Original Article

Comparison of self-assembled video laryngoscope versus McGrath MAC®: A randomised controlled trial

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ABSTRACT

Background and Aims: Video laryngoscopy highly improves the success rate for endotracheal intubation. However, commercially available video laryngoscopes such as McGrath MAC® can be costly. An economical video laryngoscope was assembled by attaching a fibreoptic videoscope into a Macintosh laryngoscope. This randomised study aimed to compare the intubation time of this self-assembled modified Macintosh video laryngoscope (SAM-VL) and McGrath MAC® (McGrath). **Methods:** This study enroled 62 adults scheduled for elective surgery under general anaesthesia with endotracheal intubation. The primary outcome was total intubation time. Secondary outcomes were the time for glottic visualisation (time A), time for tube insertion after glottic visualisation (time B), first-attempt intubation success rate, degree of glottic visualisation, and need for backward, upward, rightward pressure (BURP) assistance, complications, and user satisfaction. The tests used were: Kolmogorov-Smirnov and the Mann-Whitney test to analyse the data's distribution and the primary outcome, respectively. **Results:** The median total intubation time in the SAM-VL group versus the McGrath was 63 s (27–114s) versus 74 s (40–133s), respectively ($P = 0.032$). Intubation time B was significantly faster, while the score of glottic visualisation and BURP assistance was significantly higher in the SAM-VL group. The differences in the rate of successful first attempts and complications were not statistically significant. SAM-VL users rated the ease of blade insertion and manoeuvrability, degree of glottic visualisation, and overall rating as very high. **Conclusion:** Endotracheal intubation using self-assembled modified video laryngoscope is faster and allows better glottis visualisation than McGrath MAC®.

Key words: Glottis, intratracheal intubation, laryngoscopy

INTRODUCTION

Endotracheal intubation is considered the gold standard in definitive airway management.[1] Adding a video camera to the laryngoscope has been a substantial upgrade that improves the intubation success rate. McGrath MAC® laryngoscope is one of the most widely used commercial video laryngoscopes (VLs).[2]

Evidence shows that a video laryngoscope improves the visualisation of the larynx, making intubation easier.[3,4] However, several studies have shown that intubation time with McGrath MAC® is the same or even longer than conventional Macintosh blade.[5-7] Inserting the endotracheal (ET) tube through the vocal cords is more difficult despite good visualisation.[2,5,6] McGrath's blades are also less effective than the wider sized Macintosh blades to displace the tongue and expand the visualisation area of the larynx.[5] The cost of the device also becomes an additional limitation, especially in developing countries.[8] Alternatively, this study modified a classic Macintosh laryngoscope by attaching a flexible fibreoptic video scope to its blade.

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This study aimed to compare the intubation time of a self-assembled modified Macintosh VL (SAM-VL) and McGrath MAC®. The primary objective of this study was to compare intubation time. Secondary variables were the time for glottic visualisation (time A), tube insertion after glottic visualisation (time B), first-attempt intubation success rate, degree of glottic visualisation, complications related to intubation, and user satisfaction.

METHODS

This study was an experimental single-blinded randomised clinical trial cleared for ethics by Universitas Indonesia Ethical Board Committee (KET-432/UN2.F1/ETIK/PPM.00.02/2020) and registered at ClinicalTrials.gov (NCT04850976). The study followed the principles of the Declaration of Helsinki. Sixty-two adult patients aged 18-65 years old, with American Society of Anesthesiologists (ASA) physical status I – II and body mass index of 18-30 kg/m^2 scheduled for elective surgery under general anaesthesia from June to August 2020 were enroled. All subjects provided written consent. The study excluded possible difficult airways, pregnancy, cardiac conditions, and neuromuscular diseases.

The attachment of a portable video camera with a Wi-fi connection (Wi-fi Endoscope Video Camera model YPC99, Guangdong, China) to a size 4 Macintosh blade (Riester no. 7040) was the base for self-assembled modified Macintosh VL (SAM-VL) [Figure 1a-e]. The video signal was transmitted to an Android-based mobile phone using the Y-camera app (Google Play store). The portable two megapixels video scope has an 8 mm camera diameter with eight adjustable light-emitting diode (LED) lights and a 3-m-long cable. Video resolution output was 640 × 480 pixels (Video Graphics Array) and 1280 × 720 pixels (High Definition). The water-resistant camera had a 70° visual angle and a focal length of 4–6 cm. The camera was taped at 5 cm from the distal end of the Macintosh blade using transparent waterproof Leukofix® tape. After installation, the camera was oriented on a flat plane to set the desired image. The total cost for this camera device assembly was Indonesian Rupiah IDR 260.000 (roughly US dollars 20 or Indian Rupee INR 1320), excluding the Android smartphone. After intubation, the camera was detached from the laryngoscope. The camera tip was flushed with running water and washed with soap for at least two minutes, using a soft bristle brush to remove soiling if necessary. After drying, the camera was wiped with a 70% alcohol swab before the following procedure.

The group label was assigned using table randomisation within a sealed envelope. The groups were divided into the self-assembled modified Macintosh VL (SAM-VL) group or the McGrath MAC ® VL (McGrath) group. The person performing the intubation or the airway operator was a first-year anaesthesiology resident who had a minimum of six months of basic airway management training using a Macintosh laryngoscope.

Figure 1: Self-made video laryngoscope used in this study. (a-d) Lateral and top view of the laryngoscope. (e) Portable video camera with a Wi-fi connection (Wi-fi Endoscope Video Camera model YPC99). (f and g) Comparison of the curve and angle of the scope (f) and McGrath MAC® Laryngoscope (g)

The airway operator was the one who opened the envelope. A research assistant prepared the device according to the randomisation results. The subjects were blinded throughout the intervention as they were anaesthetised.

Anaesthesia monitoring was conducted following the ASA standards and included an electrocardiogram, non-invasive blood pressure, pulse oximeter, end-tidal carbon dioxide, and temperature.

Intravenous (IV) induction of anaesthesia was done with fentanyl 2 μg/kg, propofol 2 mg/kg and rocuronium 0.6 mg/kg. Afterwards, to maintain oxygenation before intubation, positive pressure mask ventilation was done using 80% oxygen for 3 minutes until the time for the full onset of the muscle relaxant was reached. An inspiratory oxygen fraction of 80% was maintained as part of the strategy to reduce the risk of postoperative atelectasis.[9] Haemodynamic status (systolic and diastolic blood pressure, mean arterial pressure, pulse, and peripheral oxygen saturation) was recorded at three periods: pre-induction, 3 minutes after induction, and after tracheal intubation was confirmed.

The recording of total intubation time was divided into two; time A and time B based on the following checkpoints. Time A began when the blade's tip passed through the incisors and ended when the airway operator achieved the best glottic visualisation. Time B began after glottis visualisation and ended after capnograph confirmation. One assistant was present to help inflate the ET tube's cuff and connect the circuit simultaneously, to reduce undue delays in the time measurement. Another assistant facilitated intubation by shaping the ET tube with stylet and giving backwards, upward, rightward pressure (BURP) if needed. Every BURP assistance was noted. Successful intubation was confirmed by capnography.

According to randomisation, subjects underwent laryngoscopy and intubation with McGrath MAC® or SAM-VL. During visualisation of the glottis, the airway operator mentioned the Percentage of Glottic Opening (POGO) score visualised, with the scale ranging from 0–100%. Photos and videos from the SAM-VL were recorded directly from the device. Since McGrath MAC® does not allow recording, the images were recorded using a smartphone video camera.

One failed attempt at intubation was defined when the VL blade had to be removed entirely from the mouth and then reinserted before endotracheal intubation. Three unsuccessful intubation attempts mandated that the subject not be analysed.

The complications during intubation were defined as follows: hypertension (systolic >140 mmHg and/or diastolic >90 mmHg), hypotension (systolic <90 mmHg and/or diastolic <60 mmHg), bradycardia (heart rate <60 beats per minute), tachycardia (heart rate >100 beats per minute), mucosal laceration, and oesophageal intubation. Complications during intubation such as unstable haemodynamics (hypotension and bradycardia) and decreased peripheral oxygen saturation (SpO_2) ≤90% concurrent with intubation time exceeding 120 seconds would drop the subject out. The 120 seconds time-limit set was less than the average time for SpO_2 to decrease to 90% during the apnoea following oxygenation with 80% oxygen during induction.[10] The attending anaesthesiologist would manage the complications accordingly. Management of hypotension and bradycardia were by giving IV fluid boluses (10 ml/kg body weight of Ringer's lactate), vasopressors (ephedrine 5-10 mg IV bolus), and atropine (0.5 mg IV) if necessary. Desaturation was managed by stopping intubation and giving positive pressure ventilation by mask or appropriate airway device. If the re-intubation was unsuccessful even after three attempts or if the vitals continued to deteriorate after management, the intubation technique would be changed. The subject was not included in the analysis as no intubation time data was collected [Figure 2].

This study also included a survey of airway operator experience, and the responses were recorded on the Likert scale. The items in the questionnaire were ease in blade insertion, device manoeuvrability, glottic visualisation, and overall satisfaction.

The sample sizes were calculated using numerical hypothesis testing formula for two independent populations, with 5% significance and 80% power. The set of expected effect sizes was at four seconds, and the common standard deviation was derived from a previous study, which had 25 subjects per group.[8]

After calculation of the sample sizes, an additional 10% were added to compensate for dropouts, and the final numbers were 31 subjects for each group. All numerical data were analysed for normal distribution

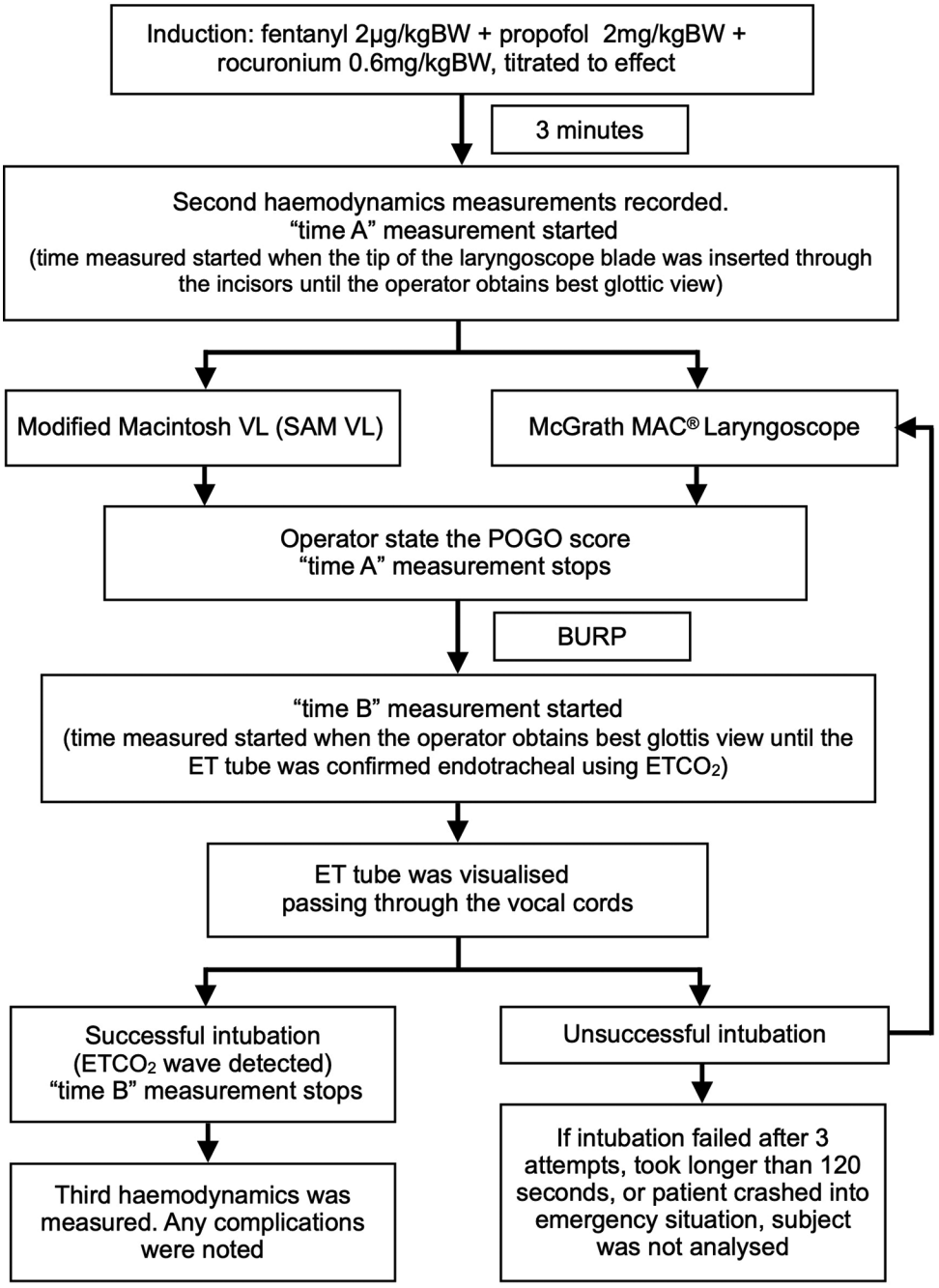

Figure 2: The study framework. BW: Body weight; SAM-VL: Self-assembled Video laryngoscope; POGO: Percentage of Glottic Opening; BURP: Backward, upward, rightward pressure; ETCO2: End-tidal carbon dioxide; ET tube: Endotracheal tube

using the Kolmogorov-Smirnov test. The primary outcome was analysed using the Mann-Whitney test. The degree of glottic visualisation data was analysed for normality using the Kolmogorov-Smirnov test. Categoric data for BURP assistance, complications related to intubation and the first-attempt intubation success rate were analysed using Fisher or Chi-square test. The results were considered significant if the *P* value was <0.05. Statistical analysis was facilitated by the Statistical Package for Social Sciences software version 24.0.

RESULTS

The study recruited 62 eligible subjects without any exclusion and divided them equally into two groups (SAM-VL and McGrath). All the subjects were analysed, and there were no recorded dropouts throughout the study. The demographic variables and ASA status were comparable in both groups [Table 1].

The median total intubation time in the SAM-VL group versus the McGrath was 63 s (27–114s) versus

74 s (40–133s), respectively (*P*-value = 0.032). Median intubation time B was 39 s (20–101s) in the SAM-VL group and 50s (27–102s) in group McGrath MAC (*P*-value = 0.003) [Table 2]. Total intubation time and time B were significantly lower in the SAM-VL group, while there was no significant difference in time A from both groups.

There was no difference in the successful intubation attempt rate between the two groups (*P* = 1.000).

Table 1: Characteristics of subjects

Characteristics	SAM-VL (*n*=31)	McGrath MAC® (*n*=31)
Age (years)*	35.10±13.25	41.03±14.34
Gender**		
Male	11 (35.5)	16 (51.6)
Women	20 (64.5)	15 (48.4)
Body Weight (kg)***	55 (36–80)	58 (47–90)
Height (cm)*	160.39±6.95	160.52±7.97
Body mass index (kg/m^2)*	21.91±2.85	23.38±3.29
ASA**		
I	3 (9.7)	5 (16.1)
II	28 (90.3)	26 (83.9)

*data described in mean value±standard deviations. **data described in frequency (percentage). ***data described in median (maximum value-minimum value). ASA – American Society of Anesthesiologists

Table 2: Comparison between SAM-VL and McGrath MAC®: intubation time, attempt rate, glottic visualisation, and complications

	SAM-VL (*n*=31)	McGrath MAC® (*n*=31)	*P*
Intubation time (seconds)*			
Total intubation time (A + B)	63 (27-114)	74 (40-133)	0.032†
Intubation Time A	18 (6-65)	21 (10-70)	0.652†
Intubation Time B	39 (20-101)	50 (27-102)	0.003†
Successful first attempt**			
Yes	28 (90.3)	27 (87.1)	1,000††
No	3 (9.7)	4 (12.9)	
Glottic visualisation**			
POGO score 100	21 (67.7)	10 (32.3)	0.018†††
POGO score 75	9 (29.0)	20 (64.5)	
POGO score 50	1 (3.2)	1 (3.2)	
POGO score 25	0 (0,0)	0 (0,0)	
POGO score 0	0 (0,0)	0 (0,0)	
BURP**			
Yes	30 (96.7)	21 (67.8)	0.003††
No	1 (3.3)	10 (32.2)	
Complications**			
Hypertension	0 (0.0)	1 (3.2)	0.500††
Hypotension	0 (0.0)	0 (0.0)	-
Tachycardia	4 (12.9)	9 (29.0)	0.106††††
Bradycardia	0 (0.0)	0 (0.0)	-
Mucosal laceration	3 (9.7)	1 (3.2)	0.306††
Oesophageal intubation	0 (0.0)	0 (0.0)	

*Data presented in median (min-max value). **Data presented in frequency (percentage). Statistical analysis: †Mann-Whitney, ††Fisher, †††Kolmogorov-Smirnov, ††††Chi-square. BURP- Backward, upward, rightward pressure. POGO- percentage of glottic opening

The degree of glottic visualisation represented by the POGO score [Figure 3] was significantly better in the SAM-VL group (*P*-value = 0.018). The BURP assistance was significantly higher in the SAM-VL group (96.7% VS 67.8%, *P* value = 0.003). There was no significant difference in complications between both groups [Table 2].

Most operators agreed that blade insertion was either easy or very easy (83.8% in SAM-VL and 80.7% in McGrath) [Table 3]. In terms of manoeuvrability, 87.1% of operators stated that the SAM-VL was easy or very easy to use, compared to 64.5% in the McGrath group. The rate for glottic visualisation was either good or very good for 93.6% of SAM-VL operators, compared to 9.7% using McGrath. About 64.5% of McGrath users in the current study rated the visualisation as poor. Overall, 90.3% of operators rated the general rating of the SAM-VL as good and very good.

DISCUSSION

Successful intubation requires adequate glottic visualisation and subsequent smooth insertion of the ET tube.[10,11] The current study showed significantly faster total intubation time using the SAM-VL than McGrath MAC® laryngoscope. To our knowledge, there is no prior study that directly compared the intubation times between the two. However, some studies have found that self-assembled VLs allowed shorter total intubation time in simulation and real-life scenarios.[8,12] The combination of a wide lens from the video camera and the familiarity of

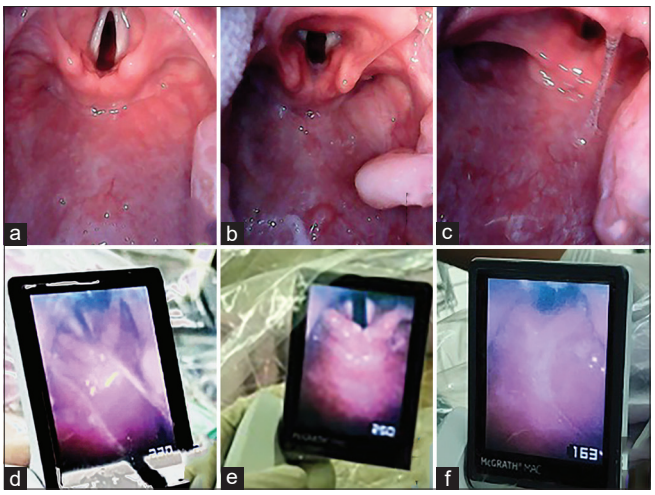

Figure 3: Video laryngoscopy images of the percentage of glottic opening (POGO) scores of 100, 75, and 50. (a-c) were obtained from the SAM-VL group, while (d-f) was obtained from the McGrath MAC® group

Table 3: Airway operator experience survey

	SAM-VL *n*=31, *n* (%)	McGrath MAC® *n*=31, *n* (%)
Blade insertion		
Very easy	13 (41.9)	3 (9.7)
Easy	13 (41.9)	22 (71.0)
Reasonable	4 (12.9)	6 (19.4)
Difficult	1 (3,2)	0 (0,0)
Device manoeuvrability		
Very easy	7 (22.6)	0 (0,0)
Easy	20 (64.5)	20 (64.5)
Reasonable	3 (9.7)	10 (32.3)
Difficult	1 (3,2)	1 (3,2)
Glottic visualisation		
Very good	16 (51.6)	0 (0,0)
Good	13 (41.9)	3 (9.7)
Enough	2 (6.5)	8 (25.8)
Poor	0 (0,0)	20 (64.5)
Overall satisfaction rating		
Very good	12 (38.7)	0 (0,0)
Good	16 (51.6)	10 (32.3)
Enough	3 (9.7)	20 (64.5)
Poor	0 (0,0)	1 (3,2)

All data expressed in frequency (percentage)

Macintosh laryngoscope facilitate favourable hand-eye coordination during intubation.

In direct Macintosh laryngoscopy, the glottic view is best when the airway operator aligns the oral-pharyngeal-laryngeal axes, which sometimes require lifting or external pressure.[7] In Macintosh-based VLs, this view is achieved both directly and indirectly via the monitor. In McGrath MAC®, blade curvature is more acutely angled. This is beneficial as it reduced the need for optimal external laryngeal manipulation (OELM) in the form of a BURP manoeuvre. McGrath VL is also known to require less OELM in children and for the insertion of a double-lumen tube.[13,14] However, this curvature might allow visual and cognitive blind spots that result in difficult intra-oral manipulation of the endotracheal tube [Figure 1f and g].[7] The stylet needed to be more acutely angled than the traditional 35° "hockey stick" angle to insert the ET tube.[15] Therefore, a longer time was needed to pull the stylet out, thus prolonging time B in the McGrath MAC® group. Unfortunately, the specific curving of the stylet used in this study was not recorded.

POGO score with the SAM-VL, was 100% in this study. This finding was better compared to other previous studies.[8,15] Better video camera resolution and bigger screen size of the SAM-VL may have attributed to this finding. Previously, the image quality of McGrath MAC® was inferior to Pentax AirwayScope.[15] Furthermore, the image quality in McGrath MAC® is proportionally dependent on battery capacity. Its vertically-positioned monitor resulted in suboptimal surveillance of the surrounding tissue. Lastly, the images produced were not of high quality [Figure 3d-f], as reported by Cierniak *et al.*[16]

Video laryngoscopy is generally associated with a less physical manipulation and, hence, milder haemodynamic perturbation than direct laryngoscopy in the normal airways or patients with hypertension.[3,17] Nonetheless, the current study showed that both groups experienced non-significant tachycardia. The success rate of the SAM-VL group was slightly higher than a reference study (93% versus 88%).[8] In a study, McGrath MAC® showed a higher successful first attempt intubation attempt rate (100%) and faster median intubation time.[15] However, this study recruited airway operators with extensive clinical experience. In the current study, the airway operators were novices and hence can truly represent device easiness. They were included to reduce operator proficiency bias and to reduce bias from the unfamiliarity with McGrath MAC®. Studies have shown that experience in using one device might affect the proficiency of using another device.[7,18,19]

The mucosal laceration was relatively higher in SAM VL, and the metallic blade of SAM-VL's blade and multiple intubation attempts were likely to be the reasons. Although attaching a non-medical grade device in the SAM-VL raises concerns about the potential mucosal burns due to the device's heat, they did not occur in the patients. The device was powered on only during intubation attempts, and its temperature during the operation was measured at 33.5°C on an industrial-grade infrared thermometer reading (Benetech® GM-320).

Better familiarity with Macintosh blades was attributed to better user satisfaction scores in the SAM-VL group. McGrath MAC® blades were slightly different from the classic ones, and hence, manoeuvring may require some adjustments. Another study with a clip-on camera SAM-VL also showed better user experience in ease of usage.[12] These findings suggest that adequate training is needed to achieve familiarity and skill in operating a VL with different blade anatomy such as McGrath. The bigger and better screen also contributed to better user satisfaction, as The C-MAC (Karl Storz, Tuttlingen, Germany) with a bigger screen was more user friendly

than King Vision laryngoscope (KVL) (King Systems, Noblesville, IN, USA).[20]

This study highlights that VL does not necessarily translate into high costs. The cost of the SAM-VL assembly is roughly 20 USD, excluding the camera phone and laryngoscope. This modification is ideal for low and middle-income countries where healthcare budgeting is an issue.[21]

This study has several limitations. Train-of-four was not measured to control the depth of muscle relaxation before intubation. The study was conducted during the coronavirus disease (COVID)-19 pandemic, and the use of full personal protective equipment may influence intubation proficiency. During sampling, the aerosol box was not yet part of the protection devices during the intubation process. However, employing this device does not significantly interfere with the overall intubation process.[22]

CONCLUSION

Self-assembled Macintosh VL showed many advantages such as faster intubation time, more successful first attempts, better glottic visualisation, and higher operator satisfaction scores than McGrath VL. Its portability and affordability can make it a suitable alternative for low resource settings. Further studies are needed to compare its use with other commercial VLs and to study its benefits for difficult airways.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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