Jurnal Kedokteran Syiah Kuala
Volume 22, Number 3, September 2022
Pages: 1-8

ISSN: 1412-1026
E-ISSN: 25500112
DOI: 10.24815/jks.v22i3.25464

Comparison of intubation procedure using macintosh laryngoscope and McGrath laryngoscope in emergency patients

[1]Taufiqurrahman, [2*]Rizki, [3]Jasa, ZK, [4]Syahrul

[1]Department of Anesthesiology, Faculty of Medicine,Universitas Syiah Kuala, Aceh, Indonesia.
[1]Department of Neurology, Faculty of Medicine,Universitas Syiah Kuala, Aceh, Indonesia
Email. omkit16@gmail.com

Abstract. Background: Intubation is one of the essential procedures that performed in emergency condition to maintain airway patency and provide respiratory support in various clinical events. Laryngoscope is critically important to allow the operator to create a line of sight on the larynx to insert the endotracheal tube.
To compare the intubation attempt and duration between the use of Macintosh and McGrath laryngoscope in intubating emergency patients.
This observational study with a cross-sectional design was conducted at the dr. Zainoel Abidin Hospital, Banda Aceh. Authors will compare the intubation accuracy (attempt) and duration between the use of Macintosh and McGrath laryngoscope. The Mann-Whitney U test analysis was carried out in this study with a 95% confidence level.
A total of 120 patients requiring emergency intubation were observed in this study with total study subject of 63 patients in Macintosh device (group I) and 57 patients in McGrath device (group II). The demographic characteristics included age, sex, body mass index and intubation indication were comparable between groups. Both groups (I vs II) showed a similar proportion of 1 time intubation attempt (84.1% vs 93%; p=0.131) and duration of intubation (10 vs 10; p=0.635).
There was no significant difference in intubation attempt (accuracy) and duration between the use of Macintosh and McGrath laryngoscope in emergency patients. Both laryngoscope modalities are equally effective in considering the accuracy and duration of intubation in emergency department patients.

Keywords: Intubation, Duration, accuracy, Macintosh, McGrath

Introduction

Intubation is defined as the procedure of inserting the endotracheal tube (ETT) into the trachea through glottis rhymes, until the distal end is approximately in the middle of the trachea between the vocal cords and bifurcation trachea. This is an essential intervention performed in emergency situations to maintain patent airway and provide respiration support in various clinical conditions. Intubation procedures performed in emergency departments are more difficult than intubation in the operating room due to various factors such as patients, operators, and the environment. When performing intubation, the effort made to be able to see the plica vocalis clearly is to reflect the lower cervical and upper cervical extensions, where the position will allow the operator to create a line of sight on the larynx to insert the ETT.[1–3] Furthermore, an operator uses a metal instrument called a laryngoscope to set aside the tongue and other soft tissues in the mouth so that the plica vocalis can be clearly seen. A retractor-type laryngoscope such as a Macintosh curved blade is the most widely used type of laryngoscope for intubation procedures and easier to find. Nevertheless, although this type of laryngoscope may set aside soft tissue well, the operator still needs a line of sight to see the larynx.[4]

In intubation attempt, the efforts to see plica vocalis will be difficult in certain conditions such as limitations of neck movement, obesity and other airway management factors.[5] Intubation failure or difficulty is associated with various complications such as hypertension, desaturation, unplanned intensive care unit (ICU) treatment and death. The prevalence of intubation difficulty is estimated to be 1 to 6% of cases and intubation failure of approximately 0.1% to 0.3%.[6] Some studies report that intubation procedures using direct laryngoscope are more prone to causing complications of airway trauma. This is allegedly related to the coercion conducted by the operator so that glottis can be clearly seen.[7]

COVID-19 is a condition that requires special attention when meet the need to perform intubation. COVID-19 is caused by severe acute respiratory syndrome corona virus-2 (SARS COV-2) which is highly contagious. Transmission may occur through droplets or direct contact with contaminated patients/objects. Actions that produce aerosols (APG) such as airway management or critical patient treatment in the ICU have a high risk of disease transmission to the health workers involved.[8] In COVID-19 patients intubation procedure, operator should provide most careful preparation to minimize repeated attempts and prolonged contact with patients. Intubation performed in emergency setting are riskier than those performed in the operating room. It is caused by the operator and surrounding setting/environment factors. As a result, the success rate of emergency intubation is relatively low, the duration of intubation is longer, and the risk of complications increases.[9] One of the efforts to improve the success of intubation attempt in emergency setting is to use video laryngoscope (VL). Currently, some types of VL commonly used in clinical applications are *Pentax-Airway Scope* (Pentax), the *King Vision* (King) and *McGrath MAC* (McGrath). Since its introduction in 2000, VL has been very commonly used in clinical applications replacing Macintosh laryngoscope because it has been shown to have a high success rate, short duration of intubation and clearer sight at glottis.[10,11]

Studies on mannequin and elective surgery have found that VL use has more superior performance in providing clearer glottis sight than Macintosh laryngoscope.[12–14] However, the effectiveness of VL compared to Macintosh laryngoscopes is still not consistent, particularly in emergency setting. Randomized clinical trial in the ICU setting found that there was no first-pass intubation attempt difference between VL compared to Macintosh.[15] Furthermore, a systematic review also reported that the intubation procedure in emergency room (ER) and ICU using VL showed no significant difference compared to Macintosh in the first-attempt success rates, although its use was associated with a lower number of attempts.[16] The McGrath Mac video laryngoscope (Covidien France SAS, Paris, France) is the most recent device with a bar like the Macintosh bar. The McGrath Mac has been reported to be better than the Macintosh laryngoscope for successful intubation on difficult airway. However, some studies show that McGrath's video laryngoscope has a lower success rate and longer duration. Hence, identification of the effectiveness of the use of Macintosh laryngoscopes and VL needs to be exercised, particularly in emergency setting to minimize complications that may arise due to intubation procedures. It is important to assess the first-attempt success rate difference of the intubation using McGrath's laryngoscope compared to Macintosh.

Methods

A total one hundred and twenty subjects who underwent intubation in emergency room were recruited for this study. The study was conducted at Dr Zainoel Abidin Hospital, Banda Aceh, Indonesia. Ethical clearance was approved by hospital ethics committee and a written informed consent from all patients were collected. The inclusion criteria were: (1) age >18 years old (2) required intubation procedures for indications included failure of maintaining patent airway, failure of secure airway from aspiration, ventilation failure, oxygen insufficiency, and impending respiratory failure state. The exclusion criteria included: (1) BMI $\geq$30 kg/m^2 (2) pregnancy (4) history of previous intubation difficulty (LEON criteria >3). The drop-out criteria were adjustment of device and airway management technique.

All subjects who admitted to Dr Zainoel Abidin Hospital, met the inclusion criteria and had no exclusion and drop-out criteria were listed by data officer. All variables included age, weight, height, body mass index (BMI), and study form number were recorded. Upon approval, subjects were intubated by operators who have been given intubation training using McGrath and Macintosh laryngoscope. The study subjects were intubated using a McGrath or Macintosh laryngoscope in accordance with clinical considerations by the physician who oversaw the patient. Furthermore, a data officer would record the number of attempts and duration of intubation using a stopwatch.

In this study author collected both primary and secondary data. Primary data included BMI, intubation method, intubation duration, attempts of intubation and blood pressure variable. While the secondary data included demographic profile and patient's diagnosis.

A study population of 53 subjects for each group was determined to have 80% power at $\alpha = 0.05$ (two-tailed) to detect a difference of 1 in intubation attempt. After conducted data cleaning, editing and coding, categorical data would be described as frequency and proportion (%). Continuous data were tested for normality using the Kolmogorov Smirnov test and showed as mean ± SD for parametric data, or as median (min-max) for non-parametric data. Statistical

analysis of data among the groups was done by Student's t test for normal distribution, and Mann-Whitney U test for non-parametric data. P value <0.05 was considered as statistically significant. SPSS version 18.0 statistics package was used for final data analysis.

Results

After collected data during the study period, as many as 120 subjects were obtained. Table 1 presents the demographic characteristic of the study subjects and the indication of intubation procedure. The demographic characteristic included age, sex, and BMI. The mean age of subjects who were intubated using Macintosh (46; 19 – 89) was relatively older than in McGrath (43; 24-78) group, and majority of the subjects were male in both groups. Based on BMI, both had normal nutritional status. Indications of intubation in both groups were mostly caused by multi-organ failure and neurological failure. There was no statistically significant difference in baseline demographic characteristic and intubation indication between group, thus the two groups are comparable for data analysis.

Table 2 shows the intubation attempt comparison analysis between Macintosh and McGrath laryngoscope in emergency department patients. Macintosh laryngoscope has lower first attempt success rate compared to McGrath (84.1% vs 93%). However, the difference is not statistically significant (p >0.05). While in Table 3, the mean duration of intubation in Macintosh group was 10 s (3-49), similar with McGrath group (10; 7-15), and after conducted Mann Whitney U test, author found no significant difference for this variable as well (p>0.05).

Table 1. Demographic characteristic and intubation indication

Variable	Intubation device		P value
	Macintosh n = 63	McGrath n = 57	
Age (years), median (Min – Max)	46 (19 – 89)	43 (24 – 78)	0,962
Sex, n (%)			0,620
Male	37 (58,7)	36 (63,2)	
Female	26 (41,3)	21 (36,8)	
Body mass index (kg/m^2), Mean + SD	23,66 + 3,48	23,81 + 3,72	0,817
Indication of intubation			0,786
Respiratory failure	7 (11,1)	9 (15,8)	
Circulation failure	10 (15,9)	7 (12,3)	
Neurological failure	24(38,1)	19 (33,3)	
Multi-organ failure	22 (34,9)	22 (38,6)	

Table 2. Intubation attempt between groups

Intubation attempt	Laryngoscope		P value
	Macintosh	McGrath	
1	53 (84.1%)	53 (93%)	0.131
≥ 2	10 (15.9%)	4 (7%)	
Total	63 (100%)	57 (100%)	

Table 3. Intubation duration between groups

Group	Intubation duration		P value
	Median	Min-max	
Macintosh	10	(3 – 49)	0.635
McGrath	10	(7 – 15)	

Hemodynamic responses before and after intubation procedure showed improvement in both laryngoscopes (Table 4). There were statistically significant differences for pre- and post-intubation systolic and diastolic blood pressure in Macintosh group (SDP p=0.001; DBP p=0.046). Similar difference was

observed in McGrath group as well (SDP p=0.016; DBP p=0.000). But only in McGrath group the pre- and post-intubation pulse rate difference was statistically significant, the pulse rate difference was not statistically significant in Macintosh group (p 0.004 vs p 0.52).

Table 4. Hemodynamic responses between groups

Hemodynamic profile	Period of intabation		P value
	Before (Mean ± SD)	After (Mean ± SD)	
Macintosh			
Systolic blood pressure (mmHg)	115±15,7	122±21,6	0,001
Diastolic blood pressure (mmHg)	75±11,5	77±12,1	0,046
Pulse rate (/min)	92±17,7	95±19,2	0,52
McGRATH			
Systolic blood pressure (mmHg)	117±20,6	124±25,3	0,016
Diastolic blood pressure (mmHg)	69±13,3	76±16,9	0,000
Pulse rate (/min)	93±20,9	98±21,2	0,004

Discussion

In this study there were 120 subjects who enrolled in the study, 63 subjects in Macintosh group and 57 subjects in McGrath group. The baseline demographic profile and indication of intubation were comparable between groups. Although author did not conduct the analysis of the characteristics and first-attempt success rate of intubation relationship, previous study conducted by Kreutziger et al. showed no association between success rate with the patient's sex, BMI, age, spinal immobilization, and indications of airway management.[17]

In general, tracheal intubation may be difficult in obese patients and associated with an increased risk of delayed intubation time due to several factors such as glottis oedema, limited posterior flexion of the neck, short neck length, and limited oropharyngeal space. All these factors may limit the adequate visualization. Glottis visualization with a Macintosh laryngoscope requires an oral axis, pharynx, and larynx in a straight-line axis, while glottis visualization using video laryngoscope is unnecessary. In addition, during tracheal intubation with the Macintosh laryngoscope, the tongue and mucosa of the opening may interfere with the visualization of the glottis opening.[10]

In this study, the mean of BMI in both groups was normal, so it did not show the superiority of McGrath to Macintosh as in previous studies. In obese patients, this problem becomes worse, the presence of a large tongue size or buccal mucous fat will narrow the oropharyngeal space. However, since the video laryngoscope has a camera attached to the blade end, this allows glottis visualization despite the narrowing. In addition, video laryngoscopes show surrounding glottis, as well as degrees of glottis oedema, which provide better tracheal intubation. For this reason, video laryngoscopes are superior to Macintosh laryngoscopes in terms of success rates, intubation time, and glottis visualization during tracheal intubation in patients with obesity.[10] It is widely known that video laryngoscope improves glottis visualization in underweight and obese patients with a variety of devices, in a variety of clinical settings, and across a variety of operator experiences.[18] A meta-analysis written by Hoshijima et al. showed similar finding that during tracheal intubation in patients with obesity, video laryngoscopes success rates, intubation times, and glottis visualization were superior to Macintosh laryngoscopes.[10]

In this study we found that the firs-attempt success rate was higher in McGrath group (93%) compared to Macintosh group (84.1%). However, this difference is not statistically significant. Potential reasons for explaining these results may be explained by the video laryngoscope bar design, operator experience or subject population characteristics.[19]

Laryngoscopy and tracheal intubation may cause hemodynamic responses, including increased blood pressure and heart rate. Hemodynamic responses would pose several risks, such as myocardial infarction and stroke, especially in elderly patients.[20] During tracheal intubation, stimulation of oropharyngeal structures and larynx with abundant sympathetic nerves will result in unpredictable responses. A variety of other risk factors including patient characteristics, opioid use during induction and the type of intubation device may trigger a hemodynamic response.[20] The most common intubation responses found in adult are hypertensive

and tachycardia conditions.[17] In this study, there was a change in hemodynamic response between pre- and post-intubation procedure using both types of laryngoscopes. Previous studies implied that the difference in intubation tools affect the intubation response. The intubation response is triggered by a reflex response due to irritation of the supra glottis and tracheal areas. The intubation response can be supressed by minimizing the stimulus on the receptors that play a role in triggering the autonomous system.

Generally video laryngoscopy does not require a position where the larynx axis provides maximum visualization hence there is no excessive stimulus in the area.[21] Study conducted by Colak et al concluded that when McGrath MAC video laryngoscopes were compared to Macintosh directive laryngoscopes in elderly patients, McGrath MAC video laryngoscopes decreased hemodynamic fluctuations due to tracheal intubation but made no difference in QTc intervals on ECG. The duration of intubation was found to be longer with a McGrath MAC video laryngoscope. It is also implied that intubation in elderly patients with McGrath MAC video laryngoscopy results in minimal hemodynamic changes and performed safely.[20]
In this study, complications of emergency setting intubation were not assessed. However, intubation may lead to some complications. A recent RCT study reported that video laryngoscopes increase side effects such as the incidence of soft tissue bleeding and tooth trauma.[22] The use of video laryngoscopy can create visual and cognitive blind spots. Manipulating the endotracheal hose to make it visible occurs within this blind spot, and this can lead to complications. However, a meta-analysis by Hoshijima et al. found a significant lower incidence of soft tissue bleeding with McGrath compared to Macintosh. Intraoral injury may be reduced due to low larynx lift.[23]

Previous study has shown that video laryngoscopes such as Glidescope and C-MAC video laryngoscope reduce lift during laryngoscopy. Unfortunately, there has been no study on lift pressure at McGrath. However, this may be similar to Glidescope and C-MAC video laryngoscopes, as these video laryngoscopes have the same type of blades as Macintosh. Reduction in larynx lift is believed to lead to a decrease in the incidence of laryngeal injuries. In addition, McGrath blades are made of polyethylene, which is softer and sharper than Macintosh stainless steel blades. Therefore, injury to the oral mucosa may be less likely with McGrath's blades.[23]

The intubation in this study was performed in emergency department, with indications of an inability to maintain the airway open, inability to secure the airway from aspiration, difficulty and failure of ventilation, oxygen insufficiency, and potential conditions leading to respiratory failure. Although author previously hypothesized that emergency department intubation used a McGrath laryngoscope has greater outcome than the Macintosh in terms of duration and first-attempt success, the results showed no significant difference.

A study that supports the results of this study is a multi-center RCT by Kreutziger et al who compared of pre-hospital emergency intubation with McGrath Video laryngoscope and direct laryngoscope. They found that there was no statistically significant difference in the duration of intubation, total of intubation attempt and intubation difficulty. Although the view to the glottis is significantly better, but the number of technical problems increases with the use of McGrath Mac Video Laryngoscope. After the first tracheal intubation attempt failed, immediate device replacement was significantly more successful than after the second attempt (90.5% vs. 57.1%; p = 0.0003).[17]

Nevertheless, the results of the Higgs et al. study reported that video laryngoscopes had a higher success rate than Macintosh in emergency department intubation. This is due to the ease of visualization, ease of use and the small risk of trauma. In the event of a failure in the direct laryngoscope, the video laryngoscope option should be available, especially in unstable patients. But the results of the study are not aligned with the results of this study even though it is the same emergency conditions. Another aspect may contribute is the level of airway difficulty in patients.

Endotracheal intubation in pre-hospital conditions can be more difficult even for experienced operators.[4] It should be noted that any intubation performed in emergency medical services is an emergency intubation. Lack of information about patient status and medical history, inability to perform anesthesia consultations in most cases, as well as lack of knowledge about the last meal, make every patient in a pre-hospital condition and emergency department considered a patient with a difficult airway.[24] The study similarly conducted in the emergency setting, but patients in this study did not have airway difficulty (LEON score >3) that may cause McGrath's advantage in patients with difficulty airway did not appear.

In a study conducted by Wallace et al who compared the difficulty of intubation using McGrath MAC video laryngoscopes, both in scrap and indirect mode, with standard Macintosh laryngoscopes. In the group of patients with a low risk of intubation, the McGrath

MAC and standard Macintosh showed the same Intubation Difficulty Score (IDS). Both require less airway intervention and less energy when compared to direct mode McGrath MAC video laryngoscopes.[19]

In a simulated study conducted by Korkut et al, endotracheal intubation in difficult airway conditions performed by paramedics using McGrath's video laryngoscope was associated with shorter procedure duration, clearer glottis visualization, and higher success rate of the first intubation attempt. The study showed that paramedics could perform intubation using McGrath video laryngoscopes with higher efficiency than in the group of standard Macintosh laryngoscopes after short training.[25] In this study, patients did not have airway difficulty (LEON score <3), and McGrath did not show better results, the results might be different if the patients had airway difficulties as in previous studies.

Difficult airways may be caused by several causes, including tongue oedema, cervical immobilization, or difficult access to patients. In all these situations, the effectiveness of the first intubation attempt is predicted to decrease, and the duration of the procedure will be longer with the use of McGrath MAC.[3] But in this study, patients did not have airway difficulty (LEON score <3), so the effectiveness of the first attempt is not expected to decrease, because the estimation of first-attempt success intubation between McGrath and Macintosh is similar.

Generally, the Cormack–Lehane laryngeal display scoring system is an accurate predictor of success on the direct laryngoscope. But its validity is still questionable in the use of video laryngoscopes, including McGrath's. Although visualization of glottis using McGrath is much better, some studies showed the duration of intubation using McGrath is much longer. So that does not guarantee ETT is easier to enter the larynx.[26] The possible cause is impaired eye and hand coordination due to indirect visualization. In addition, McGrath's lens is located at the end of the device. Thus, the pharynx and hypopharynx are not visualized during video laryngoscopy, which may result in visual and cognitive blind spots. In this condition, intra-oral manipulation of the ETT can interfere with the structure of the mouth and pharynx.[27]

Sharma et al. also reported that tracheal intubation with McGrath requires elastic rubber bougie more often than using Macintosh. She suggested that McGrath had his own technical difficulties in intubation, which may reduce the advantages previously gained from better glottis visualization.[28] Thus, the success rate of tracheal intubation with McGrath may be similar with Macintosh, as in this study.

In this study, the intubation was conducted by experienced physicians or anesthesiology residents who had been given training (10 anesthesiology residents). They are operators who have been trained to perform intubation either with Macintosh or McGrath laryngoscopes. This is expected to affect the results of this study. Referring to the study by Ray et al., the effect of intubation proficiency with Macintosh can be a considerable factor on the success of intubation. Previous studies have reported that novice operators are easier to use McGrath than Macintosh, but experienced operators have more difficulty with McGrath as in research conducted by Massen et al.[29,30] The results of a meta-analysis by Hoshijima et al. showed that McGrath provided better visualization of glottis than Macintosh, but success rates did not differ between the two devices and novice or experienced operators.[23]

One of the factors that greatly influences the first-attempt success and duration of intubation is the level of capability and experience of the operator. One of the advantages of McGrath is that there is no need for as much experience in the use of Macintosh laryngoscopes, so it can be used even by medical personnel who do not have much experience. As study conducted by Murakami et al. showed that the percentage of glottic opening (POGO) score produced by novice operators is higher when using McGrath and AirwayScope than using Macintosh in an endotracheal intubation training on mannequin for 3 days.[31] Another study conducted by Giraudon et al. explained that novice operators take longer time to perform intubation using McGrath than Macintosh.[32]

In this study, operators have been trained to use Macintosh and McGrath as well, hence results are expected to be the same. Previous research by Zhu et al., indirect video laryngoscopes were associated with higher success rates of tracheal intubation by inexperienced operators.[33] Mulcaster et al. reported that beginners who used Macintosh laryngoscope required 27 successful intubation attempts before achieving a >90% success rate.[19] In novice operators, McGrath was superior to the Macintosh because training using Macintosh was more difficult and McGrath could be learned easily. While in this study, operators have been trained to use both, so it did not show significant difference in both successful attempt and duration of intubation.

In a meta-analysis by Hoshijima et al, McGrath significantly extended the intubation time compared to the Macintosh among experienced operators only. However, the interpretation of these results needs to be careful. Of all the end results targeted in this meta-analysis, intubation time is probably the most sensitive to the level of intubation proficiency. In this RCT, experienced operators were quite skilled at intubation with the Macintosh but not with McGrath. Improved proficiency with McGrath, like the Macintosh among experienced operators, may yield different results than those in this meta-analysis. Indeed, there was no significant difference between novice and experienced operators in the duration of intubation.

In this study, operators who performed intubation were quite adept at using Macintosh, but because McGrath was less commonly used than Macintosh, the level of proficiency in using McGrath among operators were vary. Thus, the difference in operator proficiency in using McGrath in this study may affect the results.[19] A redefining of the operator's capabilities and experience in each laryngoscope is required. Therefore, the difference in results between experienced and inexperienced operators using McGrath may be further investigated.

References

1. Jung, W. & Kim, J. Factors associated with first-pass success of emergency endotracheal intubation. *Am. J. Emerg. Med.* **38**, 109–113 (2020).
2. LD, M., JM, M., AM, S., KK, T. & S., K. 3,423 Emergency Tracheal Intubations at a University Hospital. *J. Am. Soc. Anesthesiol.* 3–6 (2011).
3. Suzuki, K., Kusunoki, S., Tanigawa, K. & Shime, N. Comparison of three video laryngoscopes and direct laryngoscopy for emergency endotracheal intubation: A retrospective cohort study. *BMJ Open* **9**, 1–7 (2019).
4. Lewis, S. R. *et al.* Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation: A Cochrane Systematic Review. *Br. J. Anaesth.* **119**, 369–383 (2017).
5. Lundstrøm, L. H., Møller, A. M., Rosenstock, C., Astrup, G. & Wetterslev, J. High Body Mass Index Is a Weak Predictor for Difficult and Failed Tracheal Intubation. *Anesthesiology* **110**, 266–274 (2009).
6. Cook, T. M., Woodall, N. & Frerk, C. Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. *Br. J. Anaesth.* **106**, 617–631 (2011).
7. Pieters, B. *et al.* Indirect videolaryngoscopy using Macintosh blades in patients with non-anticipated difficult airways results in significantly lower forces exerted on teeth relative to classic direct laryngoscopy: A randomized crossover trial. *Minerva Anestesiol.* **81**, 846–854 (2015).
8. Cook, T. M. *et al.* Consensus guidelines for managing the airway in patients with COVID-19: Guidelines from the Difficult Airway Society, the Association of Anaesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists. *Anaesthesia* **75**, 785–799 (2020).
9. Simpson, G. D., Ross, M. J., McKeown, D. W. & Ray, D. C. Tracheal intubation in the critically ill: A multi-centre national study of practice and complications. *Br. J. Anaesth.* **108**, 792–799 (2012).
10. Hoshijima, H. *et al.* Videolaryngoscope versus Macintosh laryngoscope for tracheal intubation in adults with obesity: A systematic review and meta-analysis. *J. Clin. Anesth.* **44**, 69–75 (2018).
11. Griesdale, D. E. G., Liu, D., McKinney, J. & Choi, P. T. Glidescope ® video-laryngoscopy versus direct laryngoscopy for endotracheal intubation: A systematic review and meta-analysis. *Can. J. Anesth.* **59**, 41–52 (2012).
12. Liu, L. *et al.* Tracheal intubation of a difficult airway using airway scope, airtraq, and macintosh laryngoscope: A comparative manikin study of inexperienced personnel. *Anesth. Analg.* **110**, 1049–1055 (2010).
13. Carlson, J. N. & Brown, C. A. Does the use of video laryngoscopy improve intubation outcomes? *Ann. Emerg. Med.* **64**, 165–166 (2014).
14. Taylor, A. M. *et al.* The McGrath® Series 5 videolaryngoscope vs the Macintosh laryngoscope: A randomised, controlled trial in patients with a simulated difficult airway. *Anaesthesia* **68**, 142–147 (2013).
15. Janz, D. R. *et al.* Randomized Trial of Video Laryngoscopy for Endotracheal Intubation of Critically Ill Adults. *Crit. Care Med.* **44**, 1980–1987 (2016).
16. Rombey, T., Schieren, M. & Pieper, D. Originalarbeit: Video- versus direkte Laryngoskopie bei innerklinischen Notfallintubationen von Erwachsenen. *Dtsch. Arztebl. Int.* **115**, 437–444 (2018).
17. Kreutziger, J. *et al.* Comparing the McGrath Mac Video Laryngoscope and Direct Laryngoscopy for Prehospital Emergency Intubation in Air Rescue Patients: A Multicenter, Randomized, Controlled Trial. *Crit. Care Med.* **47**, 1362–1370 (2019).
18. Castillo-Monzón, C. G. *et al.* Comparison of the Macintosh and Airtraq laryngoscopes in morbidly

obese patients: a randomized and prospective study. *J. Clin. Anesth.* **36**, 136–141 (2017).
19. Wallace, C. D., Foulds, L. T., McLeod, G. A., Younger, R. A. & McGuire, B. E. A comparison of the ease of tracheal intubation using a McGrath MAC® laryngoscope and a standard Macintosh laryngoscope. *Anaesthesia* **70**, 1281–1285 (2015).
20. Colak, F. *et al.* Comparison of hemodynamic responses and QTc intervals to tracheal intubation with the McGRATH MAC videolaryngoscope and the Macintosh direct laryngoscope in elderly patients. *Kaohsiung J. Med. Sci.* **35**, 116–122 (2019).
21. A, J. & S, D. Physiologic and Pathophysiologic Responses to Intubation. in *Benumof and Hagberg's Airway Management* 184–198 (2012).
22. Lascarrou, J. B. *et al.* Video laryngoscopy vs direct laryngoscopy on successful first-pass orotracheal intubation among ICU patients: A randomized clinical trial. *JAMA - J. Am. Med. Assoc.* **317**, 483–493 (2017).
23. Hoshijima, H. *et al.* McGrath videolaryngoscope versus Macintosh laryngoscope for tracheal intubation: A systematic review and meta-analysis with trial sequential analysis. *J. Clin. Anesth.* **46**, 25–32 (2018).
24. Gawlowski, P. *et al.* Comparison of the ETView Single Lumen and Macintosh laryngoscopes for endotracheal intubation in an airway manikin with immobilized cervical spine by novice paramedics: A randomized crossover manikin trial. *Med. (United States)* **96**, 1–6 (2017).
25. Korkut, S. *et al.* Comparison of the McGrath MAC EMS Videolaryngoscope with a Conventional Laryngoscope for Standard and Difficult Airway Intubation: A Randomized, Cross-over, Simulation Trial. *Eurasian J. Emerg. Med.* **18**, 211–217 (2019).
26. McElwain, J., Malik, M. A. & Laffey, J. G. Difficult tracheal intubation. *Br. J. Anaesth.* **104**, 260–261 (2010).
27. Hoshijima, H. *et al.* C-MAC videolaryngoscope versus Macintosh laryngoscope for tracheal intubation: A systematic review and meta-analysis with trial sequential analysis. *J. Clin. Anesth.* **49**, 53–62 (2018).
28. Sharma, D. J., Weightman, W. M. & Travis, A. Comparison of the Pentax Airway Scope® and McGrath® Videolaryngoscope with the Macintosh laryngoscope in tracheal intubation by anaesthetists unfamiliar with videolaryngoscopes: A manikin study. *Anaesth. Intensive Care* **38**, 39–42 (2010).
29. Ray, D. C. *et al.* A comparison of McGrath and Macintosh laryngoscopes in novice users: A manikin study. *Anaesthesia* **64**, 1207–1210 (2009).
30. Maassen, R., Lee, R., Hermans, B., Marcus, M. & Van Zundert, A. A comparison of three videolaryngoscopes: The macintosh laryngoscope blade reduces, but does not replace, routine stylet use for intubation in morbidly obese patients. *Anesth. Analg.* **109**, 1560–1565 (2009).
31. Murakami, Y., Ueki, R., Niki, M., Hirose, M. & Shimode, N. Three-day tracheal intubation manikin training for novice doctors using Macintosh laryngoscope, McGRATH MAC videolaryngoscope and Pentax AirwayScope. *Med. (United States)* **100**, 1–7 (2021).
32. Giraudon, A. *et al.* Comparison of the McGrath® MAC video laryngoscope with direct Macintosh laryngoscopy for novice laryngoscopists in children without difficult intubation: A randomised controlled trial. *Anaesth. Crit. Care Pain Med.* **36**, 261–265 (2017).
33. Zhu, H. *et al.* A randomized controlled comparison of non-channeled king vision, McGrath MAC video laryngoscope and Macintosh direct laryngoscope for nasotracheal intubation in patients with predicted difficult intubations. *BMC Anesthesiol.* **19**, 1–9 (2019).