Outpatient neurosurgery in neuro-oncology

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Technological breakthroughs along with modern application of awake craniotomy and new neuroanesthesia protocols have led to a progressive development in outpatient brain tumor surgery and improved surgical outcomes. As a result, outpatient neurosurgery has become a standard of care at the authors' center due to its clinical benefits and impact on patient recovery and overall satisfaction. On the other hand, the financial savings derived from its application is also another favorable factor exerting influence on patients, health care systems, and society.

Although validated several years ago and with recent data supporting its application, outpatient brain tumor surgery has not gained the traction that it deserves, based on scientific skepticism and perceived potential for medicolegal issues. The goal of this review, based on the available literature and the senior author's experience in outpatient brain tumor surgery, was to evaluate the most important aspects regarding indications, clinical outcomes, economic burden, and patient perceptions.

<https://thejns.org/doi/abs/10.3171/2018.3.FOCUS1831>

KEYWORDS outpatient neurosurgery; awake craniotomy; early discharge; brain tumor

NEUROSURGERY has been exponentially evolving during the last 50 years.^{1,25} Development of tools such as neuromonitoring and neuronavigation, along with the implementation of new neuroanesthesia protocols, have helped to shorten surgical times and enhance postoperative care, enabling more rapid recovery and early discharges.^{30,44,52} All of these improvements have led to a redefinition of the primary goal of care in neuro-oncology, with the aim of preserving neurological function and ultimately offering the patient a better quality of life.^{16,26,31,39,57} Consequently, there has been a switch toward less invasive surgeries now, centered on the patient's perceptions and well-being.^{8,14,31}

The advent of awake craniotomy allowed neurosurgeons to perform safer maximal resections and decrease postoperative deficits.^{20,21,29,46,48,50} Outpatient brain tumor surgery became part of the neuro-oncology armamentarium after awake craniotomies were introduced and perfected.³² This concept was subsequently developed, demonstrating that this technique can be safely applied, with improved surgical outcomes and decreased morbidity compared to craniotomies performed under general anesthesia.^{7,44} Outpatient or same-day surgery brain tumor resection is defined according to a clearly established protocol and inclusion

criteria, in which a patient arrives at the hospital on the morning of the procedure and, regardless of the anesthesia technique used, the patient leaves the hospital the same day before 9 PM, after a specific clinical and imaging assessment.^{7,12,17,24,53} With this system, patients avoid an overnight hospital stay and can start their recuperation outside a health care facility.¹²

The goal of this paper was to review the evolution of outpatient brain tumor resection and evaluate its current applicability in modern neurosurgery.

Outpatient Neurosurgery

Awake Craniotomy: Historical Background, Anesthetic Development, and Applicability in Outpatient Setting

Over decades the main goals in neuro-oncology have been as follows: to optimize the extent of resection and to preserve neurological function and patient's quality of life.^{37,46–48,50} The breakthroughs achieved since the 19th century in the knowledge about cerebral location and cortical mapping, along with the introduction of local anesthetics and sedatives, led to the implementation of modern awake craniotomies.^{15,29} These procedures have their roots in early epilepsy surgery and in the excision of le-

ABBREVIATIONS DSU = Day Surgery Unit.

SUBMITTED January 19, 2018. **ACCEPTED** March 26, 2018.

INCLUDE WHEN CITING DOI: 10.3171/2018.3.FOCUS1831.

sions seated in anatomical regions close to eloquent areas within the brain.¹⁵

Awake craniotomy has been evolving over the last 2 decades. Several factors can be identified as key principles for this evolution: neuroanesthesia development, improvement in microneurosurgical technique and management of intraoperative seizures, and finally the significance of brain plasticity for tumors near eloquent areas.^{6,11,29,30} Regarding neuroanesthesia and surgical techniques, the advent and subsequent implementation of remifentanyl plus propofol and/or dexmedetomidine as the anesthetic regimen linked to the current cortical-subcortical mapping and neuronavigation methods have contributed to the success of awake craniotomies.^{4,6,11,21,29,30,42} Interestingly, in their paper published in 2015, Hervey-Jumper et al.²⁹ describe the evolution of awake surgery and include a comprehensive analysis of technical recommendations in challenging patients: 2-stage surgery (asleep-awake) for tumors with severe mass effect, introduction of the laryngeal mask to control hypercapnia in obese patients or those with obstructive apnea, iced Ringers solutions to control intraoperative seizures, tailored craniotomies in reoperations, and baseline neurological evaluation before the surgery. Based on their results, the authors illustrate a technique with a high degree of success and low risk profile, with an awake craniotomy failure rate of 0.5%, early (at discharge) postoperative neurological deficit of 9%, and late (more than 3 months after the surgery) neurological deficit rate of 3%.²⁹ Specifically in neuro-oncology, such advances have yielded far-reaching consequences by improving extent of resection, increasing overall survival in low-grade and high-grade gliomas, and decreasing postoperative morbidity.^{5,20,21,29,46–48,50,51} Besides its application in guiding surgery in eloquent areas, awake craniotomy constitutes an invaluable neurosurgical tool by reducing anesthesia risks as well as delivering a direct impact on resource optimization.⁵³

As a result of these potential implications, outpatient brain tumor surgery was initially introduced by Bernstein⁷ in 1996, when the senior author started applying this technique in 46 patients prospectively selected to undergo awake craniotomies to evaluate the feasibility of a new same-day brain surgery protocol. The results obtained, with an 89% successful discharge rate, paved the way for the introduction of this technique.

Impact of Awake Craniotomy on a Patient's Survival and Neurological Morbidity

The scientific evidence currently available supports the tenet that maximal safe removal of hemispheric low-grade and high-grade gliomas, along with adjuvant therapy, can positively impact a patient's survival.^{46,50,51} However, when tumors are located near an eloquent area, the likelihood of neurological worsening increases as the survival rate decreases.⁴⁷ During the last 2 decades, awake craniotomies have been applied in neuro-oncology, with the aim of maximizing the safety of brain tumor resections. In order to localize functional brain areas, both preoperative (functional neuroimaging, tractography, neuronavigation) and intraoperative techniques have been described.^{5,23,38} Previously published studies have demonstrated the

value of cortical and subcortical mapping for decreasing postoperative deficits while improving the extent of resection and overall survival in low- and high-grade gliomas.^{18,20,34,46–48,50,51} Eventually, a meta-analysis published in 2012 examining the usefulness of intraoperative mapping showed that this technique is associated with a reduction in late (more than 3 months after surgery) postoperative deficits in adult patients with supratentorial infiltrative gliomas, compared to patients in whom brain mapping was not used during surgery; this method assumed a transient increase in temporary deficits within 3 months of surgery.²¹

In conclusion, awake craniotomy with intraoperative mapping of brain functions represents the standard of care in glioma surgery near eloquent areas, because this technique increases the surgical safety and does have a positive impact on neuro-oncological outcomes by increasing the extent of resection and overall survival.

Rationale for Outpatient Brain Tumor Surgery

There has been a progressively universal trend toward minimizing the physical and psychological impact that surgery can have on oncology patients. Consequently, several factors have switched the inpatient surgery to an outpatient setting, given the fact that early discharges can decrease well-defined risks derived from an in-hospital stay and can have a positive impact on the patient's psychosocial sphere.^{12,27,49,52} Although same-day neurosurgery has proven to be a safe method, with potential benefits for the patient and the health care system globally, its expansion has been faster in other surgical specialties.^{19,22,43}

Physicians who perform intracranial neurosurgery have been reluctant to apply same-day surgery protocols, mainly because of the perceived risk of further deterioration when the patient is discharged shortly after an intracranial procedure. Be that as it may, several large-scale series analyzing complications after both biopsy and craniotomy procedures have suitably addressed the time frame after which the physician can consider it safe to discharge a patient from the hospital.^{10,33,53}

In their retrospective study performed in 1994 to analyze postsurgical complications after CT-guided stereotactic biopsy in 300 patients, Bernstein and Parrent reported that only 3 of 300 patients developed a neurologically relevant intracranial hemorrhage more than 4 hours after the procedure.⁹ In another study analyzing the incidence and timing of complications after intracranial surgery, Taylor et al. reported clinical deterioration as a consequence of postsurgical hematoma within 6 hours of the procedure in 44 of 2305 patients, and more than 24 hours after the surgery in only 6 patients.⁵⁴ Similarly, in a study of 249 patients who underwent brain biopsies, Kaakaji et al. reported postoperative intracerebral hemorrhage in 8 patients within 6 hours after the procedure.³³

Therefore, there are 2 factors that can halt an early discharge. The first factor is related to surgical site hematomas, which are acute phenomena that almost always occur within 6 hours of surgery and are responsible for almost immediate patient deterioration. The second factor is a delayed presentation after 24 hours related to edema development around the surgical cavity, which has typically

been described in up to 10% of the craniotomies^{9,52,54} but is generally manageable with the rigorous use of dexamethasone.

Supported by these data, Purzner et al.⁴⁴ published a study with 401 patients prospectively selected to undergo outpatient surgery either for biopsy (n = 152) or for craniotomy (n = 249), reporting a 94% and 93% success rate of discharge the same day after the procedure in the biopsy and craniotomy group, respectively. Those data are in favor of safe early discharge and do not support any additional benefit from keeping the patient admitted overnight.^{12,49,56}

Apart from the positive psychological impact of being in a more familiar environment, avoidance of an overnight stay can prevent the patients from increasing their exposure to hospital-related risks such as nosocomial infections, thromboembolism, and the possibility of being affected by medical errors, which are reported in approximately 7.5% of overall admissions.^{3,44} Besides, patients' perceptions regarding outpatient surgery have been evaluated by Khu and Bernstein³⁵ through qualitative studies, which concluded that this procedure is generally well tolerated by the patient.

Selection of Patients: Inclusion and Exclusion Criteria Protocol

In order to select properly those patients suitable for outpatient procedures and avoid complications, a clearly defined protocol was initially proposed by Bernstein,⁷ and further validated as a specific checklist, which should be discussed thoroughly with the patient in the preoperative visit.⁴⁴

The inclusion and exclusion criteria used for the Day Surgery Unit (DSU) are summarized in Table 1.

Potentially all patients diagnosed with intraaxial supratentorial tumors who have a close relative or caregiver with whom they can stay the first night near the hospital can benefit from this protocol.^{12,17} On the contrary, some health-related (psychological unsuitability, cases in which duration does not allow for a standard monitoring period of 6 hours, severe pulmonary and/or cardiovascular disease) and other social factors (no access to caregiver or residence far away from hospital) can pose an unacceptable risk to the patient undergoing same-day surgery, and in our view these patients should be admitted.¹⁷

Proposed Same-Day Surgery Protocol

1. Key first step: preoperative discussion with surgeon, anesthesiologist, and neuro-oncology nurse practitioner to evaluate the most frequent risks or expected events that the patient can experience.
2. Patient arrives at 5:30 AM to undergo a preoperative neuronavigation-oriented MRI scan.
3. In the operating room, the neuroanesthesia team sets the intravenous and peripheral lines; arterial and venous central lines are uncommon in this outpatient setting. Prophylactic antibiotics and steroids are administered per protocol, avoiding the use of prophylactic anticonvulsants.
4. Subsequently the patient is placed in the desired position, which fits for the specific location, and the sur-

TABLE 1. Established inclusion/exclusion criteria for outpatient procedures

Inclusion criteria
Supratentorial tumor
Patient caregiver available
Patient staying relatively close to the hospital (i.e., no more than 1 hr away)
Exclusion criteria
Already an inpatient
Significant cardiorespiratory morbidity
Airway management concerns
Uncontrolled seizures or poor neurological status
Anticipated long procedure (>4 hrs)
Psychological unsuitability or patient preference

gical procedure is performed under the appropriate anesthesia method (awake-local or general intubated). Microneurosurgical technique with image guidance and neurophysiological cortical/subcortical mapping is used to help during the surgery.

5. After the procedure is finished, the patient is transferred to the postanesthesia care unit for 2 hours and then monitored at the DSU for an additional 4 hours.
6. Patients undergo a plain CT scan 4 hours postoperatively and a physician assesses it and their neurological status and determines suitability to discharge.
7. Only patients who adhere to these criteria can be safely discharged. If one of these factors, especially unexpected clinical or imaging abnormalities, is found, the patient is admitted for monitoring.

Clinical Impact of Outpatient Surgery Program

To our knowledge, there are very few prospectively designed studies in which a brain tumor outpatient protocol has been conducted with success (Table 2).^{7,10,12,28,44,49}

The goals for which an outpatient neurosurgery is indicated are as follows: reduction in the risks and complications derived from an in-hospital stay, as well as optimization of health care costs and hospital bed flow. Furthermore, in those cases in which an awake craniotomy with brain mapping is used, which are the majority of outpatient cases, the other main goal is to improve the extent of resection^{20,21,29} while reducing neurological deficits and ultimately improving patients' quality of life.^{30,45}

The initial study published by Bernstein in 2001 showed a successful same-day discharge of 89% in a group of 46 patients, with a complication rate of 11% and no adverse effects in those patients discharged according to the protocol.⁷ This pioneer feasibility study was followed by a subsequent larger group of patients who were considered suitable to undergo biopsy in an outpatient setting and recapitulated the same rates of successful discharge and complications.^{10,11,33} This Toronto model was adopted successfully in the United Kingdom by Grundy et al., demonstrating the reproducibility of the protocol and confirming its efficacy and safety by implementing it in a different health care system.²⁸

TABLE 2. Summary of the papers evaluating outpatient brain tumor surgery

Authors & Year	Procedure (no. of pts)	Successful Discharge Rate	Complications	Comments
Bernstein, 2001	Craniotomy (46)	89%	11%	Pioneer outpatient study
Blanshard et al., 2001	Craniotomy (15)	88%	6%	1 pt had a seizure, 1 had a headache, & 1 had nausea
Kaakaji et al., 2001	Biopsy (71)	82%	6%	Among the 13 pts admitted, only 4 were due to complications
Bhardwaj & Bernstein, 2002	Biopsy (76)	97%	3%	1 pt had a small intraventricular hemorrhage & 1 developed mild leg weakness
Grundy et al., 2008	Craniotomy (11), biopsy (30)	82% craniotomy, 90% biopsy	18% craniotomy, 3% biopsy	1 pt had transient hemiparesis, 1 had a seizure, & 1 had an intraprocedural hemorrhage after biopsy
Boulton & Bernstein, 2008	Craniotomy (145), biopsy (117)	94% craniotomy, 93% biopsy	5% craniotomy & biopsy	No adverse effects in the pts discharged
Purzner et al., 2011	Craniotomy (249), biopsy (152)	93% craniotomy, 94% biopsy	7% craniotomy, 6% biopsy	1 pt had worsening of basal neurological status, 1 had nausea/headache, 2 had seizures & hemorrhage
Au et al., 2016	Craniotomy under general anesthesia (44)	86%	11%	6 pts had failure in protocol due to seizure, aphasia, wound hemostasis, cognitive impairment, & new deficit

Pt = patient.

Following these initial publications, a larger study was performed by the same group, with a sample of 117 and 145 patients selected prospectively to undergo brain biopsy and craniotomy, respectively. Among these, 95% of the outpatient craniotomies were performed with the patient awake. In this study 93% of the outpatient biopsy patients and 94% within the craniotomy group were discharged successfully from the DSU. In those who required inpatient conversion, hemorrhage with worsening basal neurological status, headache, new seizures, and familial preference were registered as the main cause for admission the same evening of the procedure.¹²

These results were also validated by the same group in 2011, which represents so far the largest prospective study that has validated the safety and importance of same-day discharge for brain tumors. In this paper, Purzner et al.⁴⁴ published a successful outpatient discharge rate of 94% and 93% for 152 and 249 patients selected to have biopsy and craniotomy, respectively, on an outpatient basis. No patients experienced a negative outcome as a result of this early discharge. These results have been maintained over the years; the current series of outpatient craniotomy is at 564 cases as of January 2018.

Outpatient Neurosurgery: Beyond Awake Procedures

The potential application of an outpatient setting is not limited to an awake surgery, but can also be suitable for patients under general anesthesia in cases of anticipated awkward positioning or lengthy procedures.

In the series published recently by Au et al.,² it was shown that same-day discharge was planned initially for 44 patients for whom general anesthesia was deemed preferable, with 38 patients (86%) successfully completing the protocol. Among the cases requiring inpatient conversion, one was admitted due to wound hemostasis problems, one due to new-onset cognitive impairment, two due to new or worsened weakness, and the other because of a new-onset seizure. These findings parallel the rates noted above for other outpatient studies.

Overall, they confirm that there are no adverse effects

as a result of an early discharge in selected patients who undergo outpatient procedures under awake or general anesthesia, and that the same inclusion and exclusion criteria should be applied regardless of the type of anesthesia required.

Patient Satisfaction and Perception

How patients experience a neurosurgical procedure is one element that is frequently overlooked in patient care. The impact of outpatient brain surgery is made not only on surgical grounds, but also on patients' perception regarding the management of their disease.

Fortunately, a few studies addressing this perspective have been conducted. Interestingly, when this idea was initially presented to 27 patients at the time they were prospectively selected for outpatient surgery, the first response was uncertainty about the possibility of early discharge after brain surgery.³⁶ However, as this study conducted in an open-ended interview format revealed, the participants gave positive feedback after they had been educated about the procedure.

Furthermore, approximately half of the patients considered that being at home early helped them in the recovery process.³⁶ The positive results regarding outpatient surgical procedures were subsequently reinforced by another group, in which a similar qualitative study designed to evaluate patients' perceptions reproduced the same reassuring feedback in a different health care system in the Western world.⁵⁸

Perioperative Patient Care: Role of Nursing in Outpatient Procedures

Addressing patients' priorities with perioperative teaching has been shown in an ambulatory setting before.¹³ Nurses in this setting help to address and alleviate some of the most common doubts regarding the surgical procedure. This person becomes one of the closest professional contacts with whom the patients can establish a fluent communication about recovery time, expected com-

plications, medication required, and eventually to manage postoperative concerns. Every outpatient program should implement the presence of this professional as one of the essentials in the protocol.

Financial Balance of Outpatient Neurosurgical Protocols

Improving surgical outcomes and preserving quality of life are considered as primary outcomes in neuro-oncology. One of the secondary advantages of the outpatient neurosurgery programs is to reduce costs without compromising these primary outcomes.⁶⁰ Very few papers have evaluated the financial impact of outpatient neurosurgery.

One report analyzing the financial differences between outpatient stereotactic biopsy and the cost of spending one night as an inpatient showed savings on the order of Can\$1200.00 per patient in favor of the early discharge. Another study based in the United States health care system demonstrated that extended observation more than 8 hours after the procedure is not necessary in terms of patient safety, and for some major academic hospitals cannot be financially affordable.³³

Importantly, one of the largest prospective outpatient spine and brain tumor surgery reports provided reassurance that the outpatient day protocol was a safe and valid surgical alternative in selected patients, with no adverse effect derived from this early discharge. Additionally, it was estimated that a total savings of Can\$1,123,200.00 could be reached in inpatient-associated costs because the hospital stays are reduced and complications such as nosocomial infections, thromboembolic events, and medical errors are minimized.⁴⁴

These results altogether confirm that outpatient cranial and spine surgery can provide cost savings and be applied regardless of the health care system, without affecting the quality of life or complications.^{55,56} As a result of this decrease in the health care resources that are needed, this format may be a solution in some low-income countries as well.⁵⁵

Other Subspecialties Benefitting From the Outpatient System

The field of outpatient surgery has been developed at a quicker pace in some specialties other than neurosurgery, such as orthopedics, general surgery, and pain interventions.^{19,22,43} Outpatient surgery, or a setting in which a surgical procedure is performed on a patient who is admitted the morning of the operation and discharged later without having stayed overnight in the hospital, can be applied successfully not only for brain tumors but also in spine operations^{41,43,44,61} and in intra-extracranial endovascular⁶² and open vascular procedures.²⁷ The discussion regarding all these details is beyond the scope of this review for brain tumors.

The Future of Outpatient Neurosurgery

It is true that with the spread in the use of awake craniotomy and the improvement of microneurosurgical techniques linked to superior neuroanesthesia protocols, outpatient intracranial surgery has experienced a revolution. It is important to clarify that there are no randomized

trials demonstrating that an outpatient protocol is superior to inpatient surgery in terms of clinical outcomes. However, many different prospective studies performed since 1991 have established its safety and efficacy. Furthermore, qualitative studies have also shown that it is a well-tolerated procedure with a positive impact on patients' disease perception.^{10,12,36,40,44,56}

Despite its validation, the protocol has not gained widespread popularity among most of the neurosurgeons devoted to neuro-oncology. In a survey of the members of the American Association of Neurological Surgeons and the Congress of Neurological Surgeons, only 6% of the physicians performed an outpatient biopsy, even though most of them agreed that discharge on the same day would be safe and an option to reconsider.⁵⁹

On the other hand, outpatient neurosurgery practice on a larger scale poses some potential additional medicolegal and ethical issues, which can contribute to a surgeon's hesitation. In the Western world this outpatient intracranial setting may increase the risk of litigations; for example, in cases in which some anesthetists might prefer not to perform these procedures without a central line or might even keep the patient in a step-down unit for more than 12 hours.⁵⁵ We presume that these factors may be responsible for the lack of reliance on outpatient brain surgery. However, this review has amply demonstrated a safety and efficacy profile that has been successfully and consistently maintained for more than 20 years now. Therefore, we would recommend that more neurosurgeons embrace these procedures in the future.

Conclusions

Outpatient neurosurgery preserves patients' safety and may provide clinical and psychological benefits. This approach represents an advance in modern minimally invasive surgery without compromising patient care, while at the same time it can provide potential financial savings for both high- and low-income countries.

The safety of outpatient brain tumor surgery has been demonstrated. Nevertheless, it is important to underline the fact that by performing outpatient neurosurgery, not only is there no increase in surgical morbidity as a result of an early discharge, but also almost certainly outpatient surgery contributes to the minimization of patients' exposure to nosocomial infections, medical errors, and thromboembolic complications. On the other hand, it decreases the unnecessary use of health care resources and improves inpatient bed occupation. As a result, it may be appropriate for introduction in the developing world. Hopefully this paper will help to underline the role of outpatient brain tumor surgery and enhance the potential for wider future applicability.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: both authors. Drafting the article: Marigil. Critically revising the article: Bernstein. Study supervision: Bernstein.

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