial cavernoma presenting with headache. Pre-operative (9) contrast axial T1 MRI with tractography. Lesion shown in circle. Tract lateral and posterior to lesion = optic radiation (arrow head). Tract anterior to lesion = posterior limb of internal capsule (arrow). Post-operative (10) axial T2 MRI following excision.Patient 16 – awake for language and vision: Left temporal-occipital lobe glioblastoma multiforme presenting with dysphasia. Pre-operative (11) and post-operative (12) contrast axial T1 MRI. The patient is currently free of macroscopic tumour at 27 months post-op.

have formally assessed the patient's perioperative experience.[9–11] The focus of our study was to assess the expectations, recall, satisfaction and functional outcome of 26 consecutive patients undergoing awake craniotomy using the 'asleep–awake–asleep' protocol[6,7] at our institution.

2. Methods

2.1. Study design

This study examined all awake craniotomies performed at our institution from 2007 to 2009 inclusive. This required a combined retrospective and prospective approach. The study design and the interview questionnaire (Appendix) were approved by the Ethics Committees at both The Canberra Hospital and Australian National University. Each patient gave informed consent.

2.2. Patient population

Patients enrolled into this study were deemed by the corresponding author (VGK) to be at moderate-to-high risk of post-operative neurological deficits if surgically treated in the conventional 'asleep' mode, owing to the eloquent location of their intracranial pathologies (Fig. 1). Seven patients had undergone their awake craniotomy prior to the start of the study and were recruited retrospectively via telephone. Another 21 patients underwent the operation after the study commenced and were recruited prospectively. Of the 28 eligible and consecutive patients, one was excluded due to significant dysphasia at presentation that precluded an appropriate interview; another declined to participate. Two of the enrolled patients underwent a second craniotomy during the period of this study. However, they were only surveyed regarding their first awake operation. Where appropriate,

magnetic resonance (MR) diffusion tensor imaging (DTI) of subcortical white matter tracts, language and motor cortical functional MR imaging (fMRI) and/or MR spectroscopy (MRS) were used as part of the pre-operative workup.

2.3. Intra-operative procedures

Awake craniotomy was performed using an *asleep–awake–asleep* anaesthetic technique[6] involving propofol and remifentanil infusions (total intravenous anaesthesia; TIVA). Adjunctive medications included clonidine and dexamethasone. Circumferential local anaesthetic nerve blocks[12] and infiltration of the planned craniotomy incision and Mayfield head-holding pin sites were instituted during an initial period of deep sedation. Positioning of the head in pins was a compromise between optimising surgical exposure, patient airway and patient comfort. In this regard, supine with maximum 45° head rotation, minimal neck flexion and a small shoulder support were used. TIVA was ceased following head fixation to check that the patient was comfortable (i.e. a very brief 'awake' time of approximately 5 min), then re-started and continued during craniotomy. In order to facilitate patient comfort and avoid startling during the awake period, no calf compressor, indwelling urinary catheter (patients were asked to void immediately prior to the procedure) or blood pressure cuff was used, and minimal IV fluids were administered. Following dural opening, the depth of anaesthesia was significantly reduced to levels of light sedation and the intracranial procedure performed with the patient responsive.With the exception of patient 14's aneurysm, all resections/clippings were carried out by the corresponding author under stereotactic MRI guidance (Stealth neuronavigation, Medtronic Corp., USA). Direct cortical stimulation was not used in this study owing to unavailability of the equipment and neurophysiologist. However, patients in our series with parenchymal masses underwent cortical and subcortical mapping shortly before surgery via fMRI and DTI,[13–16] respectively. Data from these studies were used in conjunction with frameless stereotaxy to help plan and verify the location of the corticotomy and trajectory to the lesion. From the corticotomy onwards, repetitive neurological testing intra-operatively by the anaesthetist included receptive and expressive language, reading, arithmetic, motor functions and sensory functions (i.e. the main 'awake' time of approximately 30–60 min). Once the intracranial work was completed, TIVA was resumed and the craniotomy was closed under general anaesthetic. Proseal Laryngeal Mask Airways were used instead of endotracheal intubation in order to minimise coughing or airway irritability during the wake up. Prior to the wake up, other adjunct anaesthetic medications commonly used to optimise patient comfort included analgesics such as IV paracetamol and parecoxib, and antinausea prophylaxis such as ondansetron. Surgeries were typically completed within 4 h from scalp opening to closure.

2.4. Data collection

2.4.1. Clinical data. Clinical and demographic data were obtained from hospital records and entered into an Excel datasheet (Microsoft Corp., Seattle, WA). The Australia-modified Karnofsky performance status (AKPS) scale[17] was used to quantify the 'functional status' of patients pre-operatively and monitor their progress post-operatively. The AKPS is an 11-point rating scale assessing three aspects of patient health (self-care, activity and work) and ranges from normal functioning (100) to dead (0).[17] For each patient, AKPS was determined by the corresponding author 1 day pre-operatively, 3–5 days post-operatively and at the 6-week follow-up appointment.

2.4.2. Patient interviews. Patients were asked to participate in a three-part semi-structured interview that assessed pre-operative, intra-operative and post-operative issues. All interviews were conducted by the same researcher (SM). In order to obtain the desired information, the questionnaire consisted of both closed-ended questions inviting ratings on five-point scales and open-ended questions that encouraged discussion (Appendix). Patients who were recruited prospectively were approached 1–2 days before the operation for their consent and part 1 of the interview was conducted at that time. Part 2 was conducted 3–5 days following their operation and part 3 at follow-up (6 weeks after the operation). Patients recruited retrospectively into the study were mailed out the questionnaire and consent form and an appointment was made to conduct all three interview parts at once (either in-person at the hospital or over the telephone). For each patient, all interview data collected were verified with them at the end of the final interview to ensure they were satisfied with what was recorded.

2.5. Data analysis

Patient responses to closed-ended questions such as pain, discomfort and satisfaction ratings were first analysed using the Wilcoxon Rank-Sum test to identify any differences between the retrospective and prospective groups. No significant difference (at the $p = 0.05$ level) was identified and the two groups were pooled for all subsequent analyses. Patient responses to open-ended questions were analysed using modified thematic analysis described elsewhere.[18]

3. Results

3.1. Patient profile

A total of 26 consecutive patients (17 males, 9 females) who underwent their first awake craniotomy

between 2007 and 2009 inclusive were enrolled in this study (Table I). The median age was 46 years (range 16–78). There were 15 astrocytomas (varying from WHO grade II to IV), 6 cavernomas, 1 anaplastic oligodendroglioma, 1 cerebral neuroblastoma, 1 atherosclerotic aneurysm, 1 arteriovenous fistula and 1 metastatic lung carcinoma. These lesions encroached on a range of critical structures including one or more of the following: Broca's and Wernicke's areas, primary sensory and primary motor areas and the insula (Fig. 1).

3.2. Patient expectations

Analysis of the interviews revealed the following themes:

3.2.1. Preconceptions. Patients tried to relate brain surgery to previous life experiences either from work, popular media or past surgeries.

3.2.2. Initial reactions. The initial reactions for most patients were that of shock and disbelief when the idea of being awake was first presented to them. However, they were willing to undergo it because of the perceived safety margin compared with standard craniotomy. Only one patient thought all brain surgeries involved the patient being awake and was surprised to learn there was an option to have such surgery asleep.

3.2.3. Pre-operative concerns. When asked what their primary concerns were, most patients responded with comments about surgical outcomes and complications such as death, permanent disability and suboptimal resection. They also spoke about their functional goals following the surgery, most often focusing on retaining or improving speech and other higher functions.

3.2.4. Anaesthetic protocol. All patients were aware that they would not be awake for the entire operation. When asked why, most responded that it would be unnecessary and uncomfortable. Nearly all patients felt the 'asleep–awake–asleep' anaesthetic protocol was appropriate for them. A few patients were indifferent to the anaesthetic protocol and felt the decision was best made by the treating team or made based on safety.

3.2.5. Pre-operative preparation. All 26 patients rated themselves as being confident about the surgery and attributed this to the pre-op preparation by the treating team. They were satisfied with the amount of information provided by their team, including discussions of the rationale for awake craniotomy, type of intra-operative testing and potential complications. This was corroborated post-operatively when patients were asked if there was 'any additional information they could have received, looking back at the experience'. Nearly all reported that no further information was necessary. Three patients reported that perhaps too much information was given pre-operatively. One particular patient was daunted by the list of possible surgical complications, but acknowledged the necessity of providing such information.

3.3. Patient recall

For the adverse perceptions studied (Appendix), the average rating was 'slight' to 'none'. Three of 26 (12%) patients rated their overall intra-operative discomfort as more than slight, while 2/26 (8%) reported more than slight pain. Sources of intra-operative pain or discomfort reported by patients (including the early 'induction' period and early post-operative period) were the intravenous cannulae (two patients), the bed (one patient) and Mayfield head-clamp (five patients). Four of 26 (15%) patients reported having more than slight fear, while 3/26 (12%) recalled the head-clamp as causing more than slight discomfort and pain. One patient reported feeling considerably claustrophobic and one patient reported feeling moderately hot. Seven of 26 (27%) patients had no recollection of being awake during the operation, 8/26 (31%) had partial recall and 11/26 (42%) had considerable recall. Patient memories of the awake stage were mainly of the staff members present, the conversations with and instructions given by the anaesthetic team and ambient operating theatre equipment noise.

3.4. Patient satisfaction

Early post-operatively, 10/26 (40%) patients reported more than slight pain and 11/26 (42%) reported more than slight discomfort. At this time, all but one patient were satisfied with their experience, the remaining patient reporting neither satisfaction nor dissatisfaction. At 6-week follow-up, 3/26 (12%) still reported more than slight pain, while 5/26 (20%) still reported more than slight discomfort. However, at this time, 24/26 (92%) patients were still satisfied with their experience, one was neither satisfied nor unsatisfied and another was unsatisfied. Sixteen of 26 (62%) patients felt that their quality of life had improved after having the surgery, while 7/26 (27%) felt it was about the same and 3/26 (12%) felt it was worse.

3.5. Clinical outcome indicators

3.5.1. New post-operative neurological deficits. Although in 7/26 (27%) patients surgical resection was altered (typically stopped in the anatomical location at which the deficit was found to have occurred) due to the detection of a new neurological deficit intra-operatively during repetitive testing, there was only one permanent surgical complication

TABLE I. Summary of clinical data from 26 consecutive patients undergoing awake craniotomy

Patient/ sex/age (year)	Principal diagnosis	Location (region of risk)	Presenting signs/symptoms	Surgery[a]	AKPS			Significant surgical complications (1/26 permanent: patient 13)
					1 day pre-op	3 days post-op	6 weeks post-op	
1/M/78	AVF	Orbitofrontal	blackout spells, diminished visual acuity	disconnection	90	100	100	nil
2[b]/M/42	WHO grade II ast.	L insula	seizure(s)	near-total	90	80	100	nil (reduced power + aphasia intra-op. only)
3/M/27	WHO grade II ast.	L insula	seizure	Partial	100	100	100	nil
4[b]/M/63	cavernoma	Broca's	headache, seizure(s), expressive dysphasia	volumetric	90	80	100	nil (motor aphasia intra-op. only)
5/M/20	WHO grade II ast.	L insula	seizure(s)	Partial	100	100	100	nil
6/M/56	WHO grade IV ast.	L primary motor	hemiparesis	volumetric	40	40	50	nil (reduced power + sensation intra-op. only)
7[b]/F/24	cavernoma	R primary sensory and motor	headaches, transient sensorimotor impairment	volumetric	80	60	90	nil
8/M/24	WHO grade III ast.	R primary sensory	headache, seizure(s), sensory impairment	Partial	100	50	90	wound infection, transient hemianopia post-op. (resolved at 6 months)
9[b]/M/62	WHO grade IV ast.	Wernicke's	hemiparesis, dysphasia	volumetric	50	80	80	nil (visual field impairment intra-op. only)
10/F/36	cavernoma	L premotor	seizure, blackout	volumetric	90	100	100	nil
11/M/48	WHO grade IV ast.	R primary sensory and motor	seizure(s), dysphasia, hemiparesis	volumetric	70	60	80	wound dehiscence, transient ventriculitis
12/M/16	WHO grade III olig.	L temporal and insula	asymptomatic (but recent threatened herniation)	near-total	100	80	100	nil
13[b]/M/46	cavernoma	L insula	Recurrent sensorimotor spells	near-total	70	10	60	Intra-op. and post-op. dysphasia + hemiparesis (aphasia resolved at 6 months; self-ambulatory)
14/F/64	Aneurysm	L MCA	dysphasia, hemiparesis, retrograde amnesia, sensory impairment	Clipping	80	80	90	nil
15/F/34	cavernoma	Left atrium	Headache	volumetric	100	80	90	transient dysphasia post-op. (resolved at 6 months)
16/F/47	WHO grade IV ast.	Left temporo-occipital	dysphasia, visual impairment	volumetric	80	90	100	nil
17/M/58	WHO grade II ast.	L primary sensory	Headache, dysphasia, recurrent collapses/faints	volumetric	90	90	100	nil
18/M/52	WHO grade IV ast.	L parietal	Headache, Gerstman syndrome	volumetric	70	80	90	nil
19/M/64	WHO grade IV ast.	R temporal	Asymptomatic, tumour recurrence	near-total	100	100	100	nil
20/F/34	cavernoma	L temporal, hippocampus	Seizure(s), dysphasia	volumetric	70	90	100	nil
21/M/31	neuroblastoma	L frontal	Asymptomatic, tumour recurrence	volumetric	100	100	100	nil
22/F/61	Metastatic lung carcinoma	R primary sensory	Progressive left-sided sensorimotor deficit	volumetric	80	80	90	nil
23[b]/F/39	WHO grade IV ast. + abscess	Bifrontal	Mild cognitive impairment, tumour recurrence + incidental abscess	Partial	90	90	90	nil (transient mutism intra-op.)
24[b]/M/40	WHO grade IV ast.	R temporal and occipital	Seizure, headaches, nausea and vomiting	near-total	100	90	90	transient hemianiopia post-op. (visual field impairment intra-op.)

(*continued*)

TABLE I. (*Continued*)

Patient/ sex/age (year)	Principal diagnosis	Location (region of risk)	Presenting signs/symptoms	Surgery[a]	AKPS			Significant surgical complications (1/26 permanent: patient 13)
					1 day pre-op	3 days post-op	6 weeks post-op	
25/M/46	WHO grade II ast. (gliomatosis)	R multilobar	L hypoaesthesia, loss of taste	biopsy only	90	90	90	nil
26/F/70	WHO grade IV ast.	L temporal	Dysphasia	volumetric	90	90	90	nil

[a]Extent of surgical resection for tumours and cavernomas was graded as follows: volumetric (≥95%), near-total (80–94%), partial (60–79%).
[b]Patients in whom surgical resection was altered due to the development of new deficits found on repetitive functional testing intra-operatively.
Note: WHO, World Health Organisation; AKPS, Australia-modified Karnofsky performance status; M, male; F, female; L, left; R, right; AVF, arteriovenous fistula; ast., astrocytoma; olig., oligodendroglioma; MCA, middle cerebral artery.

(1/26; 4%) in this series (patient 13 in Table I): an intra-operative haemorrhage during resection of a large cavernoma in the left insula. There were four significant post-operative complications not associated with permanent neurological deficits: one patient in the series (patient 8 in Table I) developed a wound infection and cerebritis, resulting in a hemianopia that resolved at follow-up. A second patient (patient 11 in Table I) with previous tumour surgery, radiation and steroids had impaired wound healing and developed dehiscence and transient ventriculitis post-operatively, successfully treated with wound debridement and revision and intravenous antibiotics. Another patient (patient 15 in Table I) developed mild post-operative dysphasia and was re-admitted 2 days following discharge with nausea and vomiting. This patient was managed conservatively and was completely neurologically intact at follow-up. A fourth patient (patient 24 in Table I) experienced transient partial hemianopia related to mild post-operative oedema that resolved within 6 weeks of surgery. An anaesthetic complication occurred in two patients in this series, namely, transient apnoea during the sedation for local anaesthetic skin infiltration early in both cases. In one of these, placement of a Proseal Laryngeal Mask Airway failed to provide an adequate airway for manual ventilation and therefore endotracheal intubation was required temporarily. In the other, transient bag-mask ventilation was sufficient. The remainder of these two cases proceeded without difficulty or complication.

3.5.2. Australia-modified Karnofsky performance status. Pre-operatively, the median AKPS was 90 (range 40–100), early post-operatively 85 (range 10–100) and at 6-week follow-up 90 (range 50–100). Fourteen of 26 (54%) patients showed net improvements in AKPS, while 5/26 (19%) were already at AKPS of 100 pre-operatively and remained so at follow-up. Three patients were at sub-maximal AKPS pre-operatively and remained at that same level post-operatively while 4/26 (15%) showed a net worsening of their AKPS. The median length of stay in acute care following surgery was 5 days (range 3–14 days), with nearly two-thirds of patients being discharged directly to home from acute care.

4. Discussion

Awake craniotomy is reserved by us for those patients with lesions involving or encroaching on eloquent brain regions and in whom there is a perceived elevated risk of operative complication if the entire surgery is carried out asleep. While cerebral electrophysiological recordings such as somatosensory and/or motor-evoked potentials can be beneficial in conventional asleep surgery, such recordings typically provide feedback regarding more gross neurophysiological disturbances and give no specific

information regarding language and visual function, or subtle neurological dysfunction. In this series, of the seven new intra-operative deficits encountered during surgery (Table I), six involved language or visual function and, with immediate cessation of resection in the responsible anatomical location, only one deficit was permanent, supporting the benefit of awake testing.

Although one patient in our series had an intracranial arterial aneurysm and another a dural AV fistula with venous aneurysm, we recognise that these are relatively unusual indications for awake surgery which we typically reserve for the more conventional indication of neoplasia. Patients need to be comfortable with the concept of being awake during the surgery, and communicate well enough to facilitate intra-operative testing. The present study examined the personal experience and functional outcome of 26 consecutive patients who underwent their first awake craniotomy. Overall, both subjective experience and objective outcome were found to be favourable. Many of our findings have confirmed those of the two other 'thematic' awake craniotomy studies[10,11] published during the time of our data collection. A comparison of our study's parameters and key findings with those of other series in the English peer-review literature examining the experience of awake craniotomy patients is given in Table II. The key messages of our study are discussed below.

4.1. Expectations, including protocols

Patient confidence regarding the planned operation, which we believe can be enhanced by pre-operative discussion of the basic surgical, anaesthetic and neurological protocols, is one of the most important considerations for awake craniotomy.[19] While there have been numerous reports stating that the alternating 'asleep–awake–asleep' protocol, as used in this study, is well tolerated by patients,[6] only one previous study looked at patient perceptions of awake surgery carried out in this manner[20] and found that surgery utilising the protocol was well tolerated (Table II). Our study confirms that finding, with nearly all patients reporting that this anaesthetic protocol was appropriate for them. Some institutions avoid the use of general anaesthesia altogether, particularly as it can be associated with increased operative time and airway patency risks during mechanical airway transition phases, instead choosing to keep the patient sedated but arousable throughout the entire operation. Indeed, five of the seven studies in Table II have used this 'conscious sedation' technique and shown that it is also well tolerated by patients.[8–11,21] However, two of those studies[9,21] have also reported that some patients experience significant pain or discomfort during dural manipulation, the occurrence of which can be minimised or prevented via the 'asleep–awake–asleep' protocol.

4.2. Recall

The frequency of incomplete or no recall of the awake portion of the surgery found by us and others (Table II) may be partly attributable to low dose intravenous anaesthetic agents used during the 'awake''' phase. Like Palese *et al.*[10] and Khu *et al.*[11] (Table II), we found patients' most vivid memories regarding the surgery were auditory (e.g. vibrations caused by the drill, suction noises and conversations amongst surgeons, anaesthetists and theatre staff).

4.3. Satisfaction

Some patients made suggestions for improving the surgical experience both intra-operatively and post-operatively. Intra-operative recommendations included placing pillows under the knees to improve comfort and the use of pneumatic compression devices to help massage legs and prevent calf pain. Such devices are used in most surgeries as mechanical DVT prophylaxis. Other suggestions for improvement included a practice run for patients to demonstrate positioning their head and body during surgery. One patient suggested continual physical contact (e.g. holding hands) with a member of the treating team throughout the awake stage to help them feel more secure and less anxious. Post-operative recommendations included supplying pre-existing chemotherapy information booklets to brain tumour patients.

4.4. Outcomes

The 26 patients surveyed in this study were comfortable with their experience at follow-up and none reported any negative psychological effects of the operation itself. From an anaesthesia perspective, Costello and Cormack[22] have pointed out four key determinants of a successful outcome of awake craniotomy: (1) level of pain; (2) airway obstruction; (3) nausea and vomiting and (4) seizures. Based on these four indicators, an overall low-risk anaesthetic experience was found in our series. From a neurological perspective, 1/26 (4%) patients experienced a permanent neurological deficit and 4/26 (15%) experienced transient neurological deficits. These findings are consistent with those reported internationally in other awake[3,23,24] and conventional[25,26] craniotomy series involving patients with eloquent brain masses, with up to approximately 70% transient and 30% permanent neurological deficits.[3]

4.5. Limitations

One limitation of this study (which we will address for future awake patients) was the absence of intra-operative direct cortical stimulation regarded as the gold standard of intra-operative mapping. While pre-operative fMRI and DTI are useful adjuncts,[13–16]

TABLE II. A comparison of characteristics and key findings of series in the English peer-review literature examining the experience of awake craniotomy patients

Study	Danks *et al.*[9]	Whittle *et al.*[20]	Manninen *et al.*[8]	Palese *et al.*[10]	Khu *et al.*[11]	Goebel *et al.*[21]	Present study (2011)
Country	USA	Scotland/UK	Canada	Italy	Canada	Germany	Australia
Patient population	$n=21$ (M/F not specified; age 25–73 years)	$n=15$ (8 M/7 F; age 25–67 years)	$n=50$ (28 M/22 F; age 31–67 years)	$n=21$ (10 M/11 F; age 20–63 years)	$n=27$ (16 M/11 F; age 30–76 years)	$n=25$ (14 M/11 F; age 23–71 years)	$n=26$ (17 M/9 F; age 16–78 years)
Anaesthesia	LA + monitored sedation	'Asleep–awake–asleep'	LA + monitored sedation	LA + monitored sedation	LA + monitored sedation	LA + monitored sedation	'Asleep–awake–asleep'
Patient assessment	Interview (open-ended and closed questioning, psychiatric assessment, 10-point rating scales) and 'profile of mood' questionnaire	Questionnaire (open-ended questions, 3-point rating scales)	Interview (open-ended and closed questioning, 3-point rating scales)	Interview (open-ended questioning)	Interview (open-ended questioning)	Interview (open-ended questioning, neuropsychological testing), questionnaire (3-point rating scales)	Interview (open-ended and closed questioning, 5-point rating scales)
Timing of interview/ questionnaire	2–3 days and 4 weeks post-op.	4–5 days post-op.	1 h, 4 h and 24 h post-op.	1 day pre-op., 1 day post-op.	1 week pre-op., 1–2 weeks post-op.	3–7 days post-op.	1–2 days pre-op., 3–5 days and 6 weeks post-op.
Maximum follow-up	4 weeks post-op.	4–5 days post-op.	1 day post-op.	1 day post-op.	1–2 weeks post-op.	3–7 days post-op.	6 weeks post-op.
Recall	5/21 (24%) none, 12/21 (57%) slight, 4/21 (19%) significant	3/15 (20%) none	4/50 (8%) none, 31/50 (62%) slight, 15/50 (30%) significant	NA	NA	2/25 (8%) none, 5/25 (20%) slight, 18/25 (72%) significant	7/26 (27%) none, 8/26 (31%) slight, 11/26 (42%) significant
Intra-op. pain	12/21 (57%) none, 3/21 (14%) slight, 6/21 (29%) significant	3/15 (20%) significant	10/50 (20%) none, 30/50 (60%) slight, 10/50 (20%) significant	NA	NA	12/23 (52%) none, 8/23 (35%) slight, 3/23 (13%) significant	19/26 (73%) none, 5/26 (19%) slight, 2/26 (8%) significant
Intra-op. discomfort	14/21 (67%) none, 1/21 (5%) slight, 6/21 (29%) significant	7/15 (47%) none, 4/15 (27%) slight, 3/15 (20%) significant	NA	NA	NA	Coupled with 'pain' (above)	17/26 (65%) none, 6/26 (23%) slight, 3/26 (12%) significant
Intra-op. fear	NA	9/14 (64%) none, 3/14 (21%) slight, 2/14 (14%) significant	NA	NA	NA	NA	19/26 (73%) none, 3/26 (12%) slight, 4/26 (15%) significant
Patient satisfaction	15/21 (71%) very satisfied, 3/21 (14%) partly satisfied, 3/21 (14%) neutral	13/14 (93%) happy with length of surgery, 14/14 (100%) felt adequately prepared	46/50 (92%) very satisfied, 4/50 (8%) partly satisfied	NA	Mainly positive experience; high satisfaction with outpatient craniotomy	19/25 (76%) very satisfied, 6/25 (24%) partly satisfied	21/26 (81%) very satisfied, 3/26 (12%) partly satisfied, 1/26 (4%) neutral, 1/26 (4%) partly unsatisfied

(*continued*)

TABLE II. (*Continued*)

Study	Danks *et al.*[9]	Whittle *et al.*[20]	Manninen *et al.*[8]	Palese *et al.*[10]	Khu *et al.*[11]	Goebel *et al.*[21]	Present study (2011)
Key themes	NA	NA	NA	Pre-operatively: self-preservation, working out intra-operative role; intra-operatively: having situation under control; post-operatively: seeking reassurance for self and others	Understood rationale behind awake surgery; surprised that outpatient brain surgery is possible; trust in surgeon is important; more concerned about disease than procedure	NA	Understood rationale behind awake surgery; approved the 'asleep–awake–asleep' protocol; pre-op confidence attributed to good preparation by treating team
Other parameters provided	Tumour location, complications	NA	Tumour histology, complications	NA	Tumour histology, demographics	Tumour histology & location, complications, functional status (KPS)	Tumour histology & location, complications, functional status (AKPS)

Note: AKPS, Australian-modified Karnofsky Performance Status; F, female; LA, local anaesthesia; LOS, length of stay; M, male; NA, not assessed.

they are less reliable for mapping language areas and can be inaccurate or indeterminable in certain pathologies such as arteriovenous malformation. Another limitation of this study is the possibility of recall bias in patients recruited retrospectively. The longest interval between having the operation and being recruited for the survey in the retrospective group was 8 months (patient 1). Of the remaining patients in this group, operations were approximately evenly spaced with one awake craniotomy a month. During this time, patients may have forgotten key events or re-evaluated their surgical experience, leading to an under-reporting of important events or a lower rating of any pain or discomfort they may have experienced. However, we found no significant difference in pain, discomfort and satisfaction ratings between the retrospective and prospective groups when we used the Wilcoxon Rank-Sum test to analyse the data. Finally, formal neuropsychological and psychiatric testing could be used to enhance our further research in this area.

5. Conclusions

Our study confirms that awake craniotomy using the 'asleep–awake–asleep' method is generally safe, effective and well-tolerated by patients. It provides insight into the experiences of patients undergoing awake open cranial surgery and reiterates the importance of adequate pre-operative preparation in optimising patient satisfaction and outcomes. The majority of patients felt adequately informed about the procedure and comfortable about their role intra-operatively. Those who were able to recall their intra-operative experience found this to be a positive one, and most experienced a maintained or improved functional performance at last follow-up. We believe that the technique may help facilitate maximal safe resection of gliomas,[2,3,23,27] and may be augmented in future by intra-operative MRI[21] with fMRI and DTI.[13]

Acknowledgements

The manuscript was written by SM and VGK. All awake procedures were carried out by the corresponding author (VGK) and anaesthetic team (DD, TB, JF and LZ). The manuscript was edited by DD, JF and LZ. The authors wish to thank the theatre, intensive care unit and neurosurgical nursing staff for their patient care. For this particular study frequently utilising additional comprehensive MRI pre-operative imaging protocols, the enthusiastic support of radiology staff at St. Vincents Public Hospital (Sydney), Symbion Imaging Research Centre (Sydney) and the Canberra Hospital is also gratefully acknowledged, as is the assistance of Dr. Nada Chandran, Dr. Prashanth Rao, Dr. Peter Mews, Ms. Di Lane, Mr. Andrew Janke and Dr. Joga Chaganti. Last, but by no means least, we are sincerely grateful

to each and every patient who agreed to participate in this study.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Supplementary material available online

Appendix 1 Interview Questionnaire