Comparison of VividTrac® videolaryngoscope in mannequins by novice users

Ph.D. thesis

Dóra Keresztes, MD

University of Pécs, Faculty of General Medicine

Department of Anaesthesiology and Intensive Care

Graduate School of Clinical Medicine

Head of the Graduate School: Lajos Bogár, MD, PhD, DSc

Programme leader: Zalán Szántó, MD, PhD

Supervisors: Bálint János Nagy, MD, PhD; Gábor László Woth, MD, PhD

OGYDHT, Pécs

2024

Contents

1. Introduction

Airway management is one of the cornerstones of critical care and anaesthesia [1]. The gold standard for endotracheal intubation (ETI) is direct laryngoscopy (DL) with a Macintosh blade. However, to achieve an intubation success rate of over 90%, at least 57 intubations must be performed with this method beforehand [2]. It is understood that only those working in specialised fields can have this level of experience. The difficulty of the DL is that the vocal cords, the oropharynx, the oral cavity and the oral opening must be aligned to bring the glottis into the visual field [3]. There are numerous factors that may render this difficult to perform, such as limited neck mobility, facial deformity, obesity. According to the definition of the ASA-American Society of Anesthesiologists, if a skilled anesthesiologist experiences difficulty in providing mask ventilation, laryngoscopy, SGAD-supraglottic airway devices, ETI, extubation or invasive airway, it is considered a difficult airway [4]. The prevalence of difficult airway in the care of critically ill patients outside the operating room can be as high as 15% [5][6]. The likelihood of failure and complications is further increased by the fact that the first provider's experience of intubation in such situations is often low. Cardiopulmonary resuscitation (CPR) is one of the most performed emergency interventions outside the operating room setting. The key point of CPR is adequate airway protection in addition to continuous, high-quality chest compressions [7]. However, in caregivers with limited experience, the use of DL may prolong the compression pause and increase the number of intubation attempts [8].

With advances in video technology, flexible fibre-optic video devices, so-called video laryngoscopes (VL), have become commercially available. To overcome the difficulties of DL, their optical system displays the machine input on a built-in or external monitor without the need to bring it directly into view. Their aim is to reduce the time and risks associated with ETI and increase the intubation success rate. An additional feature is that many VLs are equipped with a tube-guided blade to aid successful ETI [3,9,10]. The advantage of VLs is more pronounced in patients with limited intubation experience. Their use results in a better first-pass success rate (FPSR) and faster intubation time (IT) than DL. These devices may also offer an advantage over DL in difficult airways. However, depending on the type of VL used, they have also been shown to have advantages in terms of lower complication rates and better visualization of the glottis for experienced users [8,11-19].

VLs have experienced a renaissance in the context of the coronavirus (SARS-CoV-2) pandemic in 2019. Airway management of respiratory failure patients infected with coronavirus (COVID-19) was often performed by providers with low intubation experience. The situation was further complicated by the need of personal protective equipment to avoid transmission of infection [20]. As the mortality rate of COVID-19 was high, CPR of infected patients was thus often required. In this scenario, ETI was of high priority [21,22]. ETI of critical ill patients with COVID-19 had an FPSR of less than 80% and more than 20% of intubation with two attempts. Therefore, the use of devices that maximize FPSR and reduce the time spent per intubation attempt even for inexperienced intubators was needed [23]. Thus, VLs were inevitably brought to the forefront to achieve a better intubation success rate, without neglecting the protection of the provider by increasing the physical distance between patient and intubator [20]. However, the protective role of VLs is not only for COVID-19 but also for other respiratory tract infections. A large proportion of patients in emergency care have an unknown infectious status, so the risk of infection to the person intubating can be reduced by the use of VLs. A wide range of VLs are commercially available. However, the clear advantages of different shapes, sizes and blade shapes are not yet clear. Many studies show that different groups of VLs may be of benefit in different airway situations, but there are also differences in their advantages and disadvantages between VLs within the same group [24,25].

2. Aims

Our aim was to compare the VividTrac® VT-A100 (VT) (Vivid Medical, Palo Alto, USA) videolaryngoscope, with other commercially available VLs, a custom-made VL and the current gold standard DL in a safe, simulated environment for novice users. Although the VT which has been commercially available since 2013, it has been little or never assessed in resuscitation situations. For this purpose, we have set up a scenario simulating a difficult airway and a scenario simulating a normal and a difficult airway under continuous chest compressions.

2.1. Primary aim

Our primary endpoint was to demonstrate that the use of VT in novice users would result in improved or at least not significantly worse FPSR in difficult airway and continuous chest compressions during ETI in normal and difficult airway situations.

2.2. Secondary aims

We have identified the following as secondary endpoints in our analysis:

- number of successful intubation attempts, number of unsuccessful intubations

- laryngoscopy time-LT, tube insertion time-TIT, IT

- percentage of glottic opening (POGO)

- the technical difficulty, physical strength required for exploration and willingness to repeat use associated with the use of the device under investigation

- use of a tube guide

- complications: tooth injury, oesophageal intubation

We hypothesised that the use of VT would also lead to better, but at least not significantly worse, outcomes in terms of secondary endpoints compared to VLs and DL in all three scenarios we investigated.

3. Materials and Methods

3.1. Comparison of VividTrac® videolaryngoscope in mannequins with novice users

3.1.1. Common methods

Our investigation was carried out at the Medical Skills Lab of the Medical School, University of Pécs, among volunteer medical students. The criteria for the selection of participants were the anatomical knowledge required for airway management and the lack of real-life intubation experience. At the beginning of the study, each group took part in a 15-minute small groups hands-on training session. During practice, participants acquired manual skills and theoretical knowledge supervised by consulting specialists from the Institute of Anaesthesiology and Intensive Care at the University of Pécs Clinical Centre, thereafter the participants were given the opportunity to practice intubation with these devices in both normal and difficult airway conditions. The training took place on a Laerdal® Airway Management Trainer (Laerdal®, Stavanger, Norway).

At each practical station, the participants had equal amount of time under the supervision and instruction of an anaesthesiologist experienced in intubation with the device. During the training, students learned how to use a gum elastic bougie, an intubation stylet and how to evaluate the POGO scoring system [23], which indicates the quality of exploration. Emphasis was also placed on the understanding of the mechanism of dental injury and its importance. Following training, the students' performance was individually assessed by performing endotracheal intubation in a given airway situation with all devices in random order. The primary outcome of the study was the measurement of FPSR per device. Further, we measured the number of attempts required for successful intubation, LT, TIT, IT, POGO, recorded the occurrence of any oesophageal intubation, dental injury and the use of bougie and stylet. Finally, after the intubation attempts, we asked the students to evaluate three subjective aspects. The intubation attempt was considered failed if it lasted more than 120 seconds, if the student removed the tube from the oral cavity during the attempt or if the student recognised that oesophageal intubation had occurred. Intubation with a device was considered failed if the oesophageal intubation was not recognized, more than 3 attempts were unsuccessful, or if the participant had given up on the subsequent intubation attempt before the 3 attempts. The time elapsed from the tool blade passing the interdental line until the best POGO was achieved, i.e. the start of tube manipulation, was defined as LT, and the time until successful intubation was defined as IT. The difference in time between IT and LT was defined as TIT. Immediately after the intubation attempts, we asked the students to grade each device on a five-point Likert scale, without ranking them. They rated the technical ease of using the devices (1= easy, 5= difficult), the physical strength required to perform the exploration (1= easy, 5= difficult) and their willingness to use the device again in the future (1-never use it again, 5= would like to use it again).

3.1.2 Comparison of the VividTrac® videolaryngoscope during difficult airway intubation in mannequin by novice users

Our study was conducted under the permission of the Regional Research Ethics Committee of the University of Pécs, Hungary, No. 5825/2016. Based on previous similar studies and an estimated effect after power analysis ($\alpha=0.05$ and $\beta=0.1$), 50 students were included in the study [24,25]. The study was conducted in small group (n=5) designs. All participants provided written informed consent for the study.

The instruments included in the study were as follows (Figure 1):

- VT, adult size, with a channelled blade (Vivid Medical, Palo Alto, USA)
- King Vision® (KV) size 3 channelled blade (Ambu, Copenhagen, Denmark)
- Airtraq® (AT) with 3 channelled blade and mobile phone camera adapter (Prodol, Vizcaya, Spain)
- DL with size 3 Macintosh-blade (KaWe®, Asperg, Germany)
- Custom-made indirect laryngoscope (ID) with Macintosh size 3 blade

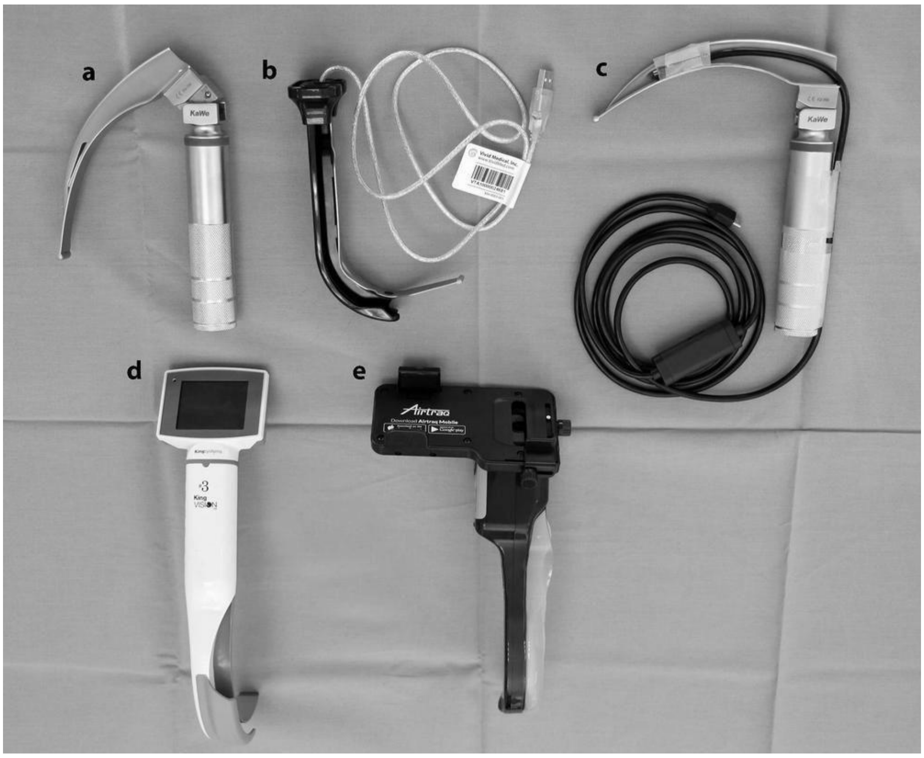

Figure 1: Devices included in the study: (a) Direct laryngoscope (DL), (b) Vivid Trac® (VT), (c) Custom-made indirect laryngoscope (ID), (d) King Vision® (KV), Airtraq® (AT) [26]

For all ETI, a 7.5 mm internal diameter cuffed plastic endotracheal tube (Mallinckrodt®, Covidien, Dublin, Ireland) was used. For real-time imaging of VT and ID, a HP (Palo Alto, California, USA) Probook laptop was used. To connect the AT, the original universal smartphone adapter (Prodol, Vizcaya, Spain) was connected to a smartphone (Xiaomi Note 9 Pro). The VT required the installation of VividVision® software and the AT required the installation of Airtraq Mobile® software. The study was performed on a Laerdal® Airway Management Trainer (Laerdal®, Stavanger, Norway). The difficult airway situation was simulated with manual in-line stabilization of the cervical spine (MILS) according to the Advanced Trauma Life Support (ATLS) recommendation [30].

3.1.3 Comparison of VividTrac® videolaryngoscope in normal and difficult airways during simulated cardiopulmonary resuscitation among novice users

Our study was performed under the permission of the Regional Research Ethics Committee of the University of Pécs, Hungary, number 7176 - PTE 2018. Our investigation was carried out at the Medical Skills Lab of the University of Pécs. Based on previous studies, we defined both the devices to be examined and the required minimum sample size [29]. Based on this, the following laryngoscopes were selected:

- VT, adult size, with a channelled blade (Vivid Medical, Palo Alto, USA) (Vivid Medical, Palo Alto, USA)
- King Vision® (KV) size 3 channelled blade (Ambu, Copenhagen, Denmark)
- DL with size 3 Macintosh-blade (KaWe®, Asperg, Germany)

VT imaging was performed using VividVision® software on a 13.3" screen size Acer Aspire V 13 laptop. Based on previous similar studies and an estimated effect size (α=0.05 and β=0.1), 44 medical students were included in the study [27-29]. The study was performed in small group (n=5). All participants provided written informed consent for the study. The study was performed using an Advanced Life Support (ALS) simulators (Ambu® Man Advanced). Students were required to perform a successful ETI during continuous chest compression, with all devices, in a randomized order, first in a normal and then in a difficult airway situation. A 7.0 mm internal diameter cuffed plastic endotracheal tube (Mallinckrodt®, Covidien, Dublin, Ireland) was used for all intubations. Chest compressions were performed according to the standard CPR protocol. The simulator software was used to verify this [31].

- Scenario A: ETI was performed in a normal airway situation, head tilting was allowed.

- Scenario B: The ETI was performed in a difficult airway situation simulated according to the ATLS protocol using MILS

3.2. Statistical analysis

Data were analysed using Statistical Package for the Social Sciences (SPSS) Statistics software version 25.0 (IBM Corporation, Armonk, NY, USA). Continuous and ordinal data are presented as median and interquartile range (IQR), while categorical data are presented as raw count (n) and frequency (%). Non-parametric tests were used, given that our data did not show a normal distribution based on the Kolmogorov- Smirnov and Shapiro-Wilk tests performed. To detect differences between instruments, we used Kruskal-Wallis analysis of variance (ANOVA) with post-hoc Dunn's test for the following variables: LT, TIT, IT, POGO, technical use, implementation effort and willingness to reuse. Chi-square tests were used to assess differences between devices in terms of intubation success, number of oesophageal intubations, incidence of dental injury, and use of bougie and stylet. A value of $p < 0.05$ was considered significant.

4. Results

4.1. Comparison of the VividTrac® videolaryngoscope during difficult airway intubation in mannequin by novice users

Table 1: Results of the difficult airway study

Difficult airway	DL (n=50)	ID (n=50)	KV (n=50)	AT (n=50)	VT (n=50)
Number of attempts (n, 1/2/3)	48/1/1	47/2/1	46/4/0¶	47/3/0	50/0/0†
Laryngoscopy time (LT) (s)	12.16[9.05-14.4]$^{\#\P}$	16.2[11.7-23.4]*†§¶	10.86[7.66-13.0]$^{\#}$	9.13[7.37-11.7]$^{\#}$	8.99[7.22-11.3]*$^{\#}$
Tube insertion time (TIT) (s)	6.52[4.33-12.97]†§¶	7.04[5.45-15.04]†§¶	3.31[2.05-11.68]*$^{\#}$	2.60[1.90-4.87]*$^{\#}$	3.17[2.13-4.87]*$^{\#}$
Intubation time (IT) (s)	19.0[14.97-26.1]§¶	23.4[19.0-35.5]†§¶	15.72[11.5-23.1]$^{\#}$	12.8[9.62-16.5]*$^{\#}$	12.7[10.0-15.8]*$^{\#}$
POGO (%)	40[20-60]†§¶	45[25-55]†§¶	75[60-85]*$^{\#}$	75[60-85]*$^{\#}$	62.5[50-90]*$^{\#}$
Ease of technical use (1-5)	4[3-4]†§¶	4[3-4]†§¶	2[1-3]*$^{\#}$	2[2-3]*$^{\#}$	2[1-2]*$^{\#}$
Ease of physical use (1-5)	4[3-5]†§¶	4[3-5]†§¶	2[1-3]*$^{\#}$	2[2-3]*$^{\#}$	2[1-2]*$^{\#}$
Willingness of reuse (1-5)	3[2-4]†¶	3[2-3]†¶	5[4-5]*$^{\#\S}$	3[3-4]†¶	5[4-5]*$^{\#\S}$
Use of bougie (n)	10†§¶	9†§¶	0*$^{\#}$	0*$^{\#}$	0*$^{\#}$
Use of stylet (n)	5$^{\#\dagger\S\P}$	11*†§¶	0*$^{\#}$	0*$^{\#}$	0*$^{\#}$
Dental injury (n)	32$^{\#\S}$	41*†¶	35$^{\#\S}$	39*†¶	35$^{\#\S}$
Oesophageal intubation (n)	1	0	0	0	0

Data are reported as the median [IQR] or as numbers (n)
AT Airtraq®, DL Direct laryngoscope (Macintosh), ID Custom-made, improvised laryngoscope, KV King Vision®, POGO Percent of Glottic Opening, VT VividTrac®
***Significant difference (P < 0.05) compared to DL; #Significant difference (P < 0.05) compared to ID; †Significant difference (P < 0.05) compared to KV; §Significant difference (P < 0.05) compared to AT; ¶Significant difference (P < 0.05) compared to VT**

The FPSR as the primary outcome of our study was highest for VT. Comparing DL with VL, there was no significant difference in FPSR. However, within the group of VLs, a significantly better FPSR was achieved with VT than with KV ($p < 0.05$). Failed intubation was not recorded for any device. The VT performed better in terms of LT compared to all devices and achieved the ideal POGO significantly faster compared to the ID and DL ($p < 0.05$). However, our ID underperformed in this respect compared to all devices ($p < 0.05$). Among the VLs, KV, AT and VT achieved faster TIT compared to ID and DL ($p < 0.\ 05$). In terms of IT, the commercial VLs gave the best results. AT and VT were significantly faster than DL (< 0.05). However, ID underperformed the other VLs ($P < 0.05$). Comparing all the devices, we registered the shortest IT when VT was used. With the exception of ID, all VLs had better POGO scores than DL ($P < 0.05$). The technical and physical ease of use of all commercially available VLs was rated as easier by participants compared to DL and ID ($P < 0.05$). ID and DL were rated as similarly difficult to use. For VT and KV, participants showed significantly greater willingness to use the device repeatedly compared to the other laryngoscopes ($p < 0.05$). Bougie and stylet use was only required for ID and DL. Stylet was used significantly more often by participants during ID than during DL ($p < 0.05$). Dental injury was observed in more than half of the intubation attempts for all devices. However, there was a significantly higher incidence of dental injury when using AT and ID compared to the other laryngoscopes ($p < 0.05$). Oesophageal intubation was only experienced once when using DL.

4.2. Comparison of the VividTrac® videolaryngoscope in normal airway intubation during simulated cardiopulmonary resuscitation among novice users

Table 2. Results of the study under continuous chest compression in a normal airway situation

Normal airway	DL (n=44)	KV (n=44)	VT (n=44)
Number of attempts (n, 1/2/3)	30/8/6	35/6/3	37/5/2
Laryngoscopy time (s)	10.09 [7.57-13.35]	9.36 [7.31-14.91]	9.3 [6.05-15.13]
Tube insertion time (s)	7.4[5.84-14]	3.35 [2.33-8.7]¶	11.69 [5.3-19.61]†
Intubation time (s)	19.19 [14.28-27.09]†	15.2 [11.1-23.9]*¶	23.08 [15.9-33.2]†
POGO (%)	75 [60, 90]	75 [70-80]	60 [50-90]
Ease of technical use (1-5)	2 [1-4]	3 [2-4]	2 [2-4]
Ease of physical use (1-5)	3 [2-4]	2 [2-3]	2 [1-3]
Willingness of reuse (1-5)	4 [3-5]	3 [2-4]	4 [2-5]
Use of bougie (n)	11¶†	0*	0*
Dental injury (n)	0	1	0
Oesophageal intubation (n)	11¶†	1*	1*

Results of our studies under continuous chest compression in a normal airway situation. Data are reported as the median [IQR] or as numbers (n). DL: Direct laryngoscope (Macintosh), KV: King Vision, POGO: Percent of glottic opening, VT: VividTrac *Significant difference (P < 0.05) compared to the DL, †Significant difference (P < 0.05) compared to the KV., ¶Significant difference (P < 0.05) compared to the VT.

Under normal airway conditions, with continuous chest compressions, no significant difference in the number of successful intubation attempts was found between devices, but the best FPSR was observed with VT. Failed intubations were not detected for any device. VT was found to be the fastest in the LT required to reach the optimal POGO value, but no significant difference was found between any of the devices compared to the others. The fastest TIT was achieved with KV, which showed a significantly better result compared to VT ($p < 0.05$). For IT, KV was also the fastest among the devices tested ($p < 0.05$). However, VT was no longer significantly slower than DL for either TIT or IT. No significant difference was found in the POGO value, between the laryngoscopes. When evaluating subjective parameters, students did not find significant differences in the physical and technical usability of the instruments, while the VT achieved the best overall score in this respect. Participants showed similar levels of willingness to reuse all tools. Bougie use occurred only with the DL ($p < 0.05$). Among complications, dental injury was detected only once, during the use of the KV, while oesophageal intubation occurred significantly more often with the DL than with the KV or VT ($p < 0.05$).

4.3. Comparison of the VividTrac® videolaryngoscope in difficult airway intubation during simulated cardiopulmonary resuscitation among novice users

Table 3. Results of the study under continuous chest compression in a difficult airway situation

Difficult airway	DL (n=44)	KV (n=44)	VT (n=44)
Number of attempts (n 1/2/3)	35/4/5	40/3/1	35/2/7
Laryngoscopy time (s)	13.7 [8.37-18.89]¶	14.52 [10.72-26.05]¶	8.04 [6.33-14.33]*†
Tube insertion time (s)	8.15 [4.4-17.09]†	4.76 [2.05-11.42]*¶	8.09 [4.03-18.64]†
Intubation time (s)	23.39 [16.93-34.31]	21.91 [14.76-39.51]	20.83 [12.65-39.45]
POGO (%)	60 [40-80]	67.5 [50-80]	60 [40-76.3]
Ease of technical use (1-5)	3 [2-4]	3[2-4]	2 [1-4]
Ease of physical use (1-5)	4 [2-4]¶	3 [2-4]	2 [1-3]*
Willingness of reuse (1-5)	3 [2-5]	3 [2-4]	4 [2-5]
Use of bougie (n)	17¶†	0*	0*
Dental injury (n)	0	0	0
Oesophageal intubation (n)	7¶†	0*	0*

Results of our studies under continuous chest compression in a difficult airway situation. Data are reported as the median [IQR] or as numbers (n). DL: Direct laryngoscope (Macintosh), KV: King Vision, POGO: Percent of glottic opening, VT: VividTrac *Significant difference (P < 0.05) compared to the DL, †Significant difference (P < 0.05) compared to the KV., ¶Significant difference (P < 0.05) compared to the VT.

In difficult airway conditions with continuous chest compressions, no significant difference was found in the number of attempts required for successful intubation between devices. No failed intubations were recorded. In terms of LT required to achieve optimal POGO, VT was significantly faster compared to KV and DL ($p < 0.05$). However, in TIT, KV performed better compared to the other devices tested ($p < 0.05$). VT was not significantly worse compared to either device in this case. However, there was no longer a significant difference between the laryngoscopes in terms of IT because of the LT and TIT results. The shortest IT was measured for VT. No significantly better POGO was achieved by the students when using any of the devices. When evaluating the subjective parameters, the participants rated the devices as having similar technical difficulty to use, but required significantly less effort to use VT compared to DL. There was no difference between the laryngoscopes in terms of willingness to reuse. Soft guides were used only in DL ($p < 0.05$). No dental injuries were recorded and oesophageal intubation occurred only in DL ($p < 0.05$).

5. Discussion

5.1. Limitations

In evaluating our results, the following limitations should be considered. Our data come from a monocentric study where students used the tools under simulation conditions. The results only refer to the anatomical conditions of the simulators we used. The simulation conditions used do not match and are not 100% transferable to real clinical practice. Complications such as device humidification or contamination with mucus could not occur and no complications other than dental injury and oesophageal intubation could be simulated. Nevertheless, the use of mannequin model is widespread, as skills and procedures can be learned and performed without endangering the patient. Participants performed the measured exercise after a 30-minute break following a 15-minute training session. For DL, the POGO value depended on the students' subjective perception. The occurrence of dental injuries was marked as yes or no. High pressure on the teeth was only indicated by the Laerdal® Airway Management Trainer with a "click" sound. This was not possible on the ALS simulator, so the occurrence of dental injury was based on subjective judgement. Within an experiment, the number of dental injuries and the degree of force exposure were not marked. The Likert scale was used to obtain feedback from the participants in the study, and more detailed qualitative data were not collected.

For our intubation study with continuous chest compressions, in addition to the above limiting factors, when evaluating our results, we must also take into account that our measurements were not performed on the same mannequin model as those on which the training was conducted. In addition, the students did not have the opportunity to intubate on the ALS simulator prior to the measurements.

5.2. Comparison of the VividTrac® videolaryngoscope during difficult airway intubation in mannequin by novice users

Effective ETI with the indirect technique is possible after only a short training period, even when simulating a difficult airway using manual in-line stabilization [32-35]. In our experience, a short training period of 15 min per device was sufficient to achieve a high FPSR above 90% for all devices we tested. This value was 100% for VT. VL is designed to facilitate ETI. For commercially available VLs, including VT, we measured significantly shorter LT and TIT compared to DL. The advantage of the curved, narrow antero-posterior diameter blade has been demonstrated in other studies in difficult airway [36]. The faster intubation may have been contributed by the better POGO value achieved with these devices. In VT, there was less dental injury and complications such as oesophageal intubation could be avoided with video techniques. And a blade with a tube guide eliminates the use of additional devices (bougie and stylet). The popularity of a particular laryngoscopic device depends mainly on the user's previous experience and subjective factors. Our results are in line with the literature, which shows that intubators found it easier to use VLs compared to DLs [27,36-40]. Accordingly, novice users would prefer to use VT and KV again for an ETI.

5.3. Comparison of the VividTrac® videolaryngoscope in endotracheal intubation during simulated cardiopulmonary resuscitation among novice users

The performance of ETI during CPR requires even greater skill than under normal conditions [17]. One reason for this is that difficult airways are more likely to occur under these conditions, even for experienced intubators. The development and use of devices to reduce intubation time is a real need. This is reinforced by the fact that in practice, especially in emergency care, providers with little intubation experience are often forced to perform CPR and airway protection during this procedure. For them, the use of VL may provide an alternative.

5.3.1. Testing under normal airway conditions

Again, the highest value for FPSR as a primary outcome was achieved using VT. Although the advantage of VT's narrow antero-posterior diameter was well demonstrated in LT, however, due to a slower TIT, we did not find a markedly faster IT using it, as was the case for the achievable POGO value. Thanks to the video technique, even with a continuously moving chest, the tube inserted through the tube guide flap could be well followed, avoiding oesophageal intubation. The VT received high scores from users.

5.3.2 Testing under difficult airway conditions

Considering that CPR is an emergency intervention, the incidence rate of difficult airway is twenty times higher than in elective cases [41]. Short- and long-term survival is determined by the time spent before intubated. Therefore, it is important to choose a device with a high probability of performing a successful ETI from the first intubation attempt, preferably without interrupting chest compressions [14,17]. In our study, we still recorded an FPSR of 80% in difficult airway conditions with continuous chest compressions. By using the VT narrow blade, we measured significantly faster LT compared to the laryngoscope in the other studies, but as before, the slower TIT did not result in significantly faster TI, but at the same time, it was not worse. With MILS, despite continuous chest compressions, head movement was limited, so presumably this was the reason why we found no significant difference in POGO achieved with the devices. The aforementioned advantages of video technology in terms of complications were also evident in this case. The use of VLs and, within this, VT was found to be the most user-friendly by intubators.

6. Conclusion

A comparison of our results with the literature shows that there is no unanimous opinion on VLs as a summary group as to which aspects are advantageous over DL, regardless of the practical experience of the user. This is also true when considering only a small group of VLs, such as the group of VLs with or without a tube guide. Therefore, they should be compared individually. The different properties of VLs should all be considered when choosing a VL. Knowing the nature of difficult intubation can make our choice easier. A device with a reduced mouth opening capacity may have a fast TIT if it is difficult to insert into the oral cavity due to the blade design and vice versa. In the case of a deviation in the primary curvature of the airway, the tube guide may make successful ETI difficult. Each VL design has its own advantages and disadvantages, as well as its area of application where it may have an advantage over other VLs. There have been studies and summary studies that can help to select the right VL for the purpose [1,24,42,43]. The range of VLs on the commercial market is constantly expanding. And new devices cannot be pigeonholed, so comparative, exploratory studies are needed for each. There is very little literature on the VT under our scrutiny, but our study found encouraging results, with significantly better FPSR, LT, TIT, IT and POGO compared to DL in MILS simulated difficult airway and no worse results than DL in either normal or difficult airway during continuous chest compressions. And the measured LT and positive user ratings in all scenarios are outstanding for VT. Based on these data, further studies towards clinical trials may be worthwhile in the future to explore areas where the use of VT may be of benefit to both patients and users.

7. Theses

7.1. Pimary aim

In our study, using VT in a difficult airway situation, we have been able to demonstrate that it achieves a better FPSR than DL, ID or other commercially available VLs. During intubation with continuous chest compressions, we recorded the highest FPSR with VT in normal airway and no significantly worse outcome in difficult airway compared to the other devices. We were able to demonstrate the same success rate as DL for ETI from the first trial.

7.2. Secondary aim

7.2.1. Comparison of the VividTrac® videolaryngoscope during difficult airway intubation in mannequin by novice users

- In a difficult airway situation, it was demonstrated that the highest FPSR was achieved with VT compared to the other devices tested.

- It was demonstrated that the VT achieved the fastest LT and IT and also outperformed all other devices tested in terms of TIT.

- We measured a better POGO using VT than using DL and ID, while the POGO achieved with this device was not significantly worse than with the other commercially available VLs.

- We confirmed that VT was easier to use for novice users compared to DL and ID and was found to be similarly easy in both technical and physical terms compared to other commercially available VL. Thus, we demonstrated a high reusability rate for VT in a heavy airway environment.

- We also proved that the use of VT did not require the use of a rigid or soft guide for successful intubation, similar to other devices utilising a tube-guided flap.

- We demonstrated that the use of VT did not result in a higher rate of dental injury compared to the other devices tested and found a significantly lower complication rate in this regard compared to ID. No oesophageal intubation was recorded with VT.

7.2.2. Comparison of the VividTrac® videolaryngoscope in normal airway intubation during simulated cardiopulmonary resuscitation among novice users

- We showed that using VT with continuous chest compressions did not result in failed intubations with a normal airway.

- In terms of TIT and thus IT, no advantage of VT over the other commercially available VLs tested could be demonstrated, however, the fastest LT was measured for VT. And compared to the gold standard DL, it did not show a worse result in any of the above times.

- We have confirmed that the POGO value obtained using VT is not significantly worse than any of the devices tested.

- Also, in the above scenario, we were able to show that novice users found VT easy to use both technically and physically and would prefer to use it again in a similar situation than KV.

-The use of a soft guide was not required, as in the other VL with a tube guide blade tested.

- In terms of complications, we demonstrated that there was no significant incidence of tooth injury or oesophageal intubation with VT compared to DL, which had significantly more oesophageal intubations than the VLs studied.

7.2.3. Comparison of the VividTrac® videolaryngoscope in difficult airway intubation during simulated cardiopulmonary resuscitation among novice users

- Compared to the other tools tested, we showed that the use of VT did not result in any ETI failures.

- We confirmed that better IT and significantly faster LT can be achieved with VT compared to the other tools tested. And in terms of TIT, it was not significantly slower compared to the other tested VL.

- It was shown that the POGO value achieved with VT was not significantly worse than the commercially available VL tested and the same quality of detectability could be achieved as with DL.

- Again, users rated VT as the easiest tool to use in all aspects tested and would most prefer to use it again in a similar situation compared to the other tools tested.

- We confirmed that the complication rate is not higher with VT than with the other devices tested. Similar to CT, tooth injury and oesophageal intubation were not recorded with VT, in contrast to DL, where the incidence of oesophageal intubation was significantly higher than with VT.

8. Acknowledgments

I am grateful to my supervisors, Bálint Nagy, MD, PhD (University of Pécs, Medical School, Department of Anaesthesiology and Intensive Therapy) and Gábor Woth , MD, PhD (Abteilung für Anästhesie, Intensiv und Schmerzmedizin, Klinik Ottakring, Wien) for their professional guidance and tireless work, during which they have been patient and helpful in planning and conducting my studies, as well as in writing the scientific publications and this thesis. I would like to thank Szilárd Rendeki, MD, PhD, Director, Assistant Professor (University of Pécs, Medical School, Medical Skills Education and Innovation Centre) for allowing me to carry out this research. I would also like to thank Ákos Mérei, MD, PhD; Zoltán Kovács-Ábrahám MD; Martin Rozanovic MD. and our former student Edina Kern-Nagy MD. for their help in conducting the studies. I would also like to thank the 94 former students of the University of Pécs, Medical School, who voluntarily participated in the studies in their free time. I would like to thank my supervisors at work, Lajos Bogár MD, PhD, DSc, former head of the institute, professor (University of Pécs, Medical School, Department of Anaesthesiology and Intensive Therapy) and Csaba Csontos MD, PhD, DSc, head of the institute (University of Pécs, Medical School, Department of Anaesthesiology and Intensive Therapy), for their flexibility and maximum support in my scientific work. I would also like to thank Diána Mühl MD, PhD, DSc, (University of Pécs, Medical School, Department of Anaesthesiology and Intensive Therapy) for her advice and guidance for the success of my scientific publication.

My heartfelt thanks to my family for their encouragement, support and most of all for their patience during the experiments, scientific publications and writing my thesis.

I would also like to thank everyone who contributed in any way to the completion of my Ph.D. thesis.

9. Publications

Publications related to the Thesis

Rendeki S., **Keresztes D.**, Woth G., Mérei Á., Rozanovic M., Rendeki M., Farkas J., MühlD., Nagy B.; Comparison of VividTrac®, Airtraq®, King Vision®, Macintosh Laryngoscope and a Custom-Made Videólaryngoscope for difficult and normal airways in mannequins by novices. BMC Anesthesiol. 2017 May 26;17(1):68. doi: 10.1186/s12871-017-0362-y. *** = equal contribution, IF: 1,788, IF based on decision of first authors IF: 0,894**

Keresztes D., Mérei Á., Rozanovic M., Nagy E., Kovács-Ábrahám Z., Oláh J., Maróti P., Rendeki Sz., Nagy B., Woth G.; Comparison of VividTrac, King Vision and Macintosh laryngoscopes in normal and difficult airways during simulated cardiopulmonary resuscitation
among novices.
PLoS One 16 : 11 Paper 0260140 , 9 p. (2021)

IF:3,752

Sum of original publications related impact factors: 4,646

Other publications

Nagy B., Szabó I., Csetényi B., Hormay E., Papp S., **Keresztes D.**, Karadi Z. Noradrenaline and acetylcholine responsiveness of glucose-monitoring and glucose insensitive
neurons in the mediodorsal prefrontal cortex.
BRAIN RESEARCH 1543 pp. 159-164. , 6 p. (2014)

IF:2,843

Peter Gedei; Szilard Rendeki; Norbert Wiegand; Peter Maroti; Ferenc Jozsef Molnar; Balint Janos Nagy; **Dora Keresztes**; Peter Kiss; Ivett Jonas; Krisztina Szekely; Mark Ughy, Jozsef Farkas:
Investigation of the effectiveness of prehospital amputation devices on cadavers.
Injury, Hungarian Supplement (accepted for publication)

IF: 2,5

Sum of impact factors in total: 9,989

Abstracts published in peer-reviewed journals

Nagy B., Papp Sz., Takács G., Szalay Cs., Lukáts B., Rábai M., Dimitrios F., **Keresztes D**., Németh L., Karadi Z. A mediodorsalis prefrontalis kéreg idegsejtjeinek neurokémiai sajátosságai Acta Physiologica Hungarica 96:108, 2009.

Nagy B., Papp Sz., Takács G., Szalay Cs., **Keresztes D**., Hideg B., Faragó B., Németh L., Csulak T., Hanna S., Karádi Z. Complex Chemosensitivity of neurons in the mediodorsal prefrontal cortex
Obesitologia Hungarica 10, (S1), p.:42, 2009.

G. Takács, Cs. Szalay, B. Nagy, B. Hideg, T. Csulak, S. Hanna, **D. Keresztes**, B. Faragó, L. Németh, Z. Karádi Pyrogenic but not anorexigenic and adipsogenic effects of interleukin-1 beta is mediated by cyclooxygenases in the nucleus accumbens of the rat Obesitologia Hungarica 10, Suppl. 1; p.:43, 2009.

Nagy B., Papp Sz., Takács G., Szalay Cs., **Keresztes D.**, Hideg B., Faragó B., Németh L., Csulak T., Hanna S. és Karádi Z. Taste responsiveness of glucose-monitoring neurons in the mediodorsal prefrontal cortex
Acta Physiologica Hungarica 97, p.: 125, 2010.

Takács G., Szalay Cs., Nagy B., Hideg B., Csulak T., Hanna S., **Keresztes D.**, Faragó B., Németh L. és Karádi Z. Differential mechanisms of the interleukin-1 beta induced homeostatic process in the nucleus accumbens of the rat
Acta Physiologica Hungarica 97, p.: 142, 2010.

Karádi Z., Nagy B., Takács G., Szalay Cs., Papp Sz., Lukats B., Fotakos D., **Keresztes D.**, Hideg B., Faragó B., Lénárd L. Előagyi glukóz-monitorozó idegsejtek a táplálkozás és az anyagcsere központi szabályozásában Obesitologia Hungarica 11, Suppl. 1; S19, 2010.

Nagy B**.**, Szabó I., Takács G., Szalay Cs., Faragó B., **Keresztes D.**, Fotakos D., Karádi Z. Intragastrikus és intraorális kémiai stimuláció hatása a mediodorsalis prefrontalis kéreg neuronjaira Acta Physiologica Hungarica 97, p.: 463. 2010.

Takács G., Szalay Cs., Nagy B., Szabó I., Fotakos D., Csulak T., Németh L., **Keresztes D.**, Hanna S., Hideg B., Faragó B., Csulak E., Karádi Z. Íz-percepciós változások a limbikus előagyi interleukin-1β mediálta anorexia hátterében Acta Physiologica Hungarica 97, p.: 480. 2010.

Z. Karádi, B. Nagy, I. Szabó, D. Fotakos, **D. Keresztes**, B. Hideg, B. Faragó Responsiveness of Forebrain Glucose-Monitoring Neurons to Intraorally and Intragastrically Delivered Monosodium Glutamate Chem.Senses 36: E10, 2011. doi: 10.1093/chemse/bjq126

Nagy B., Szabó I., Papp Sz., Takács G., Szalay Cs., **Keresztes D.**, Faragó B., Hideg B., Bajnok-Góré M., Karádi Z. Characteristic dopamine sensitivity pattern and chemical information processing of glucose-monitoring neurons in the mediodorsal prefrontal cortex Acta Physiologica Volume 202, Supplement 684, p.: 85. 2011.

Karádi Z., Nagy B., Szabó I., Szalay Cs., Takács G., **Keresztes D.**, Hideg B., Faragó B., Bajnok-Góré M., Lénárd L. Complex functional attributes of forebrain glucose-monitoring neurons in the maintanance of homeostasis Acta Physiologica Volume 202, Supplement 684, p.: 49. 2011.

Szabó I., Nagy B., Takács G., Szalay Cs., Papp S., Hideg B., Faragó B., Bajnok-Góré M., **Keresztes D.**, Karádi Z. Glucose-monitoring neurons: endogenous and exogenous chemical sensitivity in the nucleus accumbens Acta Physiologica Volume 202, Supplement 684, p.: 112. 2011.

Nagy B, Szabó I, **Keresztes D**, Faragó B, Hideg B, Góré MB, Karádi Z. Electrophysiological characteristics of feeding associated mdPFC neurons
Clinical neuroscience (Ideggyógyászati szemle) 65(S1): 47. 2012.

Other conference abstracts:

Takács G., Papp Sz., Szalay Cs., Nagy B., Hanna S., Dimitrios F., Németh L., Csulak T., Hideg B., Faragó B., **Keresztes D.** and Karádi Z. Interleukin-1beta Mediated Homeostatic Processes
in the Nucleus Accumbens of the Rat 12th Meeting of the Hungarian Neuroscience Society, Budapest, 2009.

Nagy B., Papp Sz., Takács G., Szalay Cs., **Keresztes D.**, Németh L., Hideg B., Faragó B., Csulak T., Rábai M. and Karádi Z. Endogenous and Exogenous Chemosensitivity of Neurons in the Mediodorsal Prefrontal Cortex 12th Meeting of the Hungarian Neuroscience Society, Budapest, 2009.

Keresztes D., Németh L., Hideg B., Faragó B., Csulak T., Hanna S., Fotakos D. and Nagy B. Neurochemical attributes and taste responsiveness of neurons in the mediodorsal prefrontal cortex Young Scientists and Students Conference of ISMA, 2009.

Keresztes Dóra, Németh L., Hideg B., Csulak T., Faragó B. A medidorzális prefrontális kéreg idegsejtjeinek exogén és endogén kémiai érzékenysége
Tudományos Diákköri Konferencia, Pécs, 2009.

Hideg Barnabás, **Keresztes Dóra** Glukóz-monitorozó idegsejtek patkány cinguláris kérgében Tudományos Diákköri Konferencia, Pécs, 2010 április 15-17.

Nagy B., Takács G., Szalay Cs., Szabó I., **Keresztes D.**, Hideg B., Fotakos D. és Karádi Z. A mediodorzális prefrontalis kéreg idegsejtjeinek endogén és exogén kémiai érzékenysége Biológus doktoranduszok konferenciája Pécs, 2009.

Takács G., Szalay Cs., Nagy B., Fotakos D., **Keresztes D.**, Németh L., Hanna S., Hideg B., Csulak T., Faragó B., Karádi Z. A nucleusnaccumbensbe adott interleukin-1 beta szerepe a homeosztázis központi szabályozásában Biológus doktoranduszok konferenciája Pécs, 2009.

Nagy B., Szabó I., Takács G., Szalay Cs., **Keresztes D.**, Hideg B., Fotakos D., Faragó B., Karádi Z. Neurochemical attributes and taste responsiveness of neurons in the mediodorsal prefrontal cortex IBRO International Workshop Pécs, 2010.

Takács G., Szalay Cs., Nagy B., Fotakos D., Szabó I., **Keresztes D.**, Németh L., Hanna S., Csulak T., Hideg B., Faragó B., Karádi Z. Feeding and taste perception alterations after IL-1 beta microinjection into the nucleus accumbens
IBRO International Workshop Pécs, 2010.

Nagy, B., Szabó, I., Takács, G., Szalay, Cs., **Keresztes, D.**, Hideg, B., Fotakos, D.,Faragó, B. And Karádi, Z. Mediodorsal prefrontal cortex glucose-monitoring neurons change in activity in response to intraorally and intragastrically delivered chemical stimuli
7th FENS Forum of European Neuroscience. Abstract, 144.5, p.: 195. Amsterdam, 2010.

Takacs G, Szalay C, Nagy B, Fotakos D, Szabó I, **Keresztes D**, Németh L, Hanna S, Csulak T, Hideg B, Faragó B, Karádi Z Involvement of interleukin-1beta in the control of feeding and taste perception in the nucleus accumbens
7th FENS Forum of European Neuroscience. Abstract, 175.5, p.: 217. Amsterdam, 2010.

Karádi Z, Nagy B, Szabó I, Fotakos D, **Keresztes D**, Hideg B, Faragó B Resposiveness of forebrain glucose-monitoring neurons to intraorally and intragastrically delivered monosodium glutamate 7th FENS Forum of European Neuroscience. Amsterdam, 2010.

Szabó I, Nagy B, Takács G, Szalay C, Papp S, Hideg B, Faragó B, Bajnok Góré M, **Keresztes D**, Karádi Z. Endogenous and exogenous chemical sensitivity of glucose monitoring neurons in the nucleus accumbens 13th Conference of Hungarian Neuroscience Society. Budapest, 2011.

Nagy B, Szabó I, Papp S, Takács G, Szalay C, **Keresztes D**, Faragó B, Hideg B, Bajnok Góré M, Karádi Z. Glucose-monitoring neurons in the mediodorsa prefrontal cortex: responsiveness to dopamine and exogenous chemical stimuli DA and exogenous chemical sensitivity of glucose monitoring neurons in the mdPFC 13th Conference of Hungarian Neuroscience Society. Budapest, 2011.

Nagy B., Takács G., Szabó I., Szalay C., **Keresztes D**., Faragó B., Hideg B., Bajnok Góré M., Karádi Z. Taste reactivity deficit after streptozotocin microinjection into the mediodorsal prefrontal cortex 8th FENS Forum of Neuroscience. Barcelona, 2012.

Keresztes D.
Extravascularis tüdővíz (lehetséges) szerepe égett septicus betegekben
Magyar Aneszteziológiai és Intenzív Terápiás Társaság Észak és Dél-Dunántúli Szekció I. közös Tudományos Ülése (MAITTD), Bikal, 2014.09.26-27.

Rendeki Sz., **Keresztes D.,** Csontos Cs. Scoliosis műtét váratlan posztoperatív szövődménye. Magyar Aneszteziológiai és Intenzív Terápiás Társaság (MAITT) 43. Kongresszusa, Siófok, 2015.05.28-30.

Keresztes D.. Woth G., Németh Zs., Nagy B., Farkas J., Rendeki Sz. Disaster Medic- Egészségügyi ellátás első vonalban
Pécsi Rendvédelmi és katasztrófavédelmi – jogi és igazgatási – kihívások és válaszok – az elmúlt időszak tapasztalatai tükrében. Pécs, 2016.12.02.

Keresztes D., Woth G., Németh Zs., Nagy B., Farkas J., Maróti P., Rendeki M., Kirov A., Petrik P., Rendeki Sz. Disaster Medic- Katasztrófavédelmi egészségügyi képzés új megközelítése Katasztrófavédelem 2016” Tudományos Konferencia, Budapest, 2016. november. 16.

Keresztes D.
Műveleti Medicina az első ellátásban
Mediterrán Intenzíves Randevú, Pécs, 2017. október 20-21.

Keresztes D.
Katasztrófavédelem szerepe a biológiai jellegű káresemények felszámolásában, különös tekintettel a bioterrorizmusra, hangsúlyozva a KML speciális képességeit a felszámolásban
Nemzeti Közszolgálati Egyetem Katasztrófavédelmi Intézet, Tudományos Diákköri Konferencia, Budapest, 2018.12.06.

Keresztes D.
Katasztrófavédelem szerepe a biológiai jellegű káresemények felszámolásában, különös tekintettel a bioterrorizmusra, hangsúlyozva a KML speciális képességeit a felszámolásban
XXXIV Országos Tudományos Diákköri Konferencia Nemzeti Közszolgálati Egyetem (NKE-HHK 05/059), Budapest, 2019.05.28.

Gedei P., Rendeki Sz., Maróti P., Molnár F., Jónás I., Kiss P., Székely K., **Keresztes D.**, Bogner P., Ughy M., Farkas J.; Helyszíni amputációhoz használható eszközök hatékonyságának vizsgálata cadaveren; XXI. Magyar Sürgsségi Orvostani Kongresszus az MSOTKE és a MOT közös tudományos rendezvénye, Siófok, 2022. november 10-12

Farkas J., Kiss P., Jónás I., Maróti P., Molnár F., **Keresztes D.**, Székely K., Gedei P., Reglődi D., Rendeki Sz.; Helyszíni amputációhoz használható eszközök hatékonyságának vizsgálata cadaveren; Magyar Anatómiai Társaság 2022. évi Konferenciája, Szeged, 2022. szeptember 1-2.

Farkas J., Gedei P., Rendeki Sz., Wiegand N., Maróti P., Molnár F., Nagy B., **Keresztes D.**, Kiss P., Jónás I., Székely K., Ughy M.; Investigation of the effectiveness off prehospital amputation devices on cadavers; The Annual Meeting of the HMAA (Hungarian Medical Association), Balatonfüred, 2023. augusztus 25-26.

Vincze V., Gedei P., Rendeki Sz., Wiegand N., Molnár F., Nagy B., **Keresztes D.**, Kiss P., Jónás I., Székely K., Ughy M., Farkas J.; Investigation of the effectiveness off prehospital amputation devices on cadavers; Combat Medical Care Conference, Ulm, 2023. július 05-06.

References

1. Paolini J-B, Donati F, Drolet P. Review article: video-laryngoscopy: another tool for difficult intubation or a new paradigm in airway management? Can J Anaesth. 2013;60: 184–91. doi:10.1007/s12630-012-9859-5
2. Konrad C, Schupfer G, Wietlisbach M, Gerber H. Learning Manual Skills in Anesthesiology. Anesth Analg. 1998;86: 635–639. doi:10.1097/00000539-199803000-00037
3. Pieters BM, Eindhoven GB, Acott C, Van Zundert AAJ. Pioneers of Laryngoscopy: Indirect, Direct and Video Laryngoscopy. Anaesth Intensive Care. 2015;43: 4–11. doi:10.1177/0310057X150430S103
4. Apfelbaum JL, Hagberg CA, Connis RT, Abdelmalak BB, Agarkar M, Dutton RP, et al. 2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway. Anesthesiology. 2022;136: 31–81. doi:10.1097/ALN.0000000000004002
5. Pieters BMA, Wilbers NER, Huijzer M, Winkens B, van Zundert AAJ. Comparison of seven videolaryngoscopes with the Macintosh laryngoscope in manikins by experienced and novice personnel. Anaesthesia. 2016;71: 556–564. doi:10.1111/anae.13413
6. Cook TM, Woodall N, Harper J, Benger J. 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 2: intensive care and emergency departments †. Br J Anaesth. 2011;106: 632–642. doi:10.1093/bja/aer059
7. van Schuppen H, Boomars R, Kooij FO, den Tex P, Koster RW, Hollmann MW. Optimizing airway management and ventilation during prehospital advanced life support in out-of-hospital cardiac arrest: A narrative review. Best Pract Res Clin Anaesthesiol. 2021;35: 67–82. doi:10.1016/j.bpa.2020.11.003
8. Park SO, Kim JW, Na JH, Lee KH, Lee KR, Hong DY, et al. Video laryngoscopy improves the first-attempt success in endotracheal intubation during cardiopulmonary resuscitation among novice physicians. Resuscitation. 2015;89: 188–194. doi:10.1016/j.resuscitation.2014.12.010
9. Zaouter C, Calderon J, Hemmerling TM. Videolaryngoscopy as a new standard of care. Br J Anaesth. 2015;114: 181–183. doi:10.1093/bja/aeu266
10. Pott LM, Murray WB. Review of video laryngoscopy and rigid fiberoptic laryngoscopy. Curr Opin Anaesthesiol. 2008;21: 750–758. doi:10.1097/ACO.0b013e3283184227
11. Maharaj CH, McDonnell JG, Harte BH, Laffey JG. A comparison of direct and indirect laryngoscopes and the ILMA in novice users: a manikin study. Anaesthesia. 2007;62: 1161–1166. doi:10.1111/j.1365-2044.2007.05216.x
12. Pantazopoulos I, Kolonia K, Laou E, Mermiri M, Tsolaki V, Koutsovasilis A, et al. Video

Laryngoscopy Improves Intubation Times With Level C Personal Protective Equipment in Novice Physicians: A Randomized Cross-Over Manikin Study. J Emerg Med. 2021;60: 764–771. doi:10.1016/j.jemermed.2021.01.001

13. Arulkumaran N, Lowe J, Ions R, Mendoza M, Bennett V, Dunser MW. Videolaryngoscopy versus direct laryngoscopy for emergency orotracheal intubation outside the operating room: a systematic review and meta-analysis. Br J Anaesth. 2018;120: 712–724. doi:10.1016/j.bja.2017.12.041
14. Lee DH, Han M, An JY, Jung JY, Koh Y, Lim C-M, et al. Video laryngoscopy versus direct laryngoscopy for tracheal intubation during in-hospital cardiopulmonary resuscitation. Resuscitation. 2015;89: 195–199. doi:10.1016/j.resuscitation.2014.11.030
15. Han SK, Shin DH, Choi PC. Utility of the Pentax-AWS® without interruption of chest compression: Comparison of the Macintosh laryngoscope with the Pentax-AWS® in manikin model. Resuscitation. 2010;81: 69–73. doi:10.1016/j.resuscitation.2009.09.031
16. Koyama J, Iwashita T, Okamoto K. Comparison of three types of laryngoscope for tracheal intubation during rhythmic chest compressions: A manikin study. Resuscitation. 2010;81: 1172–1174. doi:10.1016/j.resuscitation.2010.05.020
17. Min BC, Park JE, Lee GT, Kim TR, Yoon H, Cha WC, et al. C-MAC Video Laryngoscope versus Conventional Direct Laryngoscopy for Endotracheal Intubation During Cardiopulmonary Resuscitation. Medicina (B Aires). 2019;55: 225. doi:10.3390/medicina55060225
18. Lewis SR, Butler AR, Parker J, Cook TM, Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation. Cochrane Database Syst Rev. 2016. doi:10.1002/14651858.CD011136.pub2
19. Savoldelli GL, Schiffer E, Abegg C, Baeriswyl V, Clergue F, Waeber JL. Comparison of the Glidescope ® , the McGrath ® , the Airtraq ® and the Macintosh laryngoscopes in simulated difficult airways*. Anaesthesia. 2008;63: 1358–1364. doi:10.1111/j.1365-2044.2008.05653.x
20. Yun BJ, Brown CA, Grazioso CJ, Pozner CN, Raja AS. Comparison of Video, Optical, and Direct Laryngoscopy by Experienced Tactical Paramedics. Prehospital Emerg Care. 2014;18: 442–445. doi:10.3109/10903127.2013.864356
21. Resuscitation Council UK. Guidance: COVID-19. 2022. Available: https://www.resus.org.uk/library/additional-guidance/guidance-covid-19
22. Edelson DP, Sasson C, Chan PS, Atkins DL, Aziz K, Becker LB, et al. Interim Guidance for Basic and Advanced Life Support in Adults, Children, and Neonates With Suspected or Confirmed COVID-19. Circulation. 2020;141. doi:10.1161/CIRCULATIONAHA.120.047463
23. Cook TM, El-Boghdadly K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19. Anaesthesia. 2020;75: 785–799.

doi:10.1111/anae.15054

24. Greenland KB, Segal R, Acott C, Edwards MJ, Teoh WHL, Bradley WPL. Observations on the Assessment and Optimal Use of Videolaryngoscopes. Anaesth Intensive Care. 2012;40: 622–630. doi:10.1177/0310057X1204000407

25. de Carvalho CC, da Silva DM, Lemos VM, dos Santos TGB, Agra IC, Pinto GM, et al. Videolaryngoscopy vs. direct Macintosh laryngoscopy in tracheal intubation in adults: a ranking systematic review and network meta-analysis. Anaesthesia. 2022;77: 326–338. doi:10.1111/anae.15626

26. Levitan RM, Ochroch EA, Rush S, Shofer FS, Hollander JE. Assessment of Airway Visualization: Validation of the Percentage of Glottic Opening (POGO) Scale. Acad Emerg Med. 1998;5: 919–923. doi:10.1111/j.1553-2712.1998.tb02823.x

27. Malik MA, O'Donoghue C, Carney J, Maharaj CH, Harte BH, Laffey JG. Comparison of the Glidescope®, the Pentax AWS®, and the Truview EVO2® with the Macintosh laryngoscope in experienced anaesthetists: a manikin study. Br J Anaesth. 2009;102: 128–134. doi:10.1093/bja/aen342

28. Maharaj CH, Costello JF, Higgins BD, Harte BH, Laffey JG. Learning and performance of tracheal intubation by novice personnel: a comparison of the AirtraqR and Macintosh laryngoscope. Anaesthesia. 2006;61: 671–677. doi:10.1111/j.1365-2044.2006.04653.x

29. Rendeki S, Keresztes D, Woth G, Mérei Á, Rozanovic M, Rendeki M, et al. Comparison of VividTrac®, Airtraq®, King Vision®, Macintosh Laryngoscope and a Custom-Made Videolaryngoscope for difficult and normal airways in mannequins by novices. BMC Anesthesiol. 2017;17: 68. doi:10.1186/s12871-017-0362-y

30. Galvagno SM, Nahmias JT, Young DA. Advanced Trauma Life Support® Update 2019. Anesthesiol Clin. 2019;37: 13–32. doi:10.1016/j.anclin.2018.09.009

31. Perkins GD, Gräsner J-T, Semeraro F, Olasveengen T, Soar J, Lott C, et al. European Resuscitation Council Guidelines 2021: Executive summary. Resuscitation. 2021;161: 1–60. doi:10.1016/j.resuscitation.2021.02.003

32. Baciarello M, Zasa M, Manferdini ME, Tosi M, Berti M, Fanelli G. The learning curve for laryngoscopy: Airtraq versus Macintosh laryngoscopes. J Anesth. 2012;26: 516–524. doi:10.1007/s00540-012-1351-4

33. Latif RK, Akca O. Simulation based training of airway management with Macintosh blade and Glidescope video laryngoscope. Minerva Anestesiol. 2011;77: 1–3. Available: http://www.ncbi.nlm.nih.gov/pubmed/21273961

34. Pepper T. Should EMS-Paramedics Perform Pediatric Tracheal Intubation in the Field? J Emerg Med. 2009;37: 110. doi:10.1016/j.jemermed.2009.03.008

35. Hodnick R, Zitek T, Galster K, Johnson S, Bledsoe B, Ebbs D. A Comparison of Paramedic

First Pass Endotracheal Intubation Success Rate of the VividTrac VT-A 100, GlideScope Ranger, and Direct Laryngoscopy Under Simulated Prehospital Cervical Spinal Immobilization Conditions in a Cadaveric Model. Prehosp Disaster Med. 2017;32: 621–624. doi:10.1017/S1049023X17006872

36. Eismann H, Sieg L, Etti N, Friedrich L, Schröter C, Mommsen P, et al. Improved success rates using videolaryngoscopy in unexperienced users: a randomized crossover study in airway manikins. Eur J Med Res. 2017;22: 27. doi:10.1186/s40001-017-0268-7

37. Nasim S, Maharaj CH, Butt I, Malik MA, O' Donnell J, Higgins BD, et al. Comparison of the Airtraq® and Truview®laryngoscopes to the Macintosh laryngoscope for use by Advanced Paramedics in easy and simulated difficult intubation in manikins. BMC Emerg Med. 2009;9: 2. doi:10.1186/1471-227X-9-2

38. Ruetzler K, Imach S, Weiss M, Haas T, Schmidt AR. Vergleich von fünf Videolaryngoskopen und direkter konventioneller Laryngoskopie. Anaesthesist. 2015;64: 513–519. doi:10.1007/s00101-015-0051-5

39. Miki T, Inagawa G, Kikuchi T, Koyama Y, Goto T. Evaluation of the Airway Scope, a new video laryngoscope, in tracheal intubation by naive operators: a manikin study. Acta Anaesthesiol Scand. 2007;51: 1378–1381. doi:10.1111/j.1399-6576.2007.01450.x

40. Hirabayashi Y. Airway Scope versus Macintosh laryngoscope: a manikin study. Emerg Med J. 2007;24: 357–358. doi:10.1136/emj.2006.045013

41. Buis ML, Maissan IM, Hoeks SE, Klimek M, Stolker RJ. Defining the learning curve for endotracheal intubation using direct laryngoscopy: A systematic review. Resuscitation. 2016;99: 63–71. doi:10.1016/j.resuscitation.2015.11.005

42. Cierniak M, Timler D, Wieczorek A, Sekalski P, Borkowska N, Gaszynski T. The comparison of the technical parameters in endotracheal intubation devices: the Cmac, the Vividtrac, the McGrath Mac and the Kingvision. J Clin Monit Comput. 2016;30: 379–387. doi:10.1007/s10877-015-9727-2

43. Hurford WE. The video revolution: a new view of laryngoscopy. Respir Care. 2010;55: 1036–45. Available: http://www.ncbi.nlm.nih.gov/pubmed/20667151