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ORIGINAL INVESTIGATION

Airway management in general anesthesia for endovascular treatment of cerebral arteriovenous malformation: a retrospective observational study

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Abstract
Background and objective: This retrospective and observational study aimed to retrospectively evaluate the use of the endotracheal tube (ETT) and the Laryngeal Mask Airway (LMA) for the airway management with respect to airway safety, hemodynamic stability, adverse respiratory events, and recovery characteristics in patients who underwent endovascular treatment (EVT) for cerebrovascular arteriovenous malformation under general anesthesia between 2011 and 2018.
Methods: The study included data from the patient's electronic medical records and anesthesia files. The primary outcome measure was the incidence of hemodynamic disturbances and respiratory adverse events during airway management. The secondary outcome measure was the comparison of recovery characteristics.
Results: The airway was secured using ETT in 41 patients and LMA in 39 patients. Airway safety was established in all patients without a complication throughout the procedure. Mean arterial blood pressure and heart rate were increased to > 20% of baseline levels at intubation and extubation periods in more patients in the ETT group than the LMA group (27 vs. 3; $p = 0.07$, and 11 vs. 2; $p = 0.021$). Respiratory adverse events including straining and coughing were observed in ten patients in the ETT group but only in one patient in the LMA group ($p = 0.013$). Time to extubation, to neurological assessment, and to discharge from the angiography unit were similar ($p > 0.05$).

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Conclusion: It was concluded that LMA provided sufficient airway safety as with ETT and may be used as an alternative to ETT for EVTs under general anesthesia.

Introduction

Endovascular Treatment (EVT) has been increasingly used in the past twenty years as a sole therapy or more frequently, as a component of the multimodal therapy for the treatment of brain Arteriovenous Malformations (AVMs) (1). The aim of EVT is to reduce the size and blood flow of the nidus of AVM to occlude its feeders via the application of Ethylene-Vinyl Alcohol Copolymer (EVOH) or Onyx through a microcatheter.[1,2] The anesthetic management of EVT for AVM involves general principles of the interventional neuroradiology (INR), which have been adopted mainly from the traditional neurosurgery: a) providing an immobile patient, b) maintaining hemodynamic stability, c) manipulation of arterial blood pressure (ABP) as necessary, d) smooth emergence from the anesthesia, e) early recovery as shown by a neurological assessment, and f) treatment of complications.[3,4]

Among the various anesthetic techniques such as conscious sedation, general anesthesia (GA), and neurolept anesthesia, GA is the most commonly used technique because it ensures both immobilization and airway safety during the procedure. Endotracheal intubation has been generally used for airway management in GA.[5-10] Although supraglottic airway devices are well-known tools for the airway management in GA, their use in the interventional neuroradiological procedures is limited. Only four reports exist in the literature.[11-14]

Endovascular treatments were begun for cerebrovascular aneurysm in 2008 and for arteriovenous malformation in 2011 in our hospital. We have been using both the endotracheal tube (ETT) and the Laryngeal Mask Airway (LMA) for the airway management in procedures under GA.

This study aimed to retrospectively evaluate the use of ETT and LMA for the airway management with respect to airway safety, hemodynamic stability, adverse respiratory events, and recovery characteristics in patients who underwent endovascular treatment for cerebrovascular arteriovenous malformation under general anesthesiabetween 2011 and 2018.

Methods

This observational and retrospective study was conducted in a tertiary hospital from January 2011 to April 2018. After obtaining hospitals ethic committee approval, data were retrospectively collected from the hospital's computerized data base (MedData^{TM} HBYS), medical and anesthesia files of all adult patients who underwent elective endovascular treatment for uncomplicated cerebrovascular AVM by a single neuroradiologist in the INR unit. The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[15-17] Obtaining informed consent was waived with respect to the retrospective design of the study.

The inclusion criteria were as follows: elective EVT for cerebral AVM under general anesthesia and American Society of Anesthesiologists (ASA) physical status I—II patients without neurological deficits. Exclusion criteria were a history of cerebrovascular surgery, neurological impairment before the procedure, difficult airway management, insufficient data, and lost to follow-up in the perioperative period.

Anesthetic technique

All patients were examined by the anesthesiologists before the intervention. A large-bore peripheral venous cannula was inserted in the forearm, and 8—10 mL.kg^{-1} saline or Ringer's lactate was given for prehydration during the fasting period, which lasted six hours for light meals and two hours for clear fluids. Patients were monitored with electrocardiography (ECG), pulse oximetry, and noninvasive blood pressure (NIBP) in the INR unit. Baseline vital parameters were recorded. An arterial catheter was placed in the left radial artery after local anesthetic infiltration to monitor arterial blood pressure and to take blood samples for activated clotting time (ACT) measurement.

GA was induced using 2—2.5 mg^{-1}kg^{-1} intravenous (IV) propofol and 1—2 μg^{-1}kg^{-1} fentanyl. 0.6 mg^{-1}kg^{-1} rocuronium was given to facilitate endotracheal intubation or LMA insertion, and 1.5 mg^{-1}kg^{-1} lidocaine (2%) was given to suppress airway reflexes. After three minutes of mask ventilation with 100% oxygen, an ETT (ID 6.5—8.0) was placed after direct laryngoscopy or a LMA (- no 3—5) was inserted (LMA-Classic^{TM}, Intavent Orthofix Ltd., Maidenhead, Berkshire, United Kingdom). LMA was inserted using the classical method described by Brain.[18] Volume inflated in the pneumatic cuff of the LMA was 15 mL for size 3, 20 mL for size 4, and 30 mL for size 5 to minimize the pressure on the pharynx. Patients were ventilated using positive pressure ventilation (PPV). Ventilator settings were adjusted to keep the end tidal CO_2 level between 25 and 29 mmHg (mild hypocapnia) and the peak airway pressure lower than 20 cmH_2O.

A total intravenous anesthesia (TIVA) technique using remifentanil and propofol infusions was used for the maintenance of anesthesia. Remifentanil was given with a constant infusion rate (2 μgkg^{-1}h^{-1}). Propofol infusion rate was changed in a range between 3—6 μg.kg^{-1}h^{-1} to maintain mean arterial pressure (MAP) between 60 and 70 mmHg until glue injection and between 20% and 30% below the baseline MAP during the glue injection to slow the blood circulation in the injection area.

The body temperature was monitored, and a forced air warming device was used to prevent hypothermia. An urine

catheter was placed, and urine output was monitored. The baseline activated clotting time (ACT) was measured, and heparin 100 U.kg^{-1} was given as a loading dose, and an infusion was started at a rate of 15 U.kg^{-1}h^{-1} to maintain the ACT between 2 and 3 times the normal rate after the femoral artery cannulation. A total of 1200 mg N-acetylcysteine and 50 mg ranitidine were given to prevent contrast-induced nephropathy and for gastric protection. After completion of EVT, TIVA and heparin infusions were discontinued. Ventilation was controlled with 100% oxygen until the return of spontaneous ventilation. IV 1.5 mg.kg^{-1} lidocaine was given to prevent airway reflexes during extubation, and 40 μg.kg^{-1} neostigmine and 20 μg.kg^{-1} atropine were given for the reversal of the neuromuscular blocking agent in both groups. ETT or LMA was removed when spontaneous respiration resumed (tidal volume > 4 mL.kg^{-1}) and when consciousness returned.

The following recovery and discharge times were recorded: time to extubation or to removal of LMA, time to the neurological assessment, and time to discharge from the angiography unit to the intensive care unit (ICU). The neurological status of the patient was assessed by the neuroradiologist using the Glasgow Coma Scale (GCS) who performed the EVT. Patients with stable neurological and hemodynamic status, a modified Aldrete recovery score > 9, and a dry femoral artery puncture site were discharged from the angiography unit to the ICU.

Systolic arterial blood pressure (SAP), diastolic arterial blood pressure (DAP), mean arterial pressure (MAP), peripheral oxygen saturation (SpO_2), heart rate (HR), and end-tidal CO_2 ($etCO_2$) levels were monitored and recorded continuously throughout the procedure. Vital signs were recorded before induction (baseline), before (pre-intubation) and after endotracheal intubation or LMA insertion (post-intubation), after extubation or removal of LMA (post-extubation), and at 5 minutes intervals during the procedure. A bolus dose of 40 μg.kg^{-1} metoprolol was given when the MAP increased > 20% above baseline values to avoid further increments in ABP. Respiratory adverse events and other complications were assessed and recorded throughout the procedure.

The electronic medical records, medical and anesthesia files, and intensive care unit charts were evaluated to collect data including demographic characteristics, techniques of anesthesia and airway management, hemodynamic changes after airway management and extubation, respiratory adverse events throughout the procedure, recovery and discharge times after the procedure, and the other complications related to the EVT. The records with insufficient data were excluded from the study. Only the files of patients whose EVT was performed by the same neuroradiologist, and anesthesiologists were included.

The primary outcome measures were the incidence of hemodynamic disturbance that was defined as the hemodynamic parameters which were not between ±20% of baseline values and the incidence of adverse respiratory events including laryngospasm, apnea, cough, gagging, and straining. The secondary outcome measure was the comparison of recovery times after the procedure including time to extubation, time to neurological assessment, and time to discharge from the INR unit to the ICU (min).

A power analysis was conducted to calculate sample size based on a prior study using PASS 13 software.[14,19] A total sample size of 72 (36 cases for each group) was required to detect at least 30% difference in MAP between ETT and LMA groups with a power of 80% at the 5% significance level.

Statistical analysis

All records were analyzed for missing data. The patient who had partially missing data and was lost to follow-up after the intervention was excluded from the study. The data were analyzed using the Statistical Packages for Social Sciences for Windows version 11.5 pocket program (IBM Corp., Chicago, IL, USA). For intergroup comparisons, the Chi-Square test and Fisher's exact test were used to analyze nominal data, and the *t*-test for independent samples was used for quantitative data. Data were expressed as mean ± SD for continuous variables and numbers, and percentages for categorical variables. The value of $p < 0.05$ was considered significant.[20]

Results

Medical records of 80 patients were reviewed. There was no missing data and all patients have completed the follow-up period that lasted 38−42 hours (Fig. 1). Two groups were identified considering the airway management technique: the Endotracheal Tube group (group ETT ; n = 41) and the Laryngeal Mask Airway group (group LMA ; n = 39). The demographic characteristics were similar between the groups (Table 1).

Primary outcome measures

Respiratory complications related to the airway management including insufficient ventilation, desaturation, laryngospasm, or bronchospasm were not recorded. There were three periods throughout the procedure where hemodynamic changes in mean arterial blood pressure and heart rates were not ±20% of baseline values: a) After the induction of GA (pre-intubation), b) After airway management (post-intubation), and c) After extubation (post-extubation).

The pre-intubation MAP levels were lower than 20% of baseline values in 21 patients in the ETT group and in 19 patients in the LMA group ($p = 0.771$). Heart rate was reduced to < 20% of baseline levels in 11 patients in the ETT

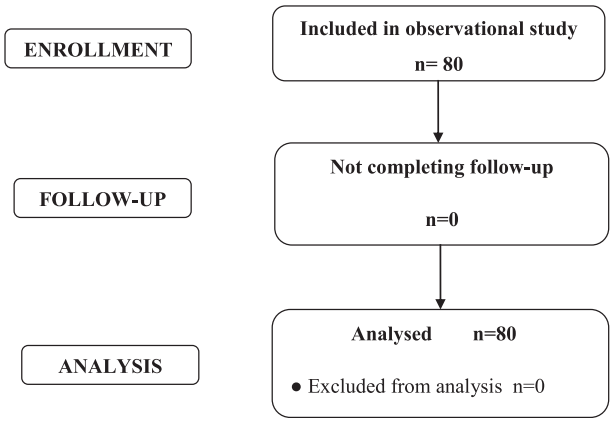

Figure 1 Flow diagram detailing participant flow through observational study.

Table 1 Patient baseline characteristics.

Parameters	Group ETT (n = 41)	Group LMA (n = 39)	*p*
Age (years)[a]	33.4 (10.3)	34.5 (11.8)	0.693
Gender (Female / Male)[b]	26 / 15	24 / 15	0.551
Body Mass Index ($kg.m^{-2}$)[a]	25.2 (2.3)	25.4 (2.0)	0.315
ASA physical status I / II[b]	36 / 5	33 /6	0.803
Mallampati Score I / II / III[b]	32 / 8 / 1	29 / 9 / 1	0.541

ETT, Endotracheal Tube; LMA, Laryngeal Mask Airway; ASA, American Society of Anesthesiologists.
[a] Data presented as mean (standard deviation).
[b] Data presented as absolute number (n).
$p < 0.05$ was considered as statistically significant.

Table 2 Comparison of changes in mean arterial blood pressure and heart rate between groups.

Parameters	ETT / LMA ± 20% of baseline	ETT / LMA < 20% of baseline	ETT / LMA > 20% of baseline	*p*
Mean Arterial Pressure[a]				
Preintubation	20 (48.8%) / 20 (51.3%)	21 (51.2%) / 19 (48.7%)	0 (0%) / 0 (0%)	0.771
Postintubation	14 (34.1%) / 36 (92.3%)	0 (0%) / 0 (0%)	27 (65.9%) / 3 (7.7%)	0.007
Postextubation	30 (73.2%) / 37 (94.9%)	0 (0%) / 0 (0%)	11 (26.8%) / 2 (5.1%)	0.021
Heart Rate[a]				
Preintubation	26 (63.4%) / 24 (61.5%)	11 (26.8%) / 12 (30.7%)	4 (9.8%) / 3 (7.6%)	0.563
Postintubation	12 (29.2%) / 30 (76.9%)	0 (0%) / 0 (0%)	29 (70.7%) / 9 (23.1%)	0.002
Postextubation	18 (43.9%) / 33 (84.6%)	0 (0%) / 0 (0%)	23 (56.1%) / 6 (15.4%)	0.002

ETT, Endotracheal Tube; LMA, Laryngeal Mask Airway.
[a] Data presented as absolute number and percentage, n (%).
$p < 0.05$ was considered as statistically significant.

group and in 12 patients in the LMA group before the intubation ($p = 0.563$) (Table 1). The pre-intubation MAP levels and heart rates were reduced to < 20% of baseline values in similar number of patients in both groups ($p = 0.771$ and $p = 0.563$, respectively) (Table 1). The post-intubation MAP levels and heart rates were increased to > 20% of baseline values in significantly more patients in the ETT group than in the LMA group (27 vs. 3; $p = 0.007$ and 29 vs. 9; $p = 0.002$, respectively) (Table 2). Similarly, the post-extubation MAP levels and heart rates were increased to > 20% of baseline values in more patients in the ETT group compared to the LMA group (11 vs. 2; $p = 0.021$ and 23 vs. 6; $p = 0.002$, respectively) (Table 2). Hemodynamic disturbances as elevation in MAP were managed successfully using metoprolol.

A total of eleven respiratory adverse events were recorded in all patients. Straining was recorded in one patient after intubation and in another five after extubation in the ETT group compared to one patient in the LMA group after extubation ($p = 0.002$). Coughing was recorded in 4 patients in the ETT group after extubation but was not recorded in the LMA group ($p = 0.001$) (Table 3). All respiratory adverse events were resolved spontaneously without an intervention and did not result in a further complication.

Secondary outcome measure

The mean duration of the procedure was 108.5±21.3 min and was not statistically different between the groups ($p > 0.05$). The mean time to extubation, time to the neurological assessment, and time to the discharge from the INR unit to ICU were not different in either group after the procedure ($p > 0.05$) (Table 3).

Table 3 Comparison of recovery times and respiratory adverse events between groups.

Parameters	Group ETT	Group LMA	*p*
Recovery Times (min)[a]			
Time to extubation	8.9 ± 1.8	9.1 ± 1.6	0.101
Time to neurological assessment	12.6 ± 2.9	12.8 ± 3.0	0.136
Time to discharge	17.5 ± 2.3	17.1 ± 1.4	0.214
Respiratory adverse events[b]			
Straining	6 (14.6%)	1 (2.5%)	0.002
Coughing	4 (9.7%)	0 (0%)	0.001

ETT, Endotracheal Tube; LMA, Laryngeal Mask Airway.
[a] Data presented as mean (standard deviation).
[b] Data presented as absolute number and percentage, n (%).
$p < 0.05$ was considered as statistically significant.

There was no procedure-related complication observed throughout the procedure. The patients were followed in the ICU for 14–22 hours, and then were transferred to the service. All patients were discharged from the hospital at the next day.

Discussion

The results of the study demonstrated that both ETT and LMA provided sufficient airway security without major complications including insufficient ventilation, desaturation,

laryngospasm, or bronchospasm. Hemodynamic disturbances were manageable and did not result in further complications. Recovery times were also similar that allowed rapid neurological assessment in the INR unit. The incidence of hemodynamic disturbance and respiratory adverse events were lower in the LMA group. According to the results, it can be stated that LMA may be safely used in patients who underwent endovascular treatments for cerebrovascular arteriovenous malformation under general anesthesia.

The anesthetic principles for EVT were developed mainly from intracranial neurosurgical anesthesia.[3-5] Endotracheal intubation is used to ensure the airway security in the intracranial surgeries because the patients are placed in the sitting, prone or lateral decubitus positions and the patient's head is sometimes fixed using a skull clamp head frame. The duration of the surgery lasts up to 3−5 hours and also painful.[4-6]

We have been also using routinely endotracheal intubation in general anesthesia for EVTs as recommended in the literature.[3-9] But, in our practice, the elevation of arterial blood pressure at intubation period induced by direct laryngoscopy, and cough and straining at the extubation periods were criticized by the neuroradiologist due to the risk for the development of an intracerebral hemorrhage, which is one of the leading factors causing morbidity and mortality.

As in neurosurgery, the maintenance of hemodynamic stability is very important in EVT. The rate of bleeding during AVM embolization has been reported to be 1.4%, and it has been found that the lack of hypotension is one of the clinical predictors of hemorrhage.[21,22] Anesthesiologists are responsible for establishing preventive measures against hemodynamic disturbances such as minimizing airway reflexes during airway management, manipulating ABP with hypotensive agents as necessary, and maintaining the anesthetic depth in a stable manner.[9] However, our efforts including intravenous lidocaine boluses to reduce airway reflexes were not always successful.

This issue directed us to investigate the availability of supraglottic airway devices in EVTs, which has been widely used as an alternative for endotracheal intubation in many other surgeries under general anesthesia. It was reported that hemodynamic disturbances were found to be significantly reduced with classical LMA than ETT during airway management at intubation and extubation periods.[23,24] Also, a systematic review and meta-analysis revealed that the incidence of laryngospasm, cough at removal, dysphagia or dysphonia, sore throat, and hoarseness was reduced with supraglottic airway devices.[25]

However, only one report existed in the literature which reported the use of LMA in three patients who underwent coiling of unruptured cerebral aneurysms under general anesthesia.[11] It was concluded that LMA may be a safe alternative by avoiding the hemodynamic effects of tracheal intubation.

Upon this, it was decided to try using LMA in the EVT of cerebrovascular aneurysms except in conditions where the use of LMA were contraindicated including history of obesity, chronic obstructive pulmonary disease, low pulmonary compliance, hiatal hernia, gastroparesis, inability to open the mouth, and an infection or pathologic abnormality in the oropharyngeal cavity.[26] As EVTs differ from the surgery, anesthetic requirements vary across both procedures at some points. The patients are in a supine position, the position of the head is neutral, and a skull clamp is not necessary to fix the head during the EVT procedure. The C-arm of the fluoroscope is turned around the head without a contact with patient's body. Those provide easy access to the airway during the procedure. It is reported that EVTs last up to 120 minutes, which is much shorter and also painless compared to the surgery.[2] Taking in the account all these factors, the conditions might not pose an additional risk to use the LMA in the EVT procedures.

The use of LMA was started first in EVTs of cerebrovascular aneurysm. After two years, it was continued in cerebrovascular AVM because there were no complications observed in the airway security related to the LMA and hemodynamic stability was established without an intervention.

There are few reports in the literature regarding the use of LMA and all were performed in the EVTs for cerebrovascular aneurysms. In a study, it was concluded that LMA ensured suitable conditions based on an analysis of cardiovascular stability in 26 patients.[12] LMA was used in another study which investigated the effect of dexmedetomidine on the recovery characteristics in 102 patients. It was reported that all patients were ventilated through LMA without a respiratory complication.[13] A retrospective study was conducted by the authors of this study in patients who underwent EVT during an eight-years period. It was concluded that LMA may be routinely used due to airway securing without respiratory complications and hemodynamic disturbance.[14]

A rapid and smooth recovery is also important for assessing of the neurological status and early diagnosis of the postprocedural complications including bleeding, vasospasm, stroke, and focal deficits.[6,7] In our study, the recovery and discharge times were similar in both groups. This is attributable to use propofol, fentanyl, and rocuronium, an intermedium acting neuromuscular blocking agent for the induction of anesthesia and a TIVA technique based on the propofol and remifentanil infusions for the maintenance. These anesthetic drugs provide stable hemodynamics and rapid recovery from anesthesia. This result is consistent with a study which found similar recovery and discharge times using remifentanil-propofolbased TIVA and an intermedium acting neuromuscular blocking drug (mivacurium) in patients undergoing elective orthopedic surgery with LMA or TT.[27]

The current study has several limitations. First, the retrospective nature of the study might have resulted in bias that affected the selection of the control group. Additionally, exposure to the interventions and outcomes may be difficult to control in both groups. To prevent this disadvantage, we used the same inclusion and exclusion criteria during the data collection period. Data were obtained from multiple sources including anesthesia files, electronic medical records, and ICU charts to reduce recall bias. A single neuroradiologist and the same anesthesiologists performed all interventions. The patient files with insufficient data were excluded. It should be noted that the study aimed to evaluate the data of the anesthetic experience with LMA and ETT focusing on the safety profile in EVT for cerebrovascular AVM which is a relatively new procedure for the anesthetic management. Therefore, we think that prospective and randomized studies are required to prove the availability of modern airway devices in this evolving area. Another limitation was the lack of the use of bispectral index and neuromuscular junction monitoring. They would provide real-time data about the depth of the anesthesia.[28,29]

It is concluded that LMA may be used as an alternative to endotracheal tube in the routine anesthetic practice for endovascular treatment of cerebral AVMs. LMA provided airway security as safe as ETT with attenuation of hemodynamic disturbance and minimal adverse respiratory events.

Author's contributions

MAS and MÖÖ conducted the study, collected the data, and contributed the writing of the manuscript. MÖÖ and COC analyzed the study results and contributed the revision of manuscript. MBE and BA assisted in analysis data and contributed the writing of the manuscript. MAS designed, directed, and reviewed the study.

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Conflicts of interest

The authors declare no conflicts of interest.

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Supplementary materials

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