

Supraglottic devices for airway management in awake craniotomy

Josefin Grabert, MD^a, Sven Klaschik, MD^a, Ági Güresir, MD^b, Patrick Jakobs, MD^a, Martin Soehle, MD^a, Hartmut Vatter, MD^b, Tobias Hilbert, MD^a, Erdem Güresir, MD^b, Markus Velten, MD^{a,*}

Abstract

Awake craniotomy is a unique technique utilized for mapping neuro and motor function during neurosurgical procedures close to eloquent brain tissue. Since active communication is required only during surgical manipulation of eloquent brain tissue and the patient is “sedated” during other parts of the procedure, different methods for anesthesia management have been explored. Furthermore, airway management ranges from spontaneous breathing to oro or nasotracheal intubation. Case reports have described the use of laryngeal masks (LMs) previously; however, its safety compared to tracheal intubation has not been assessed.

We conducted a retrospective analysis of 30 patients that underwent awake craniotomy for tumor surgery to compare the feasibility and safety of different airway management strategies. Nasal fiberoptic intubation (FOI) was performed in 21 patients while 9 patients received LM for airway management. Ventilation, critical events, and perioperative complications were evaluated.

Cannot intubate situation occurred in 4 cases reinserting the tube after awake phase, while no difficulties were described reinserting the LM ($P < .0001$). Furthermore, duration of mechanical ventilation after tumor removal was significantly lower in the LM group compared to FOI group (62 ± 24 vs. 339 ± 82 [min] mean \pm sem, $P < .0001$). Postoperatively, 2 patients in each group were diagnosed with and treated for respiratory complications including pneumonia, without statistical significance between groups.

In summary, LM is a feasible airway management method for patients undergoing awake craniotomy, resulting in reduced ventilation duration compared to FOI procedure.

Abbreviations: ASA = American Society of Anesthesiologists, BIS = bispectral index, FOI = fiberoptic intubation, LM = laryngeal mask, MAC = monitored anesthesia care, MP = Mallampati.

Keywords: awake craniotomy, difficult airway, fiberoptic intubation, laryngeal mask

1. Introduction

Awake craniotomy is a unique technique that is used for identification of the functionally important neuronal structures and has become the standard procedure for mapping sensorimotor and cognitive functions during various neurosurgical surgeries.^[1] Mostly, procedures are tumor resection, epilepsy surgery, and deep brain stimulation, located close to eloquent areas of the brain, including motor strip and Broca’s as well as Wernicke’s speech areas. Awake surgery, with mapping

sensorimotor and cognitive function allows the surgeon to optimize the resection area, thereby protecting functional brain tissue and preserving the patient’s quality of life.^[2–5]

The terminology “awake” is somehow misleading since an active participation and communication with the patient for mapping neuro and motor function is required only during surgical manipulation of the eloquent brain tissue and the patient is “sedated” during other parts of the procedure. The more surgically stimulating parts of the procedure necessitate varying levels of analgesia, requiring specific anesthesiologic strategies. Thus, different methods for anesthesia management have been explored, reaching from so called awake-awake-awake technique with monitored anesthesia care (MAC) to “classic” asleep-awake-asleep technique utilizing partially or completely protected airways.^[6]

Concerns have always been raised in the context of patient cooperation and acceptance as well as safety regarding to hemodynamic stability and most notably airway safety.^[7] The anesthetic challenge is to provide a noncompromised patient for neurological testing but adequate analgesia as well as hemodynamic and respiratory stability during all phases of the procedure.

A major task is the airway management for awake craniotomy, because the anesthetist’s access to the patient is restricted by the head positioned within the Mayfield clamp and the surrounding sterile field. Over the last years the usage of various airway management devices from supplying nasal oxygen via nasopharyngeal catheter for patients breathing spontaneously to supraglottic devices including cuffed oropharyngeal airway tubes and laryngeal masks (LMs) and conventional or fiberoptic intubation (FOI) have been described.^[8–12]

Editor: Bernhard Schaller.

GJ and KS contributed equally to this study.

The authors have no conflicts of interest to disclose.

^aDepartment of Anesthesiology and Intensive Care Medicine, ^bDepartment of Neurosurgery, University Medical Center, Rheinische Friedrich-Wilhelms University, Bonn, Germany.

*Correspondence: Markus Velten, Department of Anesthesia and Critical Care Medicine, University Medical Center, Rheinische Friedrich-Wilhelms University, Venusberg-Campus 1, 53127 Bonn, Germany (e-mail: Markus.Velten@UKBonn.de).

Copyright © 2019 the Author(s). Published by Wolters Kluwer Health, Inc. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial License 4.0 (CCBY-NC), where it is permissible to download, share, remix, transform, and buildup the work provided it is properly cited. The work cannot be used commercially without permission from the journal.

How to cite this article: Grabert J, Klaschik S, Güresir Á, Jakobs P, Soehle M, Vatter H, Hilbert T, Güresir E, Velten M. Supraglottic devices for airway management in awake craniotomy. *Medicine* 2019;98:40(e17473).

Received: 24 March 2019 / Received in final form: 1 July 2019 / Accepted: 17 July 2019

<http://dx.doi.org/10.1097/MD.00000000000017473>

Awake FOI is the recommended procedure for airway management in a difficult airway situation and the usage of a supraglottic devices including LM for airway protection is not recommended in a critical airway situation.^[13] Most publications describing the usage of LMs for awake craniotomy are case reports, not addressing the safety of a supraglottic device for airway management during awake craniotomy.^[12,14–16] Therefore, we performed a retrospective analysis to evaluate the safety and feasibility of LMs compared to nasal FOI for airway management during awake craniotomy.

2. Methods

After approval from the Ethics Committee at the University Medical Center Bonn, Germany (Chairperson: Professor K. Racke) and in accordance to the Declaration of Helsinki and §15 of the Medical Association Nordrhein's professional code of conduct, medical records of patients who underwent awake craniotomy at the University Bonn Medical Center between December 2011 and April 2018 were reviewed retrospectively. Data of perioperative evaluation and management, including age, sex, weight, height, relevant medical history and comorbidities, American Society of Anesthesiologists (ASA) physical status, preexisting neurologic deficits, and Mallampati (MP) score were collected and analyzed.

Intraoperative data including anesthetic technique, duration of awake and asleep periods, hemodynamics including blood pressure and heart rate, duration of ventilation and oxygenation, including oxygen saturation (SpO₂%) and decarboxylation (CO₂), were evaluated. Complications encountered such as "cannot intubate cannot ventilate" situation, bradycardia, tachycardia, hypotension, and hypertension (20% changes in baseline values), pain, seizure, cough, and any other complications were registered. Postoperative data included occurrence of nausea and vomiting, pulmonary complication and reintubation, seizures, and duration of intensive care unit and hospital stay.

3. Anesthesia management

Bispectral index (BIS) guided total intravenous anesthesia using propofol and remifentanyl was performed in all patients. Upon arrival in the operation room, standard monitoring such as electrocardiogram, pulse oximetry, and noninvasive blood pressure were connected and a peripheral venous cannula was inserted. A BIS electrode (XP-sensor, Covidien plc, Dublin, Ireland) was positioned on the forehead and cerebral electric activity was assessed using a BIS monitor (Version XP, BIS version 4.0, Medtronic Inc, Dublin, Ireland) to evaluate the depth of anesthesia with BIS ranges between 0, indicative of an isoelectric electroencephalograph, and 100, indicating complete consciousness. Depth of anesthesia depends on brain propofol and remifentanyl concentrations which are clinically appropriate and in equilibrium with plasma levels. We achieved Propofol effect-site levels by target controlled infusion from dedicated pharmacokinetic pumps (Alaris PK, BD, Heidelberg, Germany). Propofol effect-site concentrations were calculated based on the pharmacokinetics and pharmacodynamics model described by Schnider et al.^[17] Propofol infusion was started with a target effect-site drug concentration (Cet) of 3.5 until BIS decreased to the desired range between 40 and 60.^[17,18] Subsequently, infusion rate was reduced to keep the patient in the recommended BIS range. A urinary catheter was inserted to monitor the urine

output and the right radial artery was cannulated for invasive blood pressure measurement.

4. Airway management

For FOI, a bronchoscope (tele pack, Storz, Tuttlingen, Germany) was inserted into a tracheal tube (Portex Endotracheal Tube, Smiths Medical, Minneapolis, MN) and transnasal advanced into the trachea. Subsequently, the tube was guided into the trachea and positioned above the carina under fiber optic control. For neurological testing during the awake phase the tube was withdrawn from the trachea and positioned with the tip being placed under fiberoptic control above the vocal cords. In this position the tube may have been advanced through the vocal cords into the trachea under fiber optic control if necessary. However, in the position above the vocal cords the tube did not affect patients' ability to speak during the procedure.

In LM group, either an i-gel (Intersurgical, Sankt Augustin, Germany) or AuraOnce (Ambu, Bad Nauheim, Germany) LM was inserted after anesthesia was established. In both groups, patients were pressure control ventilated with tidal volumes of 8 mL/kg body weight with a target end expiratory CO₂ partial pressure of 34 cmH₂O during asleep phases of the procedure.

Subsequently, a scalp block was performed and 1 mL Scandicain 1% was infiltrated into the skin at the sites where the Mayfield pins were inserted^[19] and the craniotomy was performed with the patient's head fixed in the Mayfield clamp. Following opening of dura and exposing of the tumor, propofol and remifentanyl infusions were intermitted. After patients started spontaneous breathing and opened eyes upon request in FOI group the tube was withdrawn with the tip being positioned above the vocal cords and in LM group the LM was removed. Neurological testing was performed with the patient being awake and conscious. After completion of the tests and tumor removal, remifentanyl and propofol infusions were resumed and tailored to keep the BIS between 40 and 60. Surgery was finished with the patient breathing spontaneously or ventilated. For FOI group the tube was advanced thorough the vocal cords and placed in the trachea above the carina with the position confirmed by fiberoptic evaluation, while in LM group the LM was reinserted. After skin suturing had been completed, patients were transferred to the neurosurgical intensive care unit (ICU) either ventilated under anesthesia or breathing spontaneously after propofol and remifentanyl infusions were stopped again and the nasal tube or LM had been removed subsequent to emerge from anesthesia.

5. Statistics

Statistical analyses were performed using Prism 6 (GraphPad Software, La Jolla, CA). Data are presented as mean ± standard deviation and were calculated with unpaired *t* test and Welch's correction in case of normal distribution or presented as median with 95% confidence interval and calculated with Mann-Whitney *U* test in case of non-normal distribution. Fisher exact test was used for subgroup analysis to detect nonrandom association between categorical variables.

6. Results

The present study reviewed 30 patients that underwent awake craniotomy for tumor removal over a period of 6 years at the department of neurosurgery at the University Medical Center

N=29	Endotracheal intubation	Laryngeal mask	P
Number	21 (72.4%)	8 (27.6%)	
Sex			
Male	13 (61.9%)	3 (37.5%)	
Female	8 (38.1%)	5 (62.5%)	
Mean age	50.5 (22–82)	58.9 (37–79)	.24
Mean BMI	25.4 (18.3–33.5)	25.1 (20.9–27.7)	.86
Mean ASA	1.86 (1–3)	2 (1–3)	.54
Mean Mallampati	1.54 (1–2)	1.25 (1–2)	.19

ASA=American Society of Anesthesiologists.

Bonn, Germany. All patients underwent pre, intra, and postoperative evaluation by an experienced neurologic speech therapist. Standard tumor resection using general anesthesia was used for patients with preexisting neurological conditions or impaired vocalization as evaluated by a speech therapist and for patients refusing awake craniotomy. Out of the 30 patients that underwent awake craniotomy, the airway was managed by FOI in 21 patients while 9 patients received a LM and both procedures are regularly performed at our institution. Intraoperative the procedure had been converted from awake to standard tumor resection using general anesthesia due the surgeon's decision. For FOI, tube size ranged from 6.0 to 7.5 with a median of 7.0 while LM sizes 4 and 5 had been used in LM group. Patients' characteristics including age, gender, body-mass-index, relevant medical history and comorbidities, ASA physical status, preexisting neurologic deficits, and MP airway status were similar and statistical analyses indicated no difference between FOI and LM group (Table 1).

Minimum oxygen saturation was not different during the first asleep ($P=.1672$) and awake ($P=.0788$) phases between FOI and LM group. However, during second asleep phase after tumor removal, oxygen saturation was significantly lower in LM group compared to FOI group ($P=.0371$) (Fig. 1A–C). Furthermore, statistical analyses indicated no difference in maximal or minimal end-expiratory CO₂ between FOI or LM group during first or second asleep phase (Fig. 2A–D).

Mean duration of first asleep phase was 200 minutes in the FOI group and 220 minutes in the LM group. Statistical analyses indicated no difference between groups ($P=.0893$) (Fig. 3A). However, mean mechanical ventilation duration after tumor removal was 339 minutes in FOI group as opposed to 63 minutes in LM group. Statistical analyses indicated a significant lower duration of mechanical ventilation in LM group compared to FOI group ($P=.0007$) (Fig. 3B).

One patient from the FOI group was initially scheduled to receive a LM, but airway management had to be converted to FOI before the beginning of the surgery due to a ventilatory leakage after insertion. No difficulties had been observed for initial FOI and positioning of the tube. Most importantly, after awake phase airway management difficulties have been reported in 4 patients that had been intubated initially. In 3 cases the tube could not be readvanced and airway management had to be converted. A supraglottic device was utilized in 2 cases while oral FOI was used in another case. Furthermore, 1 patient where fiberoptic reintubation was difficult developed laryngeal bleeding and blood had to be withdrawn from the larynx. In contrast the LM could be reinserted successfully in all patients and no complication was reported.

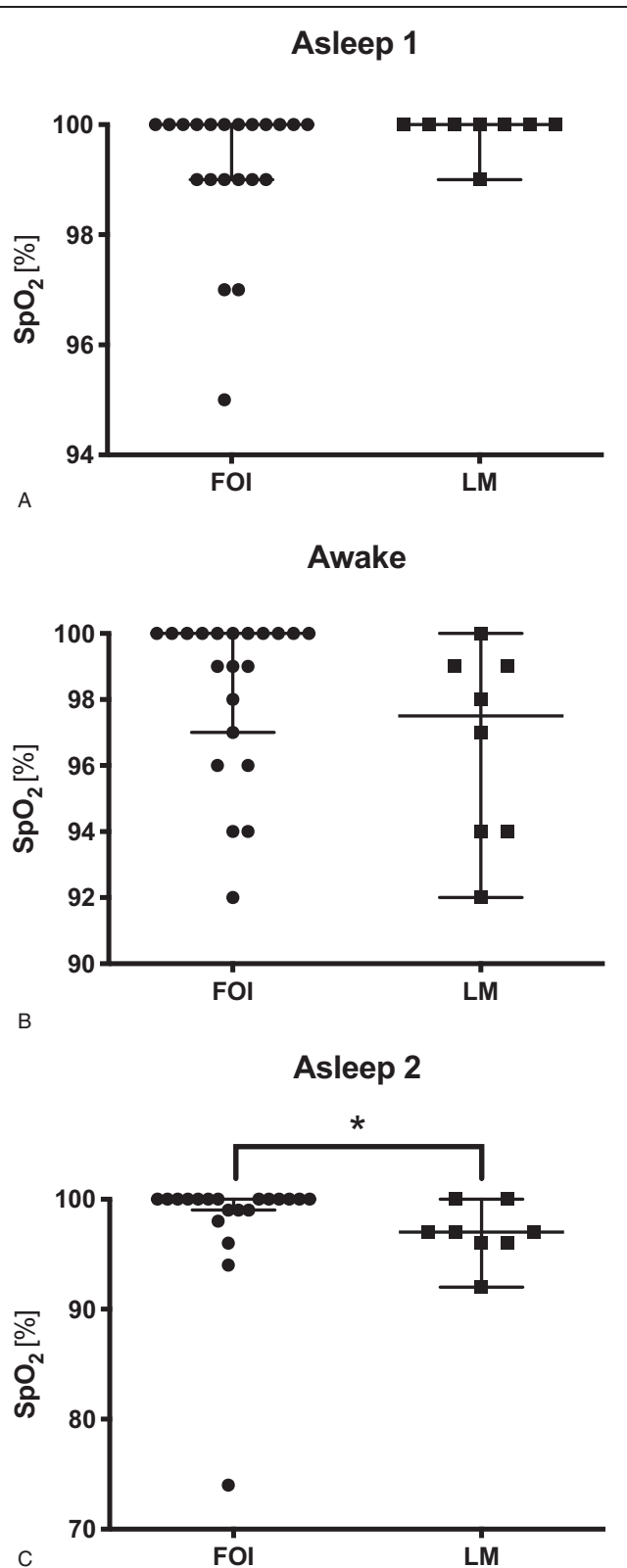


Figure 1. Oxygen saturation (%) was assessed via pulse oximetry during first asleep, awake, and second asleep phase. Statistical differences between FOI and LM group were assessed using Mann–Whitney *U* test. *, $P < .05$. FOI = fiberoptic intubation, LM = laryngeal mask.

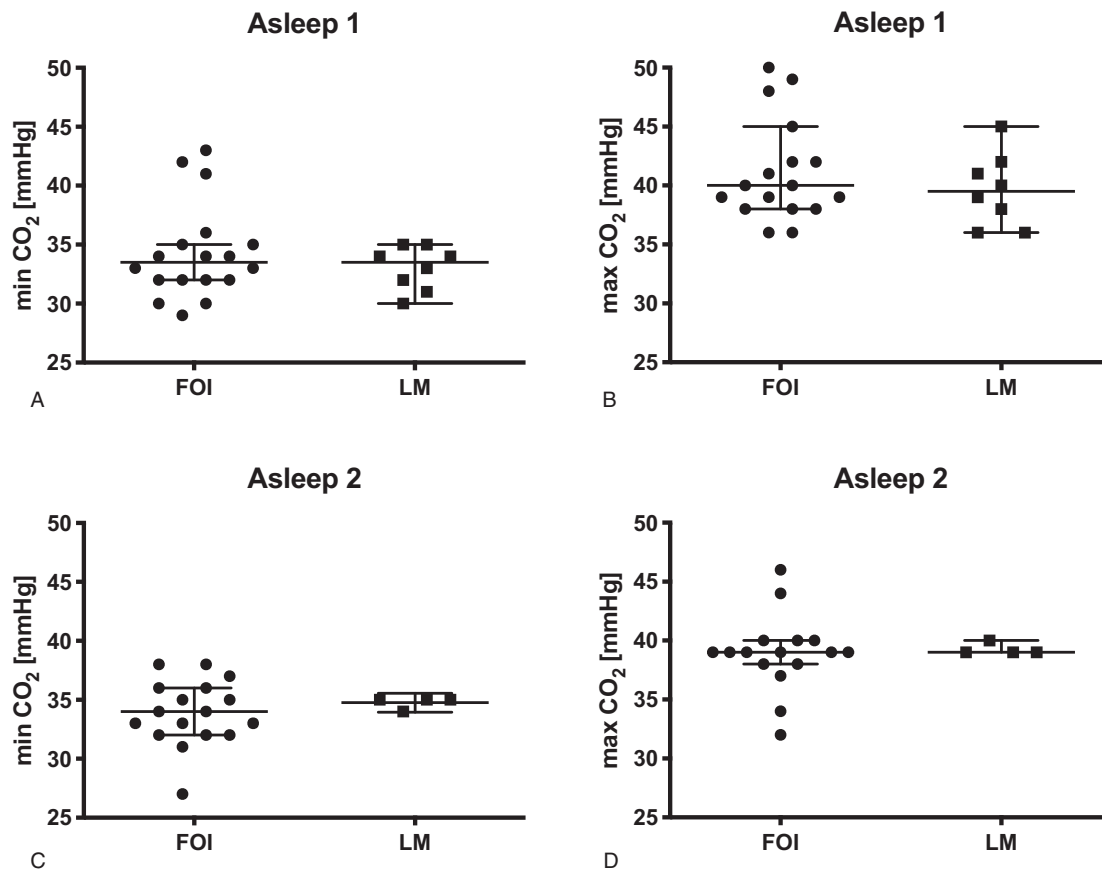


Figure 2. Minimum and maximum end-expiratory CO₂ concentrations (mm Hg) were assessed during first and second asleep phase. Statistical differences between FOI and LM group were assessed using unpaired *t* test. FOI = fiberoptic intubation, LM = laryngeal mask.

After surgery, all patients were transferred to the neurosurgical intensive care unit for postoperative neurological observation. Most importantly, all patients from LM group were breathing spontaneously when admitted to ICU. In contrast, in the FOI group 71.4% (15/21) of patients were admitted intubated and mechanically ventilated. Statistical analyses indicated a significant difference of spontaneous breathing patients at ICU admission between FOI and LM group ($P = .0007$) (Table 2).

ICU treatment for more than 1 day is regarded as complication, which applied to 4/21 patients (19%) in the FOI group, and 4/8 patients (50%) in the LM group. Statistical analysis indicated no significant difference between groups ($P = .16$) (Table 2). However, in the LM group, indications for ICU treatment were neurologic deficits in all cases and no respiratory insufficiencies had been described. In the FOI group, 2 patients suffered from respiratory complications, 1 due to pulmonary edema, and 1 due to bloody aspirates including associated wheeze. The remaining 2 patients were diagnosed with neurologic deficits.

Respiratory pathologies including perioperative aspiration and pulmonary complications within the first postoperative month including clinical and radiological diagnosed pneumonia were registered in 4 patients, 2/21 out of the FOI group and 2/8 of out the LM group. In the FOI group, 1 patient suffered from pneumonia, the other showed radiographic signs of pneumonia and exhibited bloody aspirates. In the LM group, both patients suffered from pneumonia, of which 1 had to be reintubated.

Statistical analysis indicated no significant difference of respiratory complications between FOI and LM group ($P = .55$).

7. Discussion

Conducting anesthesia for awake craniotomy contains several challenges including intraoperative timing of changes in conscious state as well as restricted access to the patient. Using short acting narcotic agents supports proper timing during the awake phase, but placing a safe airway device intraoperatively remains demanding. While several case reports describe the usage of LMs for airway management during awake craniotomy, to our knowledge this retrospective analysis is the first study comparing the safety and feasibility of LM for airway management during awake craniotomy to FOI.

During awake craniotomy, the patient's head is immobilized within the Mayfield clamp with limited access and impossible reclination. Therefore, reinduction of anesthesia and airway management after tumor resection should be treated as a predicted difficult airway and current national guidelines recommend FOI as the standard management for a predicted difficult airway.^[13]

Our results indicated that oxygen saturation and decarboxylation was within physiological limits in both groups during all parts of the procedure. However, statistical analyses indicated minimum oxygen saturation was significant lower in LM patients during the second asleep phase of the procedure. Since

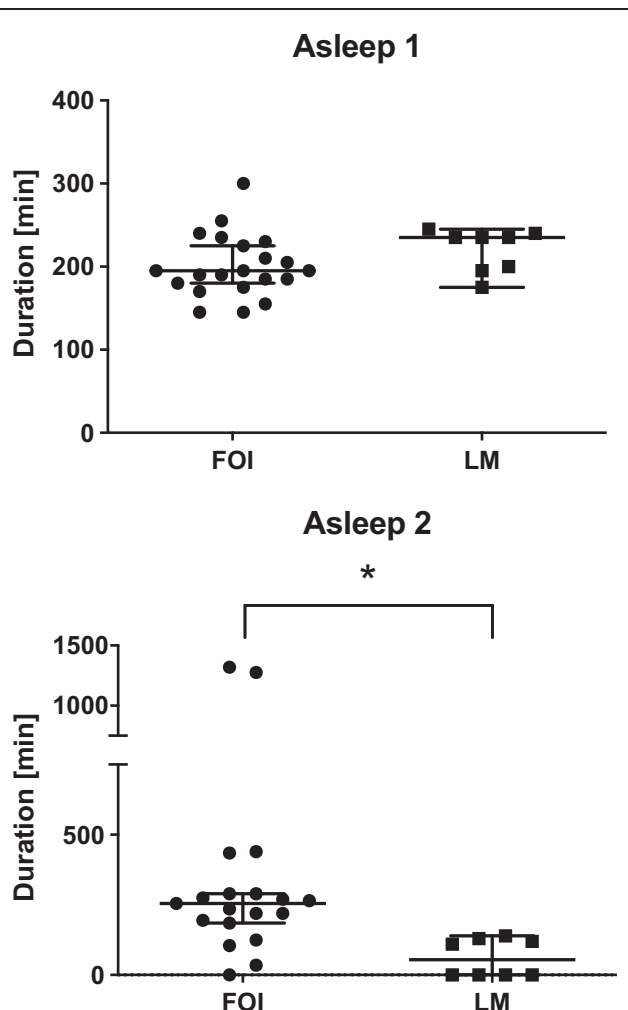


Figure 3. Duration of mechanical ventilation (min) during first and second asleep phase were assessed. Statistical differences between FOI and LM group were assessed using Mann–Whitney *U* test. *, *P* < .05. FOI = fiberoptic intubation, LM = laryngeal mask.

oxygenation and decarboxylation was not different between groups during other periods of the procedure, the observed difference may be due to spontaneous breathing. However, even if the difference reached statistical significance, oxygen saturation was within physiologic ranges in both groups, therefore the clinical impact of the reported difference maybe elusive.

Table 2
Airway/ventilation.

	Endotracheal intubation n=21	Laryngeal mask n=8	<i>P</i>
Complicated reinsertion airway	3 (14.3%)	0	<.0001
Transfer ventilated	15 (71.4%)	0	.0007
ICU stay >1 day	4 (19%)	4 (50%)	.16
Respiratory insufficiency	2 (50%)	0	
Neurologic deficit	2 (50%)	4 (100%)	
Reintubation	0	1 (12.5%)	
Respiratory complication	2	2	.55
Pneumonia	2 (100%)	2 (100%)	
Blood aspirate	1 (50%)	0	

Duration of surgery and anesthesia correlates with various perioperative complications including hypotension, hypothermia, coagulopathy, wound site infections, ventilator associated pneumonia, and lung injury.^[20–22] Patients within the LM group showed a significant shorter duration of mechanical ventilation after tumor removal compared to the FOI group with various reasons potentially responsible. After tumor removal LM was reinserted in 4 patients, while the procedure was finished with the other 4 patients breathing spontaneously without LM being reinserted, resulting in a change from classic asleep-awake-asleep technique to asleep-awake-awake technique with MAC. Furthermore, in the remaining 4 patients the LM was removed after emergence from anesthesia with the patients still being in the operating room (OR). However, both procedures resulted in a significant reduction of mechanical ventilation duration, potentially preventing subsequent ventilator associated complications. An additional benefit is the immediate postoperative neurological assessment and evaluation, detecting possible surgical complications. In contrast, in FOI group the tube was reinserted after tumor removal in 17 patients and only 4 patients were administered to ICU breathing spontaneously. The fact that only 1 of the reintubated patients was extubated in the OR after the procedure is surprising. A possible explanation might be that patients were paralyzed after tube repositioning and duration of muscle relaxant extended the end of the surgery.

While no difficulties occurred during the initial positioning of the tube, repositioning after the awake phase failed in 3 patients and an adverse event occurred in another. A possible explanation is the restricted access to the patient and reclinination of the head being impossible due to its fixation in the Mayfield clamp. In contrast, no airway management complication occurred in LM group after tumor removal, suggesting that repositioning of the LM in this special position with the head being fixed in the Mayfield clamp is feasible. Matsuda et al^[23] reported ventilation difficulties during awake craniotomy that was initially managed by LM airway requiring emergency endotracheal intubation. However, ventilation difficulties occurred due to a cannot ventilate situation as a result of tight airways that had not been observed in our study. The fact that LMs require lower airway pressure limits need to be considered. Therefore, medical history in particular preexisting pulmonary conditions need to be taken into account and require individualized airway management strategies for awake craniotomy.

The significant higher incidence of airway management complications and cannot intubate situation in the FOI group compared to LM group is surprising and need to be acknowledged. According to national guidelines, FOI is the recommended airway management strategy for a predicted difficult airway.^[13] However, based on the significant less airway complications in the LM group and the high incidence of cannot intubate situations in the FOI group our data suggest that for the specific patient positioning during awake craniotomy alternative airway management strategies need to be considered.

Prolonged ICU therapy occurred more often in the LM group without being statistically significant. However, indication for prolonged ICU therapy was neurological deterioration and not due to respiratory reasons. In contrast, respiratory complications were the indication for ICU treatment in 2 patients from the FOI group. One patient suffered from pulmonary edema and the other had bloody aspirates. The latter patient also suffered from a complicated airway reinsertion intraoperatively, indicating endotracheal trauma from reintubation.

Several limitations including the retrospective nature, a low patient number, and comparing 2 different treatments with data not being powered for have to be considered interpreting our results. Furthermore, there was a change in treatment with FOI being the standard procedure during the first part of the observational period and the use of LMs being the later. However, one of the most recent patients included in our retrospective analysis was fiberoptic intubated because of a tight LM placement being impossible, indicating that both procedures are still regular performed at our institution.

To our knowledge, this is the first study showing the safety and feasibility of LM for airway management during awake craniotomy. Most notably, our study indicated that FOI was associated with increased duration of mechanical ventilation, unsuccessful tube repositioning, and blood aspiration. In contrast, in LM group no complicated reinsertion of the LM after tumor removal and no laryngeal bleeding or blood aspiration have been observed. More importantly, the usage of LM changed the procedure resulting in reduced duration of mechanical ventilation. Moreover, in the FOI group a LM was successfully used as backup airway management in a “cannot intubate” situation for the second asleep phase.

In summary our data indicate that fewer complications occurred in patients receiving a LM compared to FOI, suggesting that airway management with a LM may be safe for patients undergoing awake craniotomy for tumor removal and justifying a deviation from current guidelines.

Author contributions

Conceptualization: Sven Klaschik, Ági Güresir, Martin Soehle, Hartmut Vatter, Erdem Güresir, Markus Velten.

Data curation: Josefin Grabert.

Formal analysis: Josefin Grabert, Tobias Hilbert.

Investigation: Josefin Grabert.

Methodology: Sven Klaschik, Ági Güresir, Patrick Jakobs, Tobias Hilbert, Erdem Güresir.

Project administration: Ági Güresir, Patrick Jakobs, Hartmut Vatter, Markus Velten.

Supervision: Patrick Jakobs, Martin Soehle, Markus Velten.

Validation: Hartmut Vatter.

Writing – original draft: Josefin Grabert.

Writing – review & editing: Martin Soehle, Erdem Güresir, Markus Velten.

References

[1] Saito T, Tamura M, Chernov MF, et al. Neurophysiological monitoring and awake craniotomy for resection of intracranial gliomas. *Prog Neurol Surg* 2018;30:117–58.

- [2] Sarang A, Dinsmore J. Anaesthesia for awake craniotomy: evolution of a technique that facilitates awake neurological testing. *Br J Anaesth* 2003;90:161–5.
- [3] Frost EA, Booij LH. Anesthesia in the patient for awake craniotomy. *Curr Opin Anaesthesiol* 2007;20:331–5.
- [4] Bilotta F, Rosa G. “Anesthesia” for awake neurosurgery. *Curr Opin Anaesthesiol* 2009;22:560–5.
- [5] Brown T, Shah AH, Bregy A, et al. Awake craniotomy for brain tumor resection: the rule rather than the exception? *J Neurosurg Anesthesiol* 2013;25:240–7.
- [6] Eseonu CI, ReFaey K, Garcia O, et al. Awake craniotomy anesthesia: a comparison of the monitored anesthesia care and asleep-awake-asleep techniques. *World Neurosurg* 2017;104:679–86.
- [7] Özlü O. Anaesthesiologist’s approach to awake craniotomy. *Turk J Anaesthesiol Reanim* 2018;46:250–6.
- [8] Huncke K, Van de Wiele B, Fried I, et al. The asleep-awake-asleep anesthetic technique for intraoperative language mapping. *Neurosurgery* 1998;42:1312–6.
- [9] Cai T, Gao P, Shen Q, et al. Oesophageal naso-pharyngeal catheter use for airway management in patients for awake craniotomy. *Br J Neurosurg* 2013;27:396–7.
- [10] Audu PB, Loomba N. Use of cuffed oropharyngeal airway (COPA) for awake intracranial surgery. *J Neurosurg Anesthesiol* 2004;16:144–6.
- [11] Cherg CH, Wu ZF, Lin BF. A modified nasopharyngeal tube for awake craniotomy. *J Neurosurg Anesthesiol* 2016;28:275–7.
- [12] Tongier WK, Joshi GP, Landers DF, Mickey B. Use of the laryngeal mask airway during awake craniotomy for tumor resection. *J Clin Anesth* 2000;12:592–4.
- [13] Piepho T, Cavus E, Noppens R, et al. S1 guidelines on airway management: Guideline of the German Society of Anesthesiology and Intensive Care Medicine. *Anaesthesist* 2015;64(Suppl 1):27–40.
- [14] Shinokuma T, Shono S, Iwakiri S, et al. Awake craniotomy with propofol sedation and a laryngeal mask airway: a case report. *Masui* 2002;51:529–31.
- [15] Marques MB, Castro CHV de, Diniz DA, et al. Use of the lateral approach for laryngeal mask insertion during awake craniotomy: case report. *Rev Bras Anestesiol* 2006;56:654–7.
- [16] Gadhinglajkar S, Sreedhar R, Abraham M. Anesthesia management of awake craniotomy performed under asleep-awake-asleep technique using laryngeal mask airway: report of two cases. *Neurol India* 2008;56:65–7.
- [17] Schnider TW, Minto CF, Gambus PL, et al. The influence of method of administration and covariates on the pharmacokinetics of propofol in adult volunteers. *Anesthesiology* 1998;88:1170–82.
- [18] Soehle M, Wolf CF, Priston MJ, et al. Comparison of propofol pharmacokinetic and pharmacodynamic models for awake craniotomy: a prospective observational study. *Eur J Anaesthesiol* 2015;32:527–34.
- [19] Costello TG, Cormack JR. Anaesthesia for awake craniotomy: a modern approach. *J Clin Neurosci* 2004;11:16–9.
- [20] Brady K, Hogue CW. Intraoperative hypotension and patient outcome: does “one size fit all?”. *Anesthesiology* 2013;119:495–7.
- [21] Rubin RH. Surgical wound infection: epidemiology, pathogenesis, diagnosis and management. *BMC Infect Dis* 2006;6:171.
- [22] Cheng H, Clymer JW, Po-Han Chen B, et al. Prolonged operative duration is associated with complications: a systematic review and meta-analysis. *J Surg Res* 2018;229:134–44.
- [23] Matsuda A, Mizota T, Tanaka T, et al. Difficult ventilation requiring emergency endotracheal intubation during awake craniotomy managed by laryngeal mask airway. *Masui* 2016;65:380–3.