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Comparing the McGrath Mac Video Laryngoscope and Direct Laryngoscopy for Prehospital Emergency Intubation in Air Rescue Patients: A Multicenter, Randomized, Controlled Trial*

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Objectives: Tracheal intubation in prehospital emergency care is challenging. The McGrath Mac Video Laryngoscope (Medtronic, Minneapolis, MN) has been proven to be a reliable alternative for in-hospital airway management. This trial compared the McGrath Mac Video Laryngoscope and direct laryngoscopy for the prehospital setting.

Design: Multicenter, prospective, randomized, controlled equivalence trial.

Setting: Oesterreichischer Automobil- und Touring Club (OEAMTC) Helicopter Emergency Medical Service in Austria, 18-month study period.

Patients: Five-hundred fourteen adult emergency patients (≥ 18 yr old).

Interventions: Helicopter Emergency Medical Service physicians followed the institutional algorithm, comprising a maximum of two tracheal intubation attempts with each device, followed by supraglottic, then surgical airway access in case of tracheal intubation failure. No restrictions were given for tracheal intubation indication.

Measurements Main Results:: The Primary outcome was the rate of successful tracheal intubation; equivalence range was ± 6.5% of success rates. Secondary outcomes were the number of attempts to successful tracheal intubation, time to glottis passage and first end-tidal Co_2 measurement, degree of glottis visualization, and number of problems. The success rate for the two devices was equivalent: direct laryngoscopy 98.5% (254/258), McGrath Mac Video Laryngoscope 98.1% (251/256) (difference, 0.4%; 99% CI, −2.58 to 3.39). There was no statistically significant difference with regard to tracheal intubation times, number of attempts or difficulty. The view to the glottis was significantly better, but the number of technical problems was increased with the McGrath Mac Video Laryngoscope. After a failed first tracheal intubation attempt, immediate switching of the device was significantly more successful than after the second attempt (90.5% vs 57.1%; $p = 0.0003$), regardless of the method.

Conclusions: Both devices are equivalently well suited for use in prehospital emergency tracheal intubation of adult patients. Switching the device following a failed first tracheal intubation attempt was more successful than a second attempt with the same device. (*Crit Care Med* 2019; 47:1362–1370)

Key Words: airway management; direct laryngoscopy; emergency care; prehospital intubation; randomized controlled trial; video laryngoscopy

Tracheal intubation (TI) remains the golden, but challenging and rare (2–12%) standard of care for securing the airway and ensuring appropriate ventilation in the prehospital emergency setting (1–4). Lacking routine (even < 12 intubations per physician and year) and the specific prehospital setting (5–7) may contribute to difficult TIs, with the literature documenting up to 50% as being impossible (8–10).

Consequently, identification of devices that may facilitate TI appears to be of utmost importance. Presently, video laryngoscopes (VLs) are considered to be effective alternatives to direct laryngoscopes (DLs) when a difficult airway is presumed (11, 12). Yet, in-hospital findings, even in the emergency department (13), as well as manikin studies (14, 15) obviously may not be transferred to the prehospital setting. The few available randomized controlled trials (RCTs) evaluating VL there (16–18) failed to prove superiority or at least equality to DL. Nevertheless, VL have become part of standard Emergency Medical Service (EMS) equipment (19–21). The Austrian Air Rescue provider OEAMTC (Austrian Automobile, Motorcycle and Touring Club) implemented the McGrath Mac VL (McGrathVL; Medtronic, Minneapolis, MN) for prehospital airway management in its Helicopter EMS (HEMS) program in 2015. This offered the opportunity to compare the McGrathVL and the DL for prehospital TI in the skilled hands of the OEAMTC HEMS crews. The hypothesis of this multicenter, RCT was that both the McGrathVL and the DL (Medicon, Tuttlingen, Germany) have equivalent success rates for TI in the prehospital emergency environment. Primary outcome was the TI success rate for each device. Secondary outcome variables were the total number of TI attempts, time until passage of the tracheal tube through the glottis and to first end-tidal Co_2 as a surrogate variable for successful TI. Additionally, the median category of visualization of the glottis, the median category of HEMS physician's subjective assessment of TI performance, technical difficulties, and any harm during TI were documented.

MATERIALS AND METHODS

This prospective, multicenter, open-label, patient-blinded, RCT was conducted at 10 physician-staffed HEMS bases operated by OEAMTC Air Rescue, following approval by the Ethics Committee of the State of Lower Austria (GS1-EK-3/124–2016).

Participants

Adult emergency patients requiring prehospital TI were enrolled and randomly assigned. Exclusion criteria were age less than 18 years and futility of further measures if survival was unlikely. The following data were collected as follows: demographic data, indication for TI, vital variables (electrocardiogram, heart rate, blood pressure, peripheral oxygen saturation, end-tidal Co_2) at various time points during prehospital care and hospital handover, modified National Advisory Committee for Aeronautics Index (22), cervical spine immobilization, and administered medication. HEMS physicians were either board-certified anesthesiologists or EMS physicians with at least 4 years of postgraduate training including inpatient anesthesia.

Interventions

Patients were randomly assigned to TI with either the McGrathVL or a DL.

Objective

The hypothesis of this trial was that both the McGrathVL and the DL (Medicon) have equivalent success rates for TI in the prehospital emergency environment. The equivalence range of success rates was ± 6.5%.

Outcome

Primary outcome was the TI success rate for each method. Secondary outcome variables were total number of TI attempts, time until passage of the tracheal tube through the glottis and to first end-tidal Co_2 as a surrogate variable for successful TI. Additionally, the median category of visualization of the glottis, defined by a slightly modified Cormack and Lehane score (1 = whole glottis, 2 = arytenoid cartilage only, 3 = posterior commissure, 4 = epiglottis only, 5 = soft palate only), the median category of HEMS physician's subjective assessment of TI performance (1 = problem-free, 2 = slightly aggravated, 3 = difficult, 4 = very difficult, 5 = impossible), technical difficulties and any harm during TI were documented.

Randomization

The web-based documentation (EDV Trimmel, Ternitz, Austria), including a computed random generator (1:1 ratio) and the electronic case report form determined the device assigned to each patient at each HEMS base. A printout of the assignment was archived at each participating HEMS base and opened by the HEMS technician on occasion. HEMS physicians subsequently performed airway management as herein defined; time was measured by the HEMS technician (triple chronometer; Oregon Scientific WB 388, Portland, OR).

Standardized Airway Management Protocol

Adherence to the predefined airway management algorithm of OEAMTC HEMS was mandatory. Whichever laryngoscope was used—video or direct—all blades were Macintosh-style blades. All tracheal tubes used in this study were factory-equipped with a semi-rigid stylet which can be bend and shaped as needed for the individual patient, thus facilitating guidance and manipulation (Kindwell Medical Equipment, Ltd., Tianjin, China). All patients were in supine position during the airway management process.

To guarantee the safety of study patients, preoxygenation and denitrogenization were ensured by high-flow oxygen via face mask or bag mask valve (AMBU, Bad Nauheim, Germany). HEMS technicians closely monitored oxygen saturation during induction of anesthesia and TI. They were instructed to prompt interruption of intubation attempts when saturation levels neared 90% or minus 10% of the basic level. Switching the device following the failed first intubation attempt, but not later than after the second attempt for each device was allowed. Accordingly, if the second TI attempt with the randomized device was not successful or discontinued, HEMS physicians were allowed to perform a further maximum of two attempts with the alternative device after ensuring appropriate oxygenation. After four failed TI attempts, a supraglottic airway had to be inserted: either a laryngeal tube (VBM Medizintechnik GmbH, Sulz am Neckar, Germany) or a laryngeal mask (Fastrach; Teleflex Medical Europe Ltd, Westmeath, Ireland) at the discretion of the HEMS physician. If this too was not feasible, a coniotomy had to be performed.

In patients undergoing cardiopulmonary resuscitation (CPR), TI was attempted without sedative drugs; in all others, rapid sequence induction (RSI) was performed using midazolam or propofol supplemented with esketamine and/or fentanyl. Succinylcholine or rocuronium (both 1.5 mg/kg body weight) was administered for RSI at the discretion of the HEMS physician. Anesthesia was maintained with repetitive boli of midazolam or propofol, esketamine and/or fentanyl.

Power Analysis

Preceding studies (17) led to the assumption that TI success rate for DL in the field should be around 97–98%. The suspected success rate for TI with the McGrathVL was 96% (13, 16, 23, 24). With a power of 90%, a significance level of 0.01 and an equivalence range of 6.5% of the success rates, 451 enrolled patients were required per group. We calculated a dropout rate of 10%. Thus, a total of 992 persons had to be included. An interim analysis was preplanned following enrollment of half of the study population (500 patients).

Statistical Analysis

In addition to descriptive statistics, analysis was performed using SPSS (release 24.0, 2016; IBM, Chicago, IL). Normal distribution was proven with the Shapiro-Wilk test. Equivalence of the success rate for the two devices was evaluated by computing the difference between the success rates and its two-sided 99% CIs. If the CI for the difference between the success rates was within the equivalence range of ± 6.5%, the two devices were deemed equally successful. The Mann-Whitney *U* test, chi-square test, and Fisher exact test were used to detect significant inter-group differences when investigating study population characteristics and secondary endpoints, as appropriate. The association between the success rate and potentially influencing factors (gender, body mass index, age, cervical spine immobilization, indication for airway management, and helicopter base) was assessed using multiple logistic regression analysis. A *p* value of 0.01 was deemed statistically significant throughout the study. Correspondingly, the CIs were 99%.

RESULTS

Between April 2017 and July 2018, the participating OEAMTC HEMS bases tended to 9,901 patients on emergency missions. Of these, 514 patients were included for analysis (**Fig. 1**). No baseline differences were observed between the groups (**Table 1**). There was only one protocol violation: one patient underwent three attempts with the McGrathVL. All results were evaluated by intention-to-treat analysis.

Following a maximum of four TI attempts, 505 of the 514 patients were successfully intubated showing equivalent results for the two devices: 254 of 258 patients (98.5%; CI, –0.6% to 2.6%) with the DL and 251 of 256 patients (98.1%; CI, –0.6% to 2.6%) with the McGrathVL. Thus, the difference in the success rates was 0.4%, and the 99% CIs for the difference in the success rates (99% CI, –2.58 to 3.39) were within the supposed equivalence range of ± 6.5% (**Table 2**).

The remaining nine patients were successfully ventilated with alternative airways: five of nine (55.6%) with a larynx tube, two of nine (22.2%) with a laryngeal mask, and two of nine (22.2%) with a coniotomy.

Multiple regression analysis showed no association between success rates and patient gender, body mass index, age, cervical spine immobilization, indication for airway management, or helicopter base.

Despite better visualization of the glottis with the McGrathVL ($p < 0.0001$), the number of TI attempts, time to passage of the tracheal tube through the glottis and to first end-tidal Co_2 measurement, as well as the category of HEMS physicians' subjective assessment of TI performance were comparable (**Table 3**). This was caused by highly significantly more technical problems (impaired sight due to fogged camera lens, monitor reflexes, ambient light) with the McGrathVL (78/294, 26.5%) than with the DL (12/285, 4.2%; $p < 0.0001$). Although the view of the glottis improved with the McGrathVL, advancement of the tube into the larynx or the trachea was significantly impaired, but ultimately equally successful as with the DL (**Tables** 2, 3, and **4**; and **Supplemental Table 1**, Supplemental Digital Content 1, http://links.lww.com/CCM/E834; **Supplemental Table 2**, Supplemental Digital Content 2, http://links.lww.com/CCM/E835; and **Supplemental Table 3**, Supplemental Digital Content 3, http://links.lww.com/CCM/E836).

Switching from the DL to the McGrathVL (success rate second attempt 15/25, 60% vs switching 15/17, 88.2%; $p = 0.081$) or vice versa (success rate second attempt 17/31, 54.8% vs 23/25, 92%; $p = 0.002$) following an unsuccessful first TI attempt was significantly more successful than switching following two attempts with the same device (**Supplemental Fig. 1**, Supplemental Digital Content 4, http://links.lww.com/CCM/E837; legend: flow diagram showing included patients, in whom TI attempts failed and the device was switched).

In trauma patients, especially those with cervical spine immobilization, and in patients undergoing CPR, the first TI attempt was more often successful with the DL. In patients with other reasons for TI (e.g., respiratory insufficiency, unconsciousness, stroke) the success rate showed no relevant difference. This did

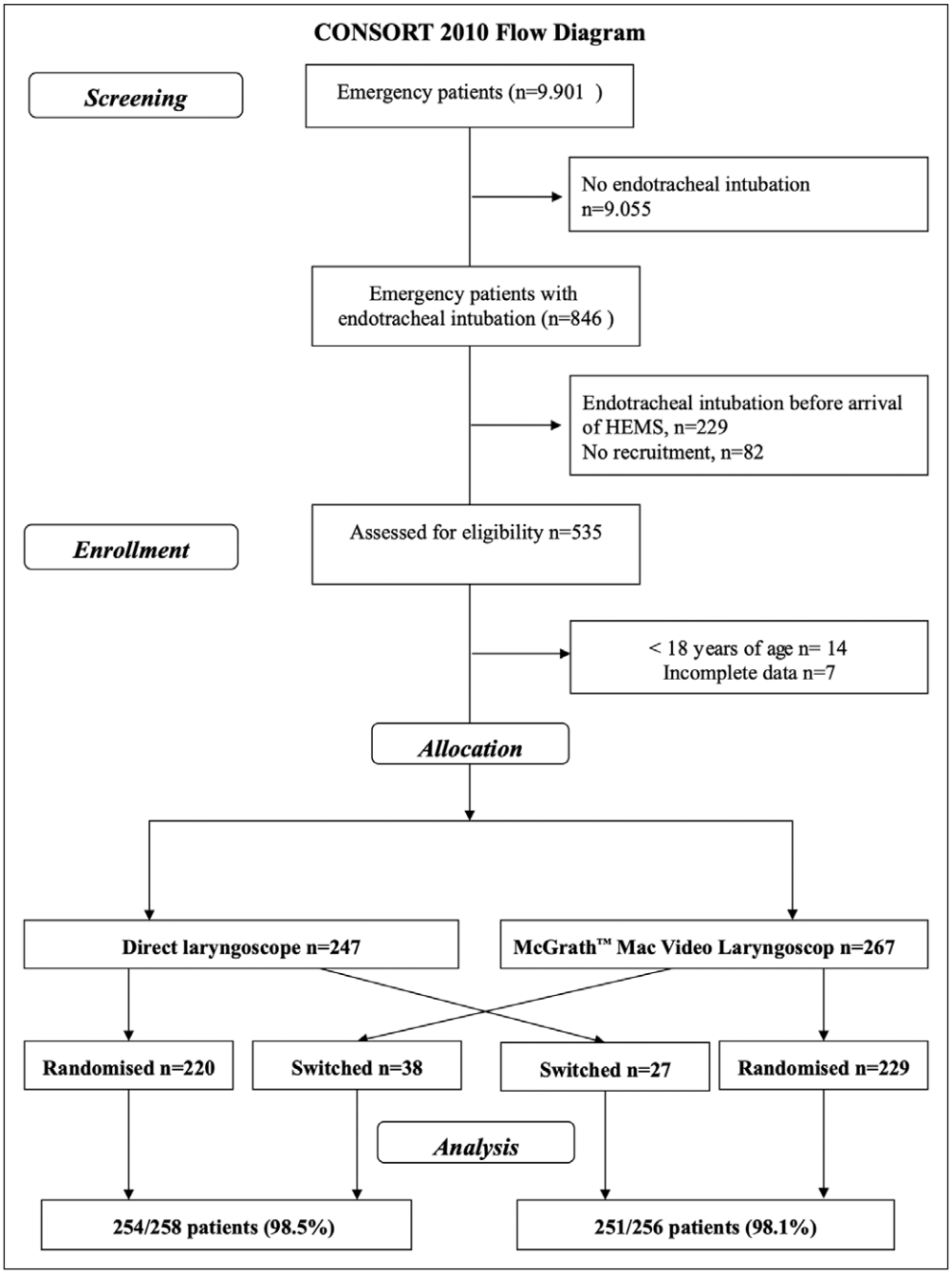

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) 2010 flow diagram. HEMS = Helicopter Emergency Medical Service. Adapted from Schulz et al (25). Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

not reach statistical significance, but the subgroups were too small to draw a meaningful conclusion. These results are displayed in Supplemental Table 3 (Supplemental Digital Content 3, http://links.lww.com/CCM/E836).

Analyzing the potential reasons for TI failure, successful and unsuccessful attempts were compared: DL in trauma patients, impaired mouth opening (1/60, 1.7% vs 3/6, 50%; $p = 0.002$). In patients undergoing CPR: impaired glottic view (1 [1–5] vs 4 [1–5]; $p < 0.0001$); in nontrauma patients impaired glottic view (1 [1–5] vs 4 [3–5]; $p = 0.0008$); with McGrathVL: in trauma patients: advancing the tube into the larynx (0/52, 0% vs 4/15, 26.7%; $p = 0.002$) or trachea (5/52, 9.6% vs 8/15, 53.3%; $p = 0.0007$); disturbing bright ambient light (7/52, 13.5% vs 11/15, 73.3%; $p < 0.0001$); in patients undergoing CPR: advancing the tube into the larynx (5/123, 4.1% vs 7/19, 36.8%; $p < 0.0001$) or the trachea (11/123, 8.9% vs 10/19, 52.6%; $p < 0.0001$); impaired sight due to mirror reflexes (0/123, 0% vs 3/19, 15.9%; $p < 0.0001$); disturbing ambient light (14/123, 11.4% vs 9/19, 47.4%; $p < 0.0001$). These differences were not found in nontrauma, non-CPR patients (Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/CCM/E834; Supplemental Table 2, Supplemental Digital Content 2, http://links.lww.com/CCM/E835; and Supplemental Table 3, Supplemental Digital Content 3, http://links.lww.com/CCM/E836).

The number of TI injuries was comparable between both groups: DL six of 285 patients (2.1%), McGrathVL eight of 294 patients (2.7%) ($p = 0.63$). In each group, there was one patient with a tooth injury (0.4% vs 0.3%); all other TI injuries were superficial dermal or mucosal abrasions.

DISCUSSION

In this nation-wide, multicenter RCT with more than 500 prehospital emergency patients with indication for prehospital TI, the McGrathVL and common DL were compared and both were found to be equally successful (98.1% vs 98.5%). These rates of successful prehospital TI were generally in line with those of other studies conducted in experienced users, even though at 83% (DL) and 79% (McGrathVL) the rate of first-pass success seems rather low. It is noteworthy that our strict protocol prompted immediate interruption of laryngoscopy when oxygen saturation dropped below 90%, thus proving that patient safety was given. The present study population equaled that of other prehospital airway trials (26–28). To our knowledge, this is the first proof of equivalence in

TABLE 1. Study Population Characteristics

Characteristic	Direct Laryngoscope	McGrath Mac Video Laryngoscope	*p*
Number of patients	247	267	
Age	64 (18–95)	65 (18–95)	0.20
Female/male, *n* (%)/*n* (%)	71 (28.7)/176 (71.3)	88 (32.9)/179 (67.1)	0.30
Body mass index	27.2 (15.6–55.6)	26.1 (13.1–47.8)	0.05
NACA indices, *n* (%)/*n* (%)			0.96
NACA 1/2/3	0/0/0	0/0/0	
NACA 4/5	9 (3.6)/102 (41.3)	11 (4.1)/106 (39.7)	
NACA 6/7	56 (22.7)/80 (32.4)	64 (24.0)/86 (32.2)	
Indications, *n* (%)			
Acute coronary syndrome	2 (0.8)	3 (1.1)	1
Cardiopulmonary resuscitation	126 (51.0)	133 (48.8)	0.79
Severe trauma	9 (3.6)	8 (3.0)	0.68
Polytrauma	24 (9.7)	28 (10.5)	0.77
Traumatic brain injury	30 (12.1)	36 (13.5)	0.65
Unconsciousness	22 (8.9)	31 (11.6)	0.32
Insult	14 (5.7)	15 (5.6)	1
Respiratory insufficiency	15 (6.1)	5 (1.8)	0.02
Burns	3 (1.2)	0 (0)	0.11
Other	2 (0.8)	8 (3.0)	0.11
Spine immobilization	54 (21.9)	54 (20.2)	0.65
Hypnotic medications			
Etomidate	28	22	0.24
Propofol	34	29	0.31
Midazolam	100	108	0.92
Analgesic medications			
Esketamine	57	78	0.11
Fentanyl	103	96	0.17
Neuromuscular blockers			
Succinylcholine	10	9	0.11
Rocuronium	121	132	0.92

NACA = modified National Advisory Committee for Aeronautics Index.
Continuous data as median and interquartile range.

a "real life" prehospital trial—despite frequent use of a wide range of VLs in prehospital airway management. In a variety of observational case series, cohort studies or retrospective analysis, products of numerous manufacturers (e.g., Pentax, Storz, Prodol) were investigated (29). However, their role in the prehospital environment remained unclear to date. Two recent meta-analyses conclude that VL has not been shown to improve TI outcomes in the EMS setting: Savino et al (30) and Jiang et al (31) identified eight of 470, and 12 of 826 trials, respectively discussing prehospital and emergency video-assisted TI. Both analyses came to comparable results: among physicians with significant DL experience, VL did not increase overall or first-pass success rates and may even lead to worsening performance or outcome (30, 31). Both authors urge that further studies be conducted in order to determine whether VL is beneficial in emergency patients. In light of these findings, we performed this trial comparing the McGrathVL and the DL for prehospital TI as used by HEMS physicians with sufficient experience in VL. VL was introduced in OEAMTC HEMS in 2015

TABLE 2. Rate of Successful Tracheal Intubation With the Direct Laryngoscope and the McGrath Mac Video Laryngoscope, Equivalence Margin ± 6.5%

	Direct Laryngoscope ($n = 247$)		McGrath Mac Video Laryngoscope ($n = 267$)			
No. of Attempts	Success Rate, %	Device Switches	Success Rate, %	Device Switches	Δ Success Rate	99% CI Δ Success Rate
1st attempt	83.0		79.0		3.97	−4.93 to 12.87
2nd attempt	95.3	17	93.8	25	1.47	−3.68 to 6.63
3rd attempt	98.1	10	97.7	13	0.41	−2.89 to 3.70
4th attempt	98.5	0	98.1	0	0.40	−2.58 to 3.39

TABLE 3. Tracheal Intubation: Performance Data

	Direct Laryngoscope			McGrath Mac Video Laryngoscope			*p*		
Data Collected	Initially Randomized	As Alternative	All	Initially Randomized	As Alternative	All	Initially Randomized	As Alternative	All
n	247	38	285	267	27	294			
Number of tracheal intubation attempts, median (IQR); mean ± SD	1 (1–2); 1.2 ± 0.3	1 (1–2); 1.1 ± 0.2	1 (1–2); 1.1 ± 0.3	1 (1–3); 1.1 ± 0.3	1 (1–2); 1.1 ± 0.3	1 (1–3); 1.1 ± 0.4	0.76	0.70	0.66
Time to glottis passage, median (IQR); mean ± SD	12 s (2–180 s); 16.4 ± 17.9	20 s (3–180 s); 33.3 ± 38.2	12 s (2–180 s); 18.6 ± 22.0	14 s (3–180 s); 20.8 ± 23.5	20 s (5–180 s); 32.4 ± 38.7	15 s (3–180 s); 21.8 ± 25.4	0.05	0.72	0.24
Time to first Co_2, median (IQR); mean ± SD	25 s (7–360 s); 40.4 ± 50.5	62.5 s (9–580 s); 97.8 ± 114.9	27.5 s (7–580 s); 48.1 ± 66.2	30 s (7–580 s); 46.8 ± 59.9	85 s (13–360 s); 122.1 ± 107.0	35 s (7–360 s); 53.8 ± 69.2	0.10	0.33	0.20
View to glottis, median (IQR); mean ± SD	1 (1–5); 2.0 ± 1.2	1 (1–5); 1.9 ± 1.2	1 (1–5); 2.0 ± 1.2	1 (1–5); 1.5 ± 1.1	1 (1–5); 2.1 ± 1.5	1 (1–5); 1.5 ± 1.1	< 0.0001	0.95	< 0.0001
Difficulty of intubation, median (IQR); mean ± SD	2 (1–5); 1.9 ± 1.2	2 (1–5); 2.0 ± 1.1	2 (1–5); 1.9 ± 1.2	1 (1–5); 1.9 ± 1.3	2 (1–5); 2.4 ± 1.4	1 (1–5); 1.9 ± 1.3	0.41	0.31	0.62

IQR = interquartile range.

following recommendations made by the German Society for Anesthesiology and Intensive Care Medicine (32) and the Difficult Airway Society (33). All HEMS physicians underwent compulsive manikin and clinical training.

Equivalence of TI success was also shown for subgroups like patients undergoing CPR or TI due to respiratory failure or unconsciousness as well as and, as a trend, also for trauma patients. Interestingly, in trauma patients, especially those with cervical spine immobilization, and in patients undergoing CPR, the first TI attempt was more often successful with the DL than with the McGrathVL. This may contradict results of previous in-hospital (34, 35) and manikin studies (15, 28, 36), but is in accordance with other prehospital investigations (1, 9, 19). The reasons for this unexpected finding are most likely related to the challenging environment at accident sites and the demanding CPR airway management during ongoing or only briefly interrupted chest compressions.

The advantage of better visualization of the glottis when using the McGrathVL is, however, offset by technical problems like fogged camera lens, monitor reflexes and disturbing ambient light and, in addition, by more difficult handling of the tube when using the VL (**Table 4**; and Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/CCM/E834; Supplemental Table 2, Supplemental Digital Content 2, http://links.lww.com/CCM/E835; and Supplemental Table 3, Supplemental Digital Content 3, http://links.lww.com/CCM/E836). This obviously prolonged the TI process: time to first end-tidal Co_2 was 48.1 ± 66.2 s for the DL versus 53.8 ± 69.2 s for the

TABLE 4. Reported Problems (Both Devices)

Reported Problem	Direct Laryngoscope			McGrath Mac Video Laryngoscope			*p*		
	Initially Randomized	As Alternative	All	Initially Randomized	As Alternative	All	Initially Randomized	As Alternative	All
n	247	38	285	267	27	294			
Impaired mouth opening, *n* (%)	10 (4.1)	1 (2.6)	11 (3.9)	7 (2.6)	2 (7.4)	9 (3.1)	0.37	0.57	0.60
Narrow pharynx, *n* (%)	5 (2.0)	3 (7.9)	8 (2.8)	3 (1.1)	1 (3.7)	4 (1.4)	0.49	0.64	0.22
Impaired sight due to blood or regurgitation, *n* (%)	64 (25.9)	10 (26.32)	74 (26.0)	62 (23.2)	8 (29.6)	70 (23.8)	0.48	0.76	0.55
Advancing the tube to the larynx, *n* (%)	0 (0.0)	1 (2.6)	1 (0.4)	19 (7.1)	2 (7.4)	21 (7.1)	< 0.0001	0.57	< 0.0001
Advancing the tube into the trachea, *n* (%)	0 (0.0)	0 (0.0)	0 (0.0)	36 (13.5)	2 (7.4)	38 (12.9)	< 0.0001	0.17	< 0.0001
Esophageal intubation, *n* (%)	7 (2.8)	2 (5.3)	9 (3.2)	13 (4.9)	1 (3.7)	14 (4.8)	0.23	1.0	0.32
Impaired sight due to fogged camera lens, *n* (%)	0 (0.0)	0 (0.0)	0 (0.0)	16 (6.0)	7 (25.9)	23 (7.8)	< 0.0001	0.0013	< 0.0001
Impaired sight due to monitor reflexes, *n* (%)	0 (0.0)	0 (0.0)	0 (0.0)	5 (1.9)	6 (22.2)	11 (3.7)	0.062	0.0036	0.0010
Impaired sight due to ambient light, *n* (%)	8 (3.2)	4 (10.5)	12 (4.2)	44 (16.5)	0 (0.0)	44 (15.0)	< 0.0001	0.13	< 0.0001

McGrathVL. This difference was found especially in trauma patients, but statistical significance was closely missed due to high variance in both groups. The main reasons for failed TI attempts with the McGrathVL were the impossibility to advance the tube into the larynx or trachea, or disturbances caused by ambient light, which was highly significant in trauma patients (in 13.5% of DL patients vs 73.3% of VL patients). Therefore, in outdoor situations with bright sunlight, a DL may be the better choice.

A prolonged TI time may be hazardous: the guidelines of the European Resuscitation Council recommend only brief interruptions in chest compressions for TI: these should not exceed 5 seconds (1). In patients undergoing CPR, we found a mean time from onset of the TI process to first end-tidal Co_2 measurement of 50.0 ± 64.9 s with the DL and 56.0 ± 69.1 s with the McGrathVL ($p = 0.28$). Thus, it is of the utmost importance to precisely plan and communicate the TI process within the EMS team.

Another main result was found in patients who had a crossover after a first failed TI attempt. Here, the probability of successful TI was 88.2% (DL) or 92% (McGrathVL), whereas the likelihood of TI success for another attempt using the same device turned out to be only 60.0% and 54.8%, respectively (Supplemental Fig. 1, Supplemental Digital Content 4, http://links.lww.com/CCM/E837). The change of the TI method after a first failed attempt was made in all cases based on the clinical assessment of an (experienced) EMS physician, who judged continuation with the randomized device not to be promising when considering patient safety as the highest priority. We thus adopted our institutional airway algorithm and recommend changing the TI method after the first failed attempt in cases with a comparable setting, namely experienced users with equal extensive training with both devices. This could significantly reduce the total number of attempts and facilitate a second-pass success rate of at least 94% in the prehospital environment.

In our opinion, the two devices supplement each other. Advantages of DL can be seen in the greater experience of HEMS staff, and consequently in faster TI performance with the well-known device, even in difficult airway situations. In contrast, the advantages of the McGrathVL are a superior view to the glottis, which occasionally may be offset by technical problems such as fogged camera lens and, mainly, bright ambient light impairing identification of anatomical structures on the monitor. In indoor situations, there was no increase in technical problems as compared with DL (Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/CCM/E834; Supplemental Table 2, Supplemental Digital Content 2, http://links.lww.com/CCM/E835; and Supplemental Table 3, Supplemental Digital Content 3, http://links.lww.com/CCM/E836). We therefore strongly recommend that both procedures and their particular pros and cons be taught accordingly during emergency physician training and also ongoing clinical training. If the technical monitor problems can be solved, the first-pass rate with the McGrathVL would be higher. This would presumably

mean shorter intubation times and thus a possible advantage of VL in the prehospital setting.

Our study was discontinued following an interim analysis after enrollment of half of the originally targeted patients; this limits the statistical power of our findings within subgroups. Nevertheless, we were able to prove that the two methods are equivalent in all patients. High-quality studies such as RCTs are difficult to perform in the prehospital environment, where human resources are generally limited and patient care is absolutely paramount and often time-critical. In addition, a too long study period may be negative, as other influences such as a personnel change might obviously influence the results. Also, as the study progresses, there is a decrease in the willingness of HEMS physicians and technicians to exert the effort required for a RCT. Nevertheless, these studies are mandatory to examine the value of methods in the reality of prehospital care: the transferability of knowledge gained from hospital or manikin studies is very limited.

CONCLUSIONS

Both devices, the DL and the McGrathVL, are equivalently well suited for prehospital emergency TI of adult patients. Switching the device following a failed first TI attempt was more successful than another attempt with the same device.

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