1. TITLE PAGE

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Evaluation of the utility of pre-operative endoscopic airway assessment for airway management in patients undergoing endolaryngeal microsurgery

Final Master's Thesis

Department of Anesthesiology
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Scientific Supervisor:
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3. SUMMARY

Author: Leon Holstermann

Title of thesis: Evaluation of the utility of pre-operative endoscopic airway assessment for airway management in patients undergoing endolaryngeal microsurgery

Aim of the research: The study aimed to evaluate the utility of pre-operative endoscopic airway examination (PEAE) for airway management and prediction of difficult intubation in patients undergoing endolaryngeal microsurgery.

Objectives:

1. To assess the frequency of difficult airway occurrence in patients undergoing endolaryngeal microsurgery.
2. To evaluate the rate of successful intubations, attempts and manoeuvres used during intubation.
3. To assess the correlation between the image of the larynx seen during endoscopic evaluation and direct laryngoscopy during intubation based on the Cormack-Lehane classification.
4. To assess the impact of preoperative endoscopic airway assessment for selecting airway management methods in patients undergoing endolaryngeal microsurgery.

Methodology: In this study, the patient population was undergoing endolaryngeal microsurgery in the anesthesiology department of the Lithuanian University of Health Sciences hospital (Kauno Klinikos). Preoperative endoscopy was performed, and the image was reviewed by an anesthesiologist. Postoperatively, an anonymized questionnaire was filled out by the anesthetist. Afterwards the data was checked for errors and missing information and statistical analysis was performed on 110 eligible patients, using SPSS.

Research results: The study found multiple significant associations between symptoms and endoscopic changes in regard to the complexity of the patient's airway. An abnormal population regarding the Endotracheal tube (ET) size was observed. Lastly the images taken during endoscopy were in the majority of patients identical with the view during laryngoscopy.

Conclusions:

1. The overall frequency of difficult airway was 20.9%, with 2.7% occurring unexpected.
2. The rate of unsuccessfull intubations was 5.5%. These patients were correctly identified for difficult airways and underwent awake intubation. Intubation tools and techniques used matched the expected rationale of utilization.

3. A strong correlation was identified between the endoscopic view and the laryngoscopy. The correlation in easy airways was stronger than in difficult airways but in both patient groups significant ($p<0.05$).
4. The impact of PEAE was not significant in regard to changing the airway management plan ($p>0.05$), but predictors for difficult airways were identified.

4. ACKNOWLEDGEMENTS

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5. CONFLICTS OF INTEREST

No conflict of interest between the author (Leon Phillip Holstermann) and the supervisor (PhD. Asta Maciuliene).

6. PERMISSION BY THE ETHICS COMMITTEE

The Ethics Committee of Biomedical Surveys provided ethical approval for the study *"Evaluation of the utility of pre-operative airway endoscopy airway examination in patients undergoing endolaryngeal microsurgery"* on the 01.03.2023, after the submission of the Ethical Self-Assessment Form, approval of the head of the department and the questionnaire used for data collection. The data collection for this study was carried out in the Department of Anesthesiology, Lithuanian University of Health Sciences (LSMU) from May 1st to September 1st, 2022. Ethical approval number: BEC-MF-236.

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* Pastaba: šis pritarimas neatleidžia tiriamąjį mokslinį darbą vykdančių asmenų nuo prievolės laikytis Bendrojo duomenų apsaugos reglamento nuostatų ir nuo atsakomybės gauti nacionalinio arba regioninio bioetikos komiteto leidimą, jei toks leidimas būtinas pagal LR Biomedicininių tyrimų etikos įstatyme numatytus reikalavimus.

7. ABBREVIATIONS

ASA	American Society of Anesthesiologists
ECMO	extracorporeal membrane oxygenation
BURP	backwards, upwards, right sided pressure
ENT	ear, nose, throat
OSA	obstructive sleep apnea
BMI	body mass index
PEAE	preoperative endoscopic airway examination
ET	endotracheal tube

8. TERMS

Capnography	monitoring of the concentration or partial pressure of carbon dioxide.
Difficult airway	the clinical situation in which a conventionally trained anesthesiologist experiences difficulty with facemask ventilation of the upper airway, difficulty with tracheal intubation, or both.
End-tidal volume	the amount of air that moves in or out of the lungs with each respiratory cycle.
Endoscopy	a procedure in which an instrument is introduced into the body to give a view of its internal parts.
Gold standard	a method, procedure or measurement that is widely accepted as being the best available.
Laryngoscopy	examination of the larynx with a mirror or camera (indirect) or with a laryngoscope (direct).
Macintosh laryngoscope	direct laryngoscope with the use of the curved “Macintosh” blade.
Stenosis	an abnormal narrowing in a blood vessel or other tubular organ or structure.
Tracheostomy	an incision of the trachea (windpipe) made to relieve an obstruction to breathing.
Video-Laryngoscope	a device that allows indirect laryngoscopy or visualization of the larynx without direct line of sight.

9. INTRODUCTION

Airway management is a daily challenge in the anesthesiologist's clinical practice. The correct assessment of patient-dependent anatomical, physiological, and clinical situations related to factors of a difficult airway is crucial for patient safety and outcomes [1,2]. Therefore, the Anesthesiology team needs to have a deep knowledge of different methods and equipment for maintaining the airway.

According to the guidelines of the American Society of Anesthesiologist's, the routine examination to evaluate an airway consists of a detailed examination of the patient preoperatively. In addition, the patients' medical records, clinical conditions, diagnostic test results, patient/family history and questionnaire responses can give information regarding factors that indicate a complex airway [3]. Furthermore, a physical examination provides additional information to identify physical characteristics that may indicate risk factors for a difficult airway [3].

Since many of these factors (tables 1-2) include pathologies related to the head and neck regions, the overall occurrence of difficult airway is much more prevalent in the otolaryngeal surgery department [4,5].

Management of the unexpectedly difficult airway is much more complicated, as this requires the preparation of specific tools for the management of such situations. Therefore, precise identification and suspicion of difficult airway preoperatively are important for patient safety and outcomes. Some studies show that up to 90% of difficult airways occur unexpectedly [6].

We hypothesised that preoperative endoscopic evaluation of the airway of patients undergoing endolaryngeal microsurgery would improve or assist the anesthesiologist's decision-making regarding assessment and management of the patient's airway. This finding would be impactful in a patient population with a much more prevalent difficult airway [4]. It may also lead to a decrease of unnecessary awake intubations in patients with a wrongly suspected difficult airway, lowering the time and resource consumption per patient for the hospital [7]

10. AIM AND OBJECTIVES

The study aimed to evaluate the utility of pre-operative airway endoscopy assessment for airway management and prediction of difficult intubation in patients undergoing endolaryngeal microsurgery.

Objectives:

1. To assess the frequency of difficult airway occurrence in patients undergoing endolaryngeal microsurgery.
2. To evaluate the rate of successful intubations, attempts and manoeuvres used during intubation.
3. To assess the correlation between the image of the larynx seen during endoscopic evaluation and direct laryngoscopy during intubation based on the Cormack-Lehane classification.
4. To assess the impact of preoperative endoscopic airway assessment for selecting airway management methods in patients undergoing endolaryngeal microsurgery.

11. LITERATURE REVIEW

11.1 Anatomy and physiology

The respiratory system in humans is classified into the upper and lower respiratory tract. The upper respiratory tract consists of the pharynx (nasopharynx, oropharynx and laryngopharynx) and parts of the larynx. The lower respiratory system includes the trachea, bronchi, bronchioles and the lungs. The larynx contains the epiglottis and the vocal cords and is the gateway from the upper respiratory tract to the lower respiratory tract.

The structures of the upper respiratory tract are essential during the endotracheal intubation procedure, given that the tube must pass them to enter the trachea for successful intubation. Therefore, large structures or anatomical abnormalities can complicate airway management. The following assessment methods are the current standard worldwide and are used extensively and combined to predict patients at risk of complex airways [8].

11.2 Intubation

11.2.1 Patient position

The chances of a successful laryngoscopy and endotracheal intubation is maximised by proper patient positioning. The typical “sniffing” position, where the head is stretched at the atlanto-occipital joint and the neck is flexed, is ideal for direct laryngoscopy with a Macintosh-blade in most patients [9,10]. However, for the obese patient, the “ramped” position is recommended, because it improves laryngeal exposure during direct laryngoscopy. Furthermore, it also increases passive oxygenation during apnoea [10,11].

11.2.2 Laryngoscope

The choice of laryngoscope is a relevant factor for successful intubation. Video laryngoscopes have better visualization than the more traditional direct laryngoscope (Miller-, Macintosh-blade) and have shown more successful intubations on the first attempt [12]. Therefore, many consider the video-laryngoscope the ideal tool for intubation if used by an experienced and proficiently trained anesthetist and should be available in every setting that requires intubation. [10,12,13].

11.2.3 External laryngeal manipulation

To improve visibility during laryngoscopy, external laryngeal manipulation using the "BURP" manoeuvre (backward, upward, proper-sided pressure) may be applied during intubation by either the anesthetist or preferably an assistant [14] .

11.2.4 Bougie and/or Stylet

Two tools frequently used to aid the anesthetist in tracheal intubation are the stylet and the tracheal tube introducer, commonly known as bougie [10].

A stylet is a malleable metal rod placed inside the endotracheal tube before insertion, making it stiffer and allows for the endotracheal tube to pass into the trachea. A bougie is a more flexible plastic rod that is inserted into the trachea and is then used as a guide for the endotracheal tube to be inserted over the bougie [15]. These devices provide plasticity, making it able to pre-shape the endotracheal tube, thus increasing the chance for successful intubation [16]. To avoid trauma and perforation, the bougie/stylet should be introduced under direct vision. Recent studies suggest that the bougie facilitates a higher first attempt intubation rate in patients with complex airway characteristics in comparison to the endotracheal tube with stylet [17,18].

11.2.5 Confirmation of endotracheal tube placement

Problems with endotracheal tube placement are usually caused by poor laryngeal view and exposure, although they may also be caused by tube impingement or anatomical changes. Visual confirmation of the tube passing the vocal cords is recommended in order to confirm the proper positioning of the endotracheal tube. Furthermore, bilateral chest rising combined with vesicular breathing on auscultation and capnography verify the appropriate placement [10]. According to the published guidelines from ASA and the Difficult Airway Society, the gold standard for the confirmation of proper endotracheal intubation is the usage of capnography with appropriate end-tidal volumes of

CO_2 [3,10]. Capnography is an essential monitoring tool and is recommended by the Association of Anaesthetists to be available in every location where a patient may require anesthesia [19].

11.3 The difficult airway

The scientific community has yet to agree to an official definition of the difficult airway which would be recognized internationally. However, the Society of Anesthesiologist's task force on management of the difficult airway defines it as: "the clinical situation in which a conventionally trained anesthesiologist experiences difficulty with facemask ventilation of the upper airway, difficulty with tracheal intubation, or both" [20]. It must be noted that the difficult airways occurs unexpectedly in most cases (ranging from 75-93%) and only 25% of patients with anticipated difficult airways actually present with it during the intubation procedure [6]. Most complications during endotracheal intubation only temporarily harm the patient but failure to secure the airway can lead to tracheostomy and even death. Occurrence of failure to intubate was found to be around 3.7% of cases where mask ventilation was difficult, and only 0.1% of cases where mask ventilation was unproblematic, indicating that mask ventilation plays a vital role in difficult airway management [6]. Management of the anticipated and unanticipated difficult airway differs slightly. In the predicted difficult airway, the anesthetists may choose awake intubation or regional/spinal anesthesia whenever possible. The perioperative situation differs very little regarding anticipation. The Society of Anesthesiologists task force on management of the difficult airway recommends: "(1) calling for help, (2) optimising oxygenation, (3) use of cognitive aid (fig.1), (4) noninvasive airway management devices, (5) combination techniques, (6) invasive airway management interventions (7) ECMO" [3].

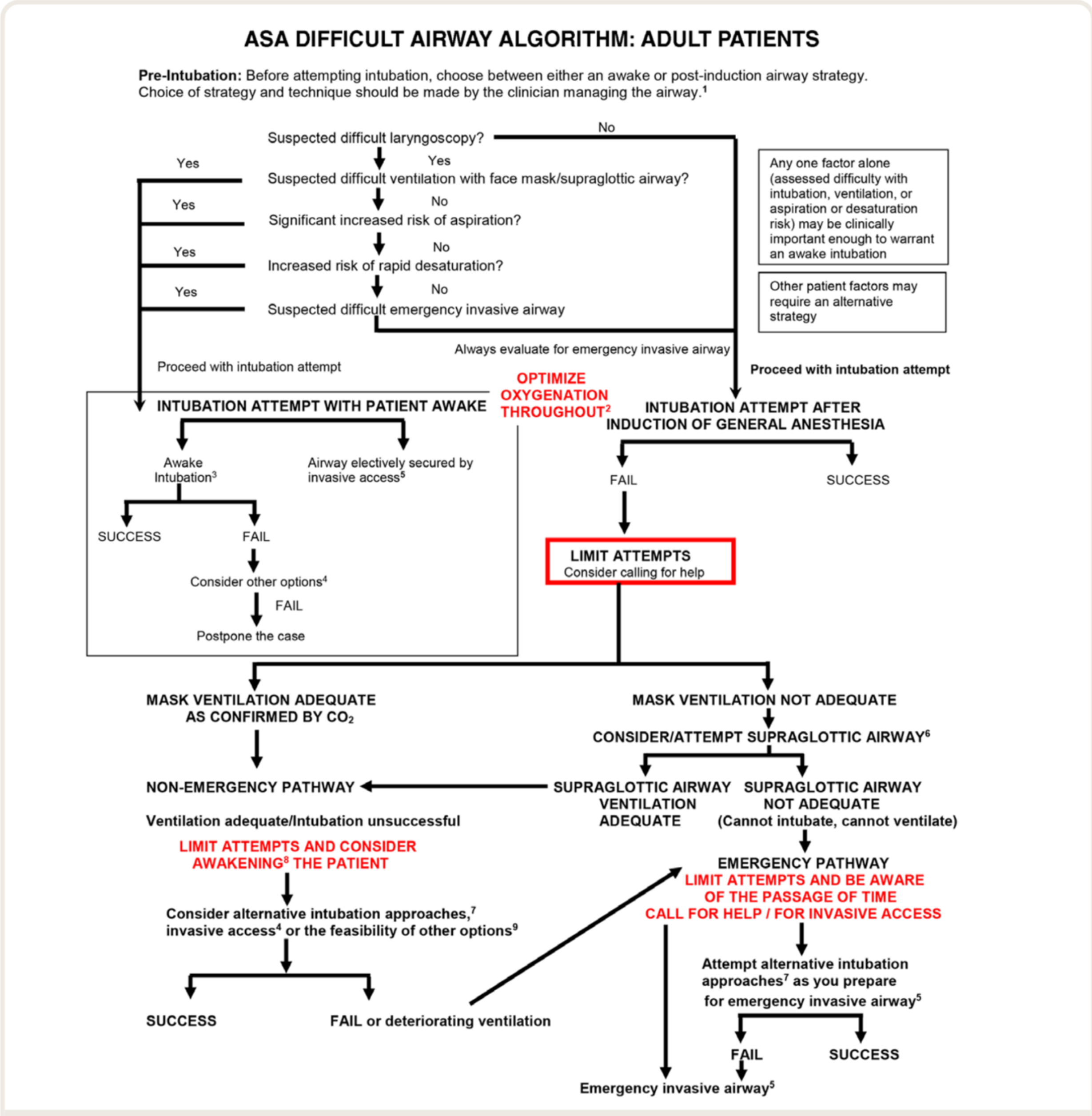


Fig. 1. ***"Difficult airway algorithm"*** (taken from ASA) [3]

11.4 Predictors and risk factors of the difficult airway

A previous history of difficult airway is an easy and effective way of identifying patients who are likely to present with a difficult airway again [21]. Obstructive sleep apnea (OSA) is another risk factor with significant relevance in ear nose throat (ENT) surgery, that is underdiagnosed in most patients [22]. Therefore, a preoperative screening is likely to identify most patients suffering from OSA and those at risk [22].

According to Hillmann et al.: “anesthesia and sleep predisposes the patient to upper airway obstruction through state-induced reductions in pharyngeal dilator muscle activation and lung volume”[22]. This is prevalent in the perioperative period, where the patient is very vulnerable, because of compromised reflexes that protect the patient from asphyxia during physiological sleep [22]. Patients with OSA are 44% more likely to present with difficult intubation [23]. Tables 1-3 list different predictors for difficult ventilation, direct and indirect laryngoscopy.

Table 1 ***Predictors of difficult and impossible mask ventilation*** *taken from [24], Courtesy of Dr. Vladimir Nekhendzy; Adapted from:* [25–27]

Difficult mask ventilation	**Impossible mask ventilation**
Mallampati grade 3 or 4	Mallampati grade 3 or 4
Decreased mandibular protrusion	Male sex
Presence of beard	Presence of beard
Obesity (BMI >30)	Neck radiation changes
Age >57 years	OSA (moderate to severe)
Lack of teeth	
History of snoring	

Table 2 ***Predictors of difficult videolaryngoscopy*** *taken from* [24] *Courtesy of Dr. Vladimir Nekhendzy, Adapted from:* [28–35]

Predictors of difficult videolaryngoscopy
Otolaryngologic or cardiac surgery
Sniffing head position
Abnormal neck anatomy (neck scar, neck mass, radiation changes)
Decreased cervical spine motion
Decreased oral entry (obesity, decreased mouth opening, decreased jaw mobility)
Restricted oropharyngeal space (edema, bleeding, retrognathia)

Table 3 ***Predictors of combined difficulty with mask ventilation and direct laryngoscopy*** *taken from* [24] *Courtesy of Dr. Vladimir Nekhendzy, Adepted from:* [36]

Predictors of difficult/impossible mask ventilation	**Modified and additional predictors**
Mallampati grade 3 or 4	Age >46 years
Decreased mandibular protrusion	Presence of teeth
Presence of beard	Neck radiation changes or mass
Obesity (BMI >30)	Thick or short neck
Male sex	Unstable neck or decreased neck extension
OSA (severe to moderate)	Decreased thyromental distance

11.4 Mallampati score

The Mallampati score was introduced in the 1980s when Seshagiri Rao Mallampati hypothesized that the base of the tongue relative to the size of the oropharyngeal cavity may indicate a difficult airway [8,37]. The following study to prove his hypothesis included 210 patients and concluded that the visibility of the faucial pillars and uvula can predict the exposure of the larynx during direct laryngoscopy. After the statistically highly significant results, the author introduced a simple grading system.

Mallampati I: The soft palate, uvula and pillars are completely visible.

Mallampati II: The soft palate and part of the uvula are visible.

Mallampati III: Only the soft palate is visible.

Shortly after in 1985 the doctors Samson and Young proposed the addition of another grade to the score. The grade IV includes patients for whom none of the beforehand mentioned structures can be visualized (fig. 2). All failed intubations in their study were retrospectively graded Mallampati IV and only one exception with grade II was reported who proved to have tracheal stenosis [38].

In 1998 another grade was introduced to the scoring system. Class 0 includes patients in whom the epiglottis can be visible when evaluating the pharynx and indicates easy airway management [39,40]. The added scores over the years resulted in the “modified Mallampati score”:

Mallampati 0: any part of the epiglottis is visible.

Mallampati I: The soft palate, uvula and pillars are completely visible.

Mallampati II: The soft palate and part of the uvula are visible.

Mallampati III: Only the soft palate is visible.

Mallampati IV: Only the hard palate is visible.

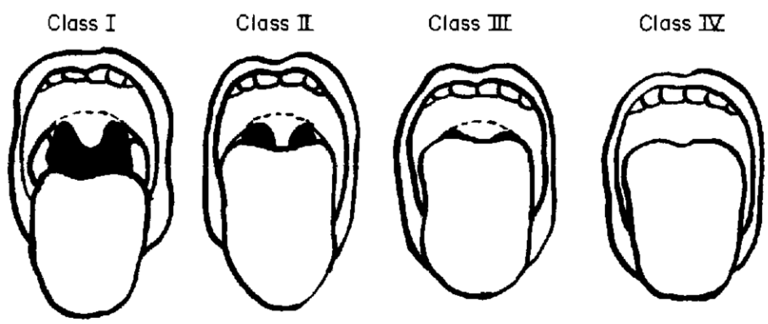


Fig. 2 ***Pictoral classification of the pharyngeal structures during assessment, modified Mallampati score [38].***

A recent meta-analysis measured the sensitivity and specificity of the modified Mallampati score to identify patients with difficult airway. The sensitivity of 0.51 was the highest for indications of difficult tracheal intubation among all other screening tests included and the specificity was measured at 0.87 [2].

Overall, the modified score is a quick and easy evaluation tool for patients regarding airway management but is not precise enough to be used independently of other evaluation methods.

11.5 Cormack-Lehane classification

In 1984 the team consisting of Cormack and Lehane published a grading method to assess the difficulty of airway management based on the anatomical structures seen during direct laryngoscopy

[41]. The original grading system was developed to simulate difficult airways for new anesthetists resulting in the following (fig 3):

Cormack-Lehane grade I: most of the glottis can be visualized.

Cormack-Lehane grade II: the posterior extremity of the glottis can be visualized.

Cormack-Lehane grade III: only epiglottis can be visualized (no glottis visible).

Cormack-Lehane grade IV: neither glottis nor epiglottis can be visualized.

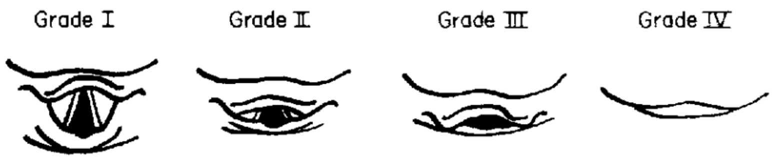


Fig. 3 ***Laryngoscopic views obtained during direct laryngoscopy used by Cormack and Lehane in their original classification [38].***

Several years later in 1998 a modified system was introduced [42] and subdivided grade II into IIa and IIb. This modified system provides more information for the anesthetist (fig 4).

Cormack-Lehane grade I: most of the glottis can be visualized.

Cormack-Lehane grade IIa: the glottis can be partially visualized.

Cormack-Lehane grade IIb: only the posterior part of the glottis or only arytenoid cartilages can be visualized.

Cormack-Lehane grade III: only epiglottis can be visualized (no glottis visible).

Cormack-Lehane grade IV: neither glottis nor epiglottis can be visualized.

Original Cormack and Lehane system	1 Full view of the glottis	2 Partial view of the glottis or arytenoids		3 Only epiglottis visible	4 Neither glottis nor epiglottis visible
View at laryngoscopy					
Modified system	1 As for original Cormack and Lehane above	2a Partial view of the glottis	2b Arytenoids or posterior part of the vocal cords only just visible	3 As for original Cormack and Lehane above	4 As for original Cormack and Lehane above

Fig. 4 ***Visual description of the modified grading system. E=Epiglottis, LI=Laryngeal inlet [42]***

Since its implementation, the application of the system has exceeded the original scope of its intended use by Cormack and Lehane and is nowadays used worldwide in order to describe the anatomy during laryngoscopy.

11.6 American Society of Anesthesiologists scoring system (ASA score)

ASA requested a committee in 1941 led by Meyer Saklad to develop a system that could be used to predict the statistical outcome and risk of patients undergoing surgical procedures with the intention to clear up and streamline the categorization of patients. They quickly realized that such a task would be impractical, if not impossible, considering all possible variables. The proper approach was to evaluate the physical state of the patient preoperatively. Consequently, the committee led by M. Saklad devised following classes [43]:

Class I: No organic pathology or patients in whom the pathological process is localized and does not cause any systemic disturbance or abnormality.

Class II: A moderate but definitive systemic disturbance, caused either by the condition that is to be treated by surgery or which is caused by other existing pathological processes.

Class III: Severe systemic disturbance from any cause or causes. It Is impossible to state an absolute severity measure, as this is a matter of clinical judgement.

Class IV: Extreme systemic disorders which already have become an eminent threat to life regardless of the type of treatment. Because of their duration or nature, there has already been irreversible damage to the organism. This class is only intended for patients in a deplorable physical state.

Class V: Emergencies that would otherwise be graded into class I and II.

Class VI: Emergencies that would otherwise be graded into classes III and IV.

The ASA proposed a scoring system for preoperative anesthetic risk assessment based on the patient's physical state in 1963 [44]. Henceforth, the scores have been updated and revised and find application worldwide. The current classification in 01/2023 by the ASA is the following:

ASA I: A regular healthy patient.

ASA II: A patient with a mild systemic disease.

ASA III: A patient with a severe systemic disease.

ASA IV: A patient with a severe systemic disease that is a constant threat to life.

ASA V: A moribund patient who is not expected to survive without the operation.

ASA VI: A declared brain dead patient whose organs are being removed for donor purposes.

**The addition of "E" to the ASA Class denotes an emergency surgery*

Although the ASA physical status scoring system is an excellent tool for predicting the preoperative anesthetic risk and can even predict short- and long-term complications and mortality [45,46], it has to be noted that the classification has limitations. While the ASA physical status scoring system is a simple tool that is easy to apply, it is still an individual and subjective decision by a particular doctor. Furthermore, understanding the definition of systemic disease may differ between countries, clinics and even doctors.

Despite these limitations, the classification is still able to predict the short- and long-term outcome of complications and mortality for patients. Several studies investigated the link between ASA physical status and surgical mortality and showed similar conclusions. [45–48].

12. RESEARCH METHODOLOGY AND METHODS

12.2 Study population

The group of subjects consisted of the patients referred for endolaryngeal microsurgery. The inclusion criteria were adult patients undergoing endolaryngeal microsurgery, endoscopic larynx image available before the anesthesia, and questions filled in correctly. Exclusion criteria were age < 18 years old, and the questionnaire being filled in inappropriately. Of all patients scheduled for endolaryngeal microsurgery surgery during the study period, 110 patients were identified as eligible to participate. Twenty-five patients were excluded because an endoscopic image of the larynx was unavailable for the anesthesiologist preoperatively, and 14 questionnaire forms were filled unproperly.

The questionnaire (provided in the annex) included depersonalised patient data (gender, age, body mass index, ASA score, smoking experience), clinical data (diagnosis, clinical symptoms, hoarseness or voice changes, shortness of breath, wheezing, difficulty swallowing, previous larynx radiation), patient's anatomy-dependent factors for difficult airway (short neck, big tongue etc.).

In addition, it included the description of the larynx according to Cormack-Lehane classification, the intubation process, manoeuvres used during intubation (stiletto, bougie, applied laryngeal pressure, sniffing position, change of the blade, laryngoscope, or endotracheal tube size). The document was filled out by the anesthesiologist postoperatively.

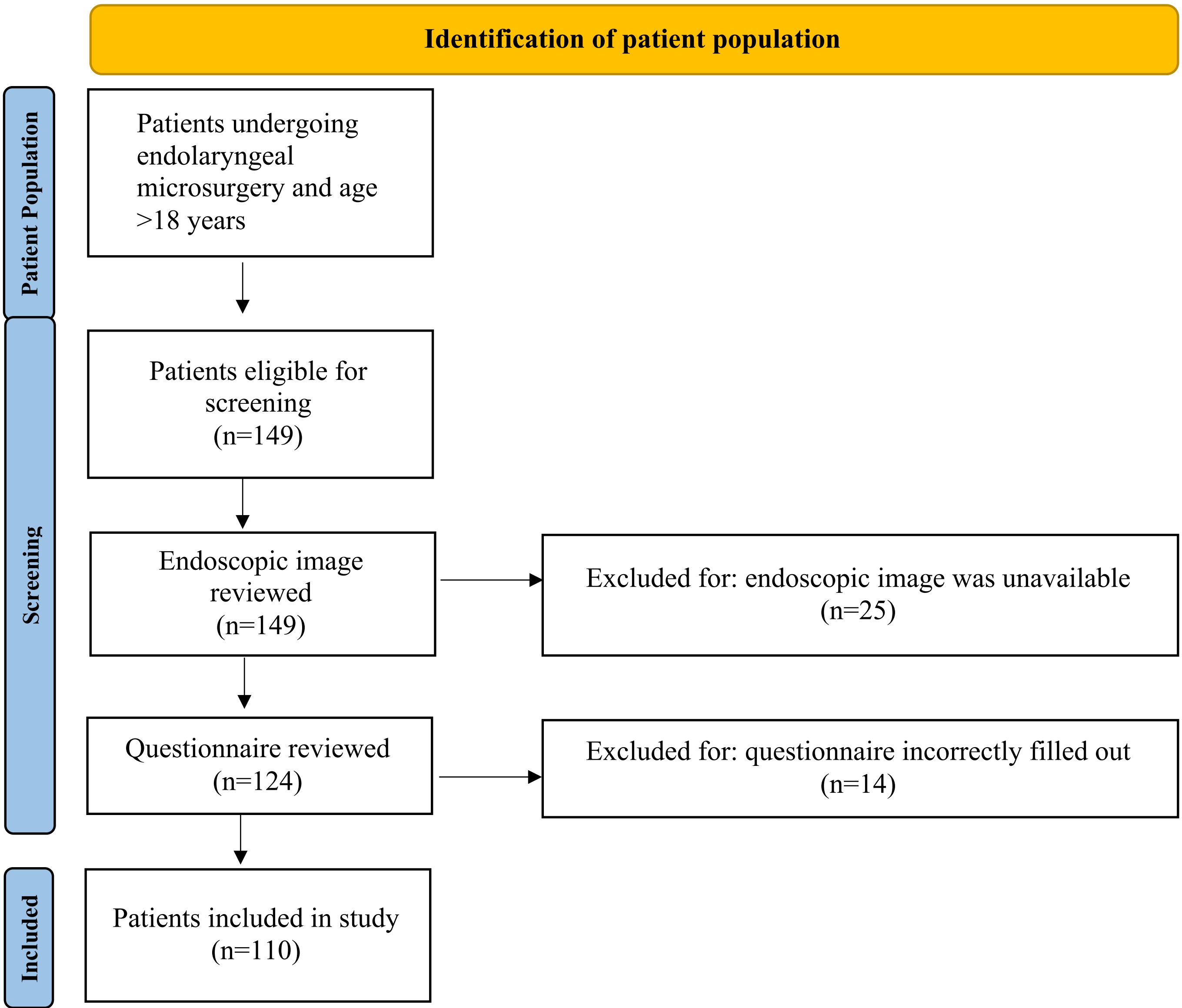


Fig. 5: ***Inclusion and exclusion criteria of patient population***

12.3 Endoscopic evaluation

All patients underwent a laryngeal evaluation using a XION EndoSTROB DX® video system (Xion GmbH, Berlin, Germany) with a 70° rigid endoscope. Otolaryngologists performed this evaluation as a part of routine clinical practice before the surgery.

12.4 Airway management

Anesthesiologists were asked to evaluate the image of the larynx preoperatively. In the questionnaire, they were asked to note if the endoscopic appearance of the larynx forced them to revise their airway management plan (awake intubation, video laryngoscopy vs direct laryngoscopy, tracheostomy under local anesthesia, smaller endotracheal tube etc.). Also, they were asked to note if the image seen during the endoscopic evaluation of the larynx were the same as during direct laryngoscopy according to Cormack-Lehane's score. They were asked to report the difficulty of intubation on a scale from 1 to 3 were 1 – easy intubation, 2 – moderate intubation, and 3 – difficult intubation. The number of attempts to intubate was also reported.

12.5 Study endpoints

The primary endpoint included the frequency of difficult airway occurrence in patients undergoing endolaryngeal microsurgery, the rate of successful intubation attempts and manoeuvres used during intubation. The secondary endpoint was to evaluate the correlation between the image of the larynx seen during endoscopic evaluation and direct laryngoscopy during intubation based on the Cormack-Lehane score and to assess the impact of preoperative endoscopic airway assessment for selecting airway management methods in patients undergoing endolaryngeal microsurgery.

12.6 Statistical analysis

Data were analyzed using the SPSS 24.0 software. The Kruskal-Wallis tests were used for the comparison of data distributions. A nonparametric χ^2 test was used for the analysis of nominal qualitative data. The Mann-Whitney U test was used to compare the distributions of two samples. A binary logistical regression model was used to identify the risk factors for difficult airway prediction. A significance level of 0.05 was considered for all tests.

13. RESULTS

13.1 Demographic characteristics

A total of 110 patients, who underwent endolaryngeal microsurgery were included in the data analysis. Demographic, characteristics, diagnosis, ASA and Mallampati score were evaluated for all participants. The most common diagnosis for men was laryngeal cancer, affecting 75% of all male patients in this population, followed by polyps in 23.7% of male patients. For females, the leading diagnosis was polyps in 76.4% of all females, followed by cancer in 11.8% of patients. For detailed patient characteristics see Table 4.

Table 4 ***Participants characteristics***

Variables	**The patient underwent endolaryngeal microsurgery (n=110)**
Age (y), mean (SD)	57 (11.6)
BMI, mean (SD)	25 (5)
Diagnosis:	
Cancer	61 (55.5)
Polyp/Polyposis	46 (41.8)
Sex:	
Female, n (%)	34 (31)
Male, n (%)	76 (69)
ASA status	
I, n (%)	7 (6.4)
II, n (%)	57 (51.8)
III, n (%)	44 (40)
IV, n (%)	2 (1.8)
Mallampati score:	
I, n (%)	52 (47)
II, n (%)	45 (41)
III, n (%)	12 (11)
IV, n (%)	1 (1)

Anatomical features:	
Normal, n (%)	89 (81)
Short neck, n (%)	20 (18)
Big tongue, n (%)	1 (1)
Previous larynx radiation	9 (8)
Smokers	69 (63)
Non-smokers	41 (37)
Pack years (for smokers), mean (SD)	26 (10)

13.2 Frequency of expected and actual difficult airway

The group of perioperative difficult airways included patients rated as difficult or patients who underwent tracheostomy procedures. The easy airway group consisted of patients rated as easy or moderate difficulty by the anaesthesiologist.

After initial patient and airway examination as well as reviewing the patient's history, an easy airway was expected in 64.5% (n=71) of patients and a total of 35.5% (n=39) of patients were expected to have a difficult airway.

Normal induction was chosen for every patient (n=71) with an expected easy difficulty. Additionally, 35.9% (n=14) patients with the prediction of a difficult airway were also planned to undergo normal induction. Awake intubation was the intubation plan for 56.4% (n=22) of patients with expected difficult airway, with 1.8% (n=2) requiring additional awake examination of the larynx. Planned tracheostomy under local anaesthesia was only planned for 0.9% of patients (n=1).

Table 5 ***Association of intubation plan and expected airway difficulty***

Variable	**Easy airway expected n=71**	**Difficult airway expected n=39**	**Total n=110**	**P value**
Normal induction	71 (100%)	14 (35.9%)	85 (77.3%)	<.001
Awake intubation	0 (0%)	22 (56.4%)	22 (20%)	<.001
Additional awake examination	0 (0%)	2 (5.1%)	2 (1.8%)	.124

Tracheostomy under local anesthesia	0 (0%)	1 (2.6%)	1 (0.9%)	.355

Data are in n. (%).

The actual difficulty of the airway that was experienced in the surgery room was not identical with the expected amount (table 6). Of the 39 (35.5%) expected difficult airways, 20 patients (51.3%) presented with a difficult airway during intubation. Out of a total of 23 difficult airways, this correctly categorized 87.1% of all difficult airways. Only 2.7% of patients (n=3) had an unanticipated difficult airway. Overall, difficult airways presented in 21 male patients, compared to 2 female patients (p=.010).

Table 6 ***difficulty of airway expected and actual difficulty of airway***

	Easy airway experienced	**Difficult airway experienced**	**Total**	**P Value**
Easy airway expected	68	3	71	
Difficult airway expected	19	20	39	
Total	87	23	110	<.001

Data are in n.

Table 7 lists the presence of clinical symptoms and radiation history of the patients according to the airway difficulty. Statistically relevant were the findings of dyspnea, wheezing, dysphagia and larynx radiation with p values of <.001. Dyspnea occurred in 17 out of 23 patients with difficult airways (73.9%) and in 2 out of 85 easy airway patients (2.4%). Wheezing was observed in 12 out of 23 (52.2%) patients with difficult airways and was not observed in easy airways (0%). Dysphagia was described in 15 out of the 23 patients in the difficult airway group (65.2%) and 12 times (14.1%) in the easy airway population. Lastly, larynx radiation was part of the patient's history in 6 (26.1%) patients with a difficult airway and in 3 (3.5%) patients with an easy airway.

Table 7 ***Patient symptoms / history and frequency of different airway difficulties***

Symptoms	Difficult airway n=23	Easy airway n=85	P value
Hoarseness	18 (78.3%)	79 (92.9%)	.054
Dyspnea	17 (73.9%)	2 (2.4%)	<.001
Wheezing	12 (52.2%)	0 (0%)	<.001
Dysphagia	15 (65.2%)	12 (14.1%)	<.001
Larynx radiation	6 (26.1%)	3 (3.5%)	<.001

Data are in n (%). The results of χ^2 *analysis and Fisher exact test (P value) are given.*

13.3 Material and techniques used for intubation

The laryngoscope of choice for easy airways was the Macintosh laryngoscope with a curved blade. It was used in 89.7% (n=78) of all easy airways. Whereas the video-laryngoscope was more utilised in the difficult airway (65.2%; n=15). The frequency of the laryngoscopes were statistically significant towards the difficulty of the airway. Table 8 and table 9 show the frequency of each laryngoscope in easy and difficult airways respectively.

Table 8 ***Frequency of laryngoscopes in easy airways***

	Used	Percentage	P value
Macintosh	78	89.7%	<.001
Video-laryngoscope	9	10.3%	<.001

Data are in n

Table 9 ***Frequency of laryngoscopes in difficult airways***

	Used	Percentage	P value
Macintosh	7	30.4%	<.001
Video-laryngoscope	15	65.2%	<.001

Data are in n

Table 10 summarizes all the additional tools and techniques used by the anaesthesiologist to assist in successful intubation, subdivided into groups regarding the difficulty of encountered airway. Stylets were utilised more often in a total of 30% (n=33) of all intubations, 69.6% of the time in difficult airways (n=16) and 19.5% (n=17) of times in the easy airway. The bougie was exclusively used in difficult airways, 8 out of 23 times (34.8%). Both tools showed a strong association with a p value of <.001. Furthermore, additional manipulation was the most common performed technique, performed in 100% of patients with a difficult airway (n=23) and in 34.5% (n=30) of easy airways. Another statistically relevant (p= .001) finding in this table is the association of the sniffing position with difficult airways.

Table 10 ***Additional tools and techniques for intubations***

Variable	**Difficult airway n=23**	**Easy airway n=87**	**Results**	**P value**
Stylet	16 (69.6%)	17 (19.5%)	χ^2 =21.677	<.001
Bougie	8 (34.8%)	n0 (0%)	χ^2 =32.634	<.001
Laryngeal pressure	4 (17.4%)	18 (30.7%)	χ^2 =.124	.725
Sniffing position	5 (21.7%)	1 (1.1%)	χ^2 =14.954	.001
Changed blade	0 (0%)	0 (0%)	χ^2 = n/a	n/a
Changed laryngoscope	2 (8.7%)	1 (1.1%)	χ^2 =3.905	.110

Changed tube size	6 (26.1%)	4 (4.6%)	χ^2=10.164	.005
Not intubated	6 (26.1%)	0 (0%)	χ^2=24.005	<.001

Data are in n (%). The results of χ^2 analysis, Spearman correlation and Fisher exact test (P value) are given.

Figure 6 and figure 7 respectively show the distribution of ET size for each sex. The observed sizes are displayed on the x-axis and the frequency on the y-axis. The expected distribution, based on the standards of Kaunas clinics is represented by the bell curve.

The standard ET size for male patients is 8.0 and for female patients is 7.0. The collected data shows a deviation from the expected population towards smaller ET sizes (p=<.001). One male patient was excluded from the data, because his procedure was a planned tracheostomy, and no endotracheal tube was selected for the procedure.

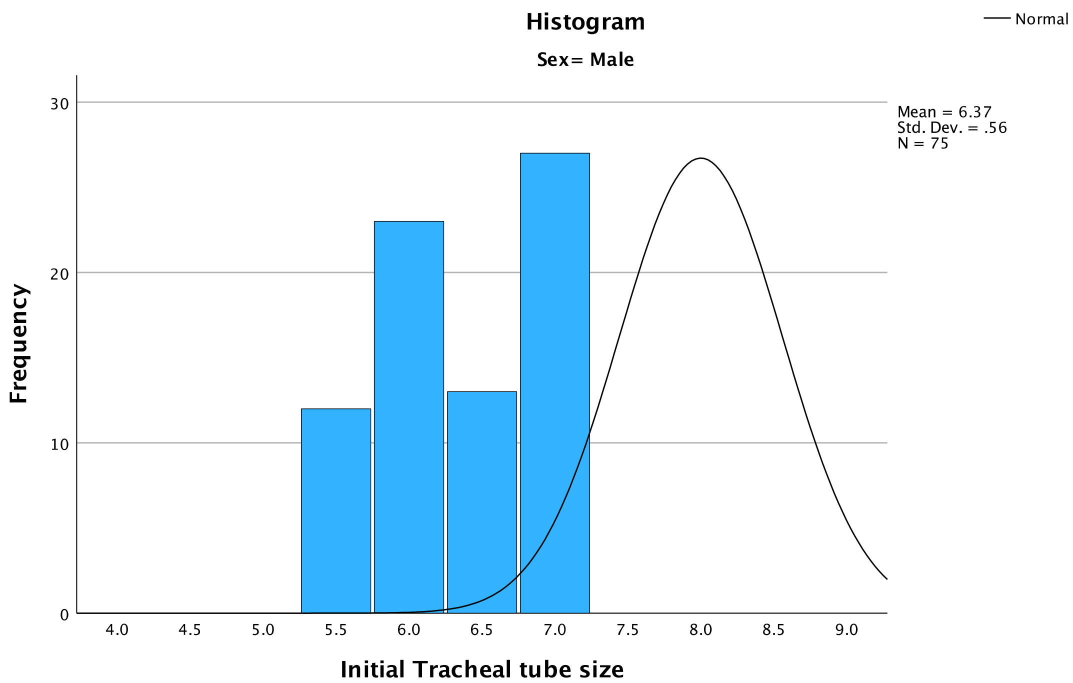


Fig. 6 ***Initial tracheal tube size for men***

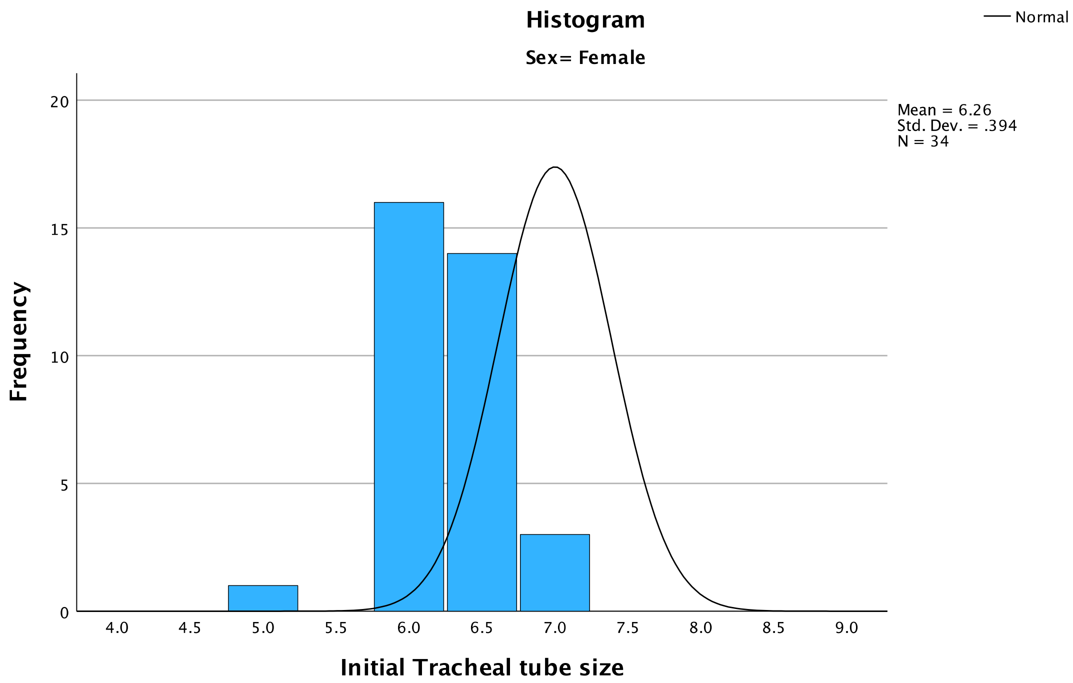


Fig. 7 ***Initial tracheal tube size for woman***

Table 11 shows the distribution of which ET sizes were changed in the operative room. Overall tube sizes were changed in 9.1% (n=10) of patients and most of the initial tube sizes were used to successfully intubate the patient in 90% (n=99) of intubations. One patient was excluded, because the procedure was a planned tracheostomy, and no intubation tube size was considered.

Table 11 ***Change of ET size perioperatively separated by tube size***

Initial ET size	**Amount (n)**	**Changed (n)**	**Did not change (n)**
5.0	1	0	1
5.5	12	0	12
6	39	3	36
6.5	27	6	21
7.0	30	1	29
7.5	0	0	0
8.0	0	0	0
Total	**109**	**10**	**99**

Data are in n.

13.4 PEAE and intubation

Table 12 lists the preoperatively and perioperatively assessed Cormack-Lehane scores against the difficulty of intubation. A significant result (p= <.001) is observed for both variables. The results suggest a relevant correlation between the observed Cormack-Lehane score and the experienced complexity of the airway.

Table 12 ***Spearman coefficient correlation of experienced intubation difficulty***

Variables	**Spearman coefficient for intubation difficulty**	**P value**	**Number of patients**
Cormack-Lehane score (pre-op.)	.629	<.001	110
Cormack-Lehane score (peri-op.)	.722	<.001	110

Table 13 shows the patients where the preoperative endoscopic evaluated Cormack-Lehane score was identical to the Cormack-Lehane score visualized during perioperative intubation. This was further subdivided into difficult and easy airways. The data shows that the PEAE showed the identical view in 68.2%(n=15) of all difficult airway patients and in 92.0% (n=80) of easy airway patients. The two scores show a statistical correlation (p=<.001).

Table 13 ***Frequency of endoscopic Cormack-Lehane-score matching laryngoscopic view***

	Difficult airway n=22	**Easy airway n=87**	**Total n=109**
Same score	15 (68.2%)	80 (92.0%)	95
Different score	7 (31.8%)	7 (8.0%)	14
P value	<.001	<.001	

Data are in n. (%)

13.5 Impact of PEAE for airway management and prediction

The endoscopic changes were tested for association towards plan of intubation and airway difficulty as seen in table 14. Statistically significant were minimal changes, bilateral immobility and surrounding tissue changes. Observed minimal changes showed a significant association (p=.001) with 48 patients out of 92 (52.2%) having no changes in the intubation plan after the endoscopy. Furthermore, bilateral immobility of the vocal cords was statistically significant (p=.038), with 4 out of 18 (22.2%) patients having changes in their intubation plan and 5 out of 92 (5.4%) have no changes in the plan.

The most changes in the intubation plan were observed in patients with surrounding tissue changes (p=<.001). Out of 18 patients, 9 (50%) had their intubation plan changed. Whereas 10 out of 92 (10.9%) had no changes in their plan.

Table 14 ***Intubation plan changes based on changes observed in endoscopy***

Variable	Intubation plan changed n=18	Intubation plan did not change n=92	P value
Minimal changes	2 (11.1%)	48 (52.2%)	.001
Immobility of vocal cord (unilateral)	2 (11.1%)	10 (10.9%)	1.000
Immobility of vocal cord (bilateral)	4 (22.2%)	5 (5.4%)	.038
Tumor, polyps or Keratosis	8 (44.4%)	37 (40.2%)	.739
Surrounding tissue changes	9 (50.0%)	10 (10.9%)	<.001

Data are in n (%). The results of χ^2 analysis, Fisher exact test (P value) are given.

After PEAE, the intubation plan changed in 16.4% (n=18) of all patients and remained unchanged in 83.6% (n=92) of patients.

Table 15 displays the endoscopic changes observed based on the experienced airway difficulty. Statistically relevant were the findings for minimal changes, tumor polyps and keratosis and surrounding tissue changes. In 49 out of 87 (56.3%) easy airway patients, minimal changes were observed (p=<.001). Only 1 out of 22 (4.5%) patients with difficult airway displayed this feature.
Tumor, polyps and keratosis were present in 16 out of 22 (72.7%) patients with difficult airway and 28 out of 87 (32.2%) times in patients with an easy airway (p=.001). Surrounding tissue changes showed a strong association with difficult airways (p=<.001). In 13 out of 22 (59.1%) patients with difficult airway, these changes were identified. Additionally, 5 out 87 (5.7%) patients with an easy airway also presented with surrounding tissue changes.

Table 15 ***Observed changes regarding airway difficulty***

Variable	**Difficult airway n=22**	**Easy airway n=87**	**Results**	**P value**
Minimal changes	1 (4.5%)	49 (56.3%)	χ^2 =18.959	<.001
Immobility of vocal cords (unilateral)	3 (13.6%)	9 (10.3%)	χ^2 =.194	.705
Immobility of vocal cords (bilateral)	1 (4.5%)	8 (9.2%)	χ^2 =.501	.683
Tumor, polyps or keratosis	16 (72.7%)	28 (32.2%)	χ^2 =11.991	.001
Surrounding tissue changes	13 (59.1%)	5 (5.7%)	χ^2 =36.243	<.001

Data are in n (%). The results of χ^2 analysis, Fisher exact test (P value) are given.

To further investigate the association of the endoscopic changes and the airway difficulty, the predictive value and odds ratio of these changes were calculated with the use of binary logistical regression. As shown in table 16, statistically significant is only the result for observed surrounding tissue changes with an odds ratio of 10.5 and a binary regression coefficient of 2.355.

Table 16 ***Binary logistical regression model for endoscopic changes and airway difficulty***

Variable	B	S.E.	Wald	P Value	Odds ratio
Minimal changes	-2.376	1.328	3.202	.074	.093
Unilateral immobility of vocal cords	-.136	1.077	.016	.900	.873
Bilateral immobility of vocal cords	-.995	1.401	.505	.477	.370
Tumor, polyps, keratosis	.447	.941	.226	.635	1.564
Surrounding tissue changes	2.355	.678	12.081	<.001	10.537
Constant	-1.563	.999	2.446	.118	.210

Another data observation is that in 82.7% (n=91) of intubations, according to the intubating anaesthetist, the PEAE was helpful in predicting the difficulty of intubation. Table 17 shows a statistically significant result between the usefulness of endoscopic image for the prediction of airway difficulty and the expected airway difficulty.

Table 17 ***Endoscopy perceived as helpful for anesthesiologist for different airways***

Variable	Difficult airway expected n=39	Easy airway expected n=71	Results	P value
Endoscopy was helpful to predict difficulty of intubation	39 (100%)	52 (73.2%)	χ^2 =12.616	>.001

Data are in n (%).

Furthermore, the endoscopic assessment was helpful in predicting the difficulty of laryngoscopy according to the intubating anaesthesiologist in 54.5% (n=60) of cases.

There was no statistically significant finding regarding the experience of the anaesthesiologist, resident or doctor, regarding the observed data.

14. DISCUSSION

The leading cause of men's endolaryngeal microsurgery was cancer at 75% and polyps for females at 76.4%. This discrepancy may be due to many factors, such as genetic risk factors for laryngeal cancer based on gender [49], combined with heavy smoking throughout the observed patient population. Previous studies however showed no significant impact of gender on polyp development [50].

Another data point that initially seems abnormal is the lower mean weight for male patients than female patients. Nevertheless, this is likely caused by the prevalent cancer diagnosis in male patients with a general higher ASA classification and a worse overall condition.

The study shows that the most challenging airways were correctly identified, and the incidence of unexpectedly difficult airways was 2.7% of all patients. However, the overall occurrence of the difficult airway in this patient population with 20.9%, can be explained by the pathologies of this patient group that are related to the head and neck region. This corresponds with the scientific consensus on the matter [4,5].

Dyspnea, wheezing, dysphagia and surrounding tissue changes were highly significant symptoms ($p=<0.001$) regarding the peri-operative difficult airway and were more associated with difficult airways. Another significant ($p=<.001$) variable was the history of larynx radiation for difficult airways.

The Macintosh laryngoscope was the laryngoscope of choice for most patients, especially those presenting with easy airways. Conversely, the video-laryngoscope was the superior tool for difficult airway patients by significantly improving laryngeal exposure [33]. Other tools and techniques used by the anaesthesiologist, including stylets and bougies, were associated with difficult airways.

A prominent finding in this study is the abnormal distribution of ET sizes in both genders. An explanation for the observed shift towards smaller ET sizes is the preoperative visualization of the vocal cords and the surrounding tissues. The PEAE provides a special assessment regarding the tube size, leading to overall more appropriate tube sizes and lower perioperative changes.

One of the main objectives of this study was the assessment of the utility of PEAE regarding airway difficulty. The preoperative and perioperative Cormack-Lehane score showed a strong correlation with the difficulty of the airway. In 86.4% (n=95), the preoperatively assessed Cormack-Lehane score was identical with the Cormack-Lehane score visualized during intubation. Furthermore, 68.2% (n=15) of difficult airways displayed the same Cormack-Lehane score. These findings indicate that the preoperative endoscopic assessment can be a valuable tool for predicting the complexity of the airway for intubation. Furthermore, the endoscopic image assists the anaesthesiologist in giving him an accurate view of what he will likely encounter during the patient's intubation.

Going through the significant observed changes during the endoscopic examination, minimal changes led to no change in the intubation plan (p=.001) and were associated with easy airways (p=<.001. Bilateral vocal cord immobility was only significant for intubation plan changes (p=.038). Tumors, polyps and keratosis were associated with difficult airways (p=.001).

The most exciting finding to prognose a difficult airway was the observed surrounding tissue changes of the larynx. This factor was highly significant for intubation plan changes (p=<.001) and very indicative for difficult airways (p=<.001). In addition, the predictive value of surrounding tissue changes in patients is very significant (p=<.001). Patients with these changes are 10.5 times more likely to present a difficult airway than patients without it.

In 91 (82.7%) of 110 patients the intubating anaesthesiologist perceived the endoscopic image as applicable. For the patient group with difficult airway this was the case for all 23 patients (100%).

Overall, the data suggests that PEAE is a potent and helpful tool for anaesthesiologists to be used in conjunction with conventional assessment methods to identify difficult airways correctly. However, comparing other results in this field is difficult because, there hasn't been any research in this area.

Furthermore, the endoscopic assessment prior to surgery, gave an accurate prediction of the airway that will be encountered during the procedure. The superior visualization of the structures via endoscopy improves the identification of the difficult airway, leading to increased patient safety and decreased adverse outcomes. The procedure can be easily incorporated for patients undergoing endolaryngeal microsurgery without much discomfort and loss of time [7].

The findings of the study are limited by the limited information and research done in this topic. The rather small sample size of the data may also not be representable for all populations.

15. CONCLUSION

1. More than one in five of the intubations in endolaryngeal microsurgery patients were classified as difficult. We observed 23 (20.9%) difficult intubations out of 110 cases.
2. The rate of unsuccessful intubations was 5,5 % and ended in tracheostomy under local anesthesia. However, all these patients were correctly identified as patients with difficult airways and underwent awake intubation. The most common additional equipment used under challenging airways was stylet 69,6%, bougie 34.8%, and change of endotracheal tube 26,1%.
3. The endoscopic larynx images correlated well with those seen during direct laryngoscopy. Images matched entirely in 86.4% of cases. The most common factor that prognoses difficult airways is the involvement of the surrounding larynx tissue.
4. The endoscopic evaluation of the airway before the surgery helped to prognose the difficulty of intubation more precisely, however, the difference was not significant, and the endoscopic image led to a change of intubation plan in only 18 patients (16.3%) ($p>0.05$).

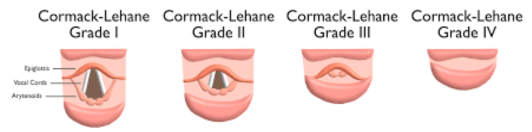
16. PRACTICAL RECOMMENDATIONS

Regardless of the limitations, these novel findings indicate a need for further research with potentially impactful consequences. A randomized controlled clinical study with a larger sample size is recommended to consolidate the results. We think that preoperative endolaryngeal airway examination plays a vital role in the anaesthesiologist's assessment of the patient's airway and its full potential is yet to be discovered.

Furthermore, a team timeout-like dialogue about the preoperative endoscopic image obtained from the patient between the anaesthesiologist and the Otolaryngologist, who performed the endoscopy, might be an uncomplicated solution to incorporate the endoscopic finding into the decision making of the anaesthesiologist.

17. ANNEX

"Priešoperacinio kvėpavimo takų endoskopijos vertė kvėpavimo takų valdymui pacientams, kuriems atliekama endolaringinė mikrochirurgija" duomenų lentelė

Atvejo numeris	
Amžius	
Lytis	
Diagnozė	
ASA kl	
Svoris	
Ūgis	
Malampati	1 – I 2 – II 3 – III 4 - IV
Lydintys simptomai	0 – nieko 1 – užkimimas 2 – dusulys 3 – švokštimas 4 – sunkumas ryti
Kaklas	0 – n.y 1 – trumpas
Balso klostės	1 – n.y. 2 – viena klostė nejudri 3 – abi nejudrios 4 – naviko, polipai, keratozė 5 – aplinkiu audiniu pokyčiai
INTUBACIJA	
Numatoma sunki intubacija	0 – ne 1 – taip
Planas	0 – įprasta indukcija 1 – apžiūra be relaksantų 2 – apžiūra būdraujant 3 – intubacija būdraujant 4 – tracheostomija vietinėje nejautroje
Laringoskopas	1 – lenktas laringoskopas 2 – video laringoskopas 3 – bronchoskopas 4 – neintubuotas
Intubacija	0 – planas nesikeitė 1 – planas keitėsi
Intubuota	0 – įprastai, be papildomų priemonių 1 – įdėtas stiletas 2 - bužas 3 – taikytas gerklų paspaudimas 4 – galvos prilenkimas 5 – keistas laringoskopas 6 – neintubuotas
Intubacija Cormack Leheine 	1 2 3 4
Ar endoskopija padėjo numatyti sunkią intubaciją	0 – ne 1 – taip
Ar endoskopinis vaizdas atitiko matomą laringoskopijos metu	0 – ne 1 – taip
Ar endoskopinis vaizdas sutapo su raringoskopijos vaizdu	0 – ne 1 – taip
Ar endoskopinis vaizdas padėjo numatyti problemas įvedant ET vamzdelį per balso plyšį	0 – ne 1 – taip
Rūkymo stažas	
Intubacijos sunkumas	0 – lengva 1 – vidutinio sunkumo 2 – sunki

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