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Original Article

Hyperangulated vs. Macintosh videolaryngoscopy in adults with anticipated difficult airway management: a randomised controlled trial

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Summary

Background It is not certain whether the blade geometry of videolaryngoscopes, either a hyperangulated or Macintosh shape, affects glottic view, success rate and/or tracheal intubation time in patients with expected difficult airways. We hypothesised that using a hyperangulated videolaryngoscope blade would visualise a higher percentage of glottic opening compared with a Macintosh videolaryngoscope blade in patients with expected difficult airways.

Methods We conducted an open-label, patient-blinded, randomised controlled trial in adult patients scheduled to undergo elective ear, nose and throat or oral and maxillofacial surgery, who were anticipated to have a difficult airway. All airway operators were consultant anaesthetists. Patients were allocated randomly to tracheal intubation with either hyperangulated (C-MAC D-BLADE™) or Macintosh videolaryngoscope blades (C-MAC™). The primary outcome was the percentage of glottic opening. First attempt success was designated a key secondary outcome.

Results We assessed 2540 adults scheduled for elective head and neck surgery for eligibility and included 182 patients with expected difficult airways undergoing orotracheal intubation. The percentage of glottic opening visualised, expressed as median (IQR [range]), was 89 (69–99 [0–100])% with hyperangulated videolaryngoscope blades and 54 (9–90 [0–100])% with Macintosh videolaryngoscope blades ($p < 0.001$). First-line hyperangulated videolaryngoscopy failed in one patient and Macintosh videolaryngoscopy in 12 patients (13%, $p = 0.002$). First attempt success rate was 97% with hyperangulated videolaryngoscope blades and 67% with Macintosh videolaryngoscope blades ($p < 0.001$).

Conclusions Glottic view and first attempt success rate were superior with hyperangulated videolaryngoscope blades compared with Macintosh videolaryngoscope blades when used by experienced anaesthetists in patients with difficult airways.

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Introduction

Videolaryngoscopy is used increasingly as a first-line technique to facilitate tracheal intubation (referred to commonly as `universal´, `default´ or `habitual´ videolaryngoscopy) [1, 2]. Accordingly, a universal classification for videolaryngoscopy has been introduced recently [3, 4]. It has been assumed that hyperangulated videolaryngoscope blades provide a better glottic view than Macintosh videolaryngoscope blades and debate is ongoing as to whether any hypothetical improvement in visualising the glottis with a hyperangulated videolaryngoscope blade results in faster tracheal intubation and higher first attempt success rates [5–8].

A recent Cochrane analysis showed that Macintosh and hyperangulated videolaryngoscope blades reduce airway-related adverse events compared with direct laryngoscopy [9]. It was uncertain, however, how the blade shape might impact glottic view, success rate and tracheal intubation time, and which blade geometry might be most favourable for a particular patient, individual user or specific clinical context [8, 10]. A recent meta-analysis failed to show significant differences in glottic view and tracheal intubation success rate between Macintosh and hyperangulated videolaryngoscope blades; only the tracheal intubation time was increased with hyperangulated blades (mean difference 3.5 s), but this was not considered to be clinically relevant [8]. Importantly, most studies excluded patients with predictors for difficult tracheal intubation; hence, complex airways – where hyperangulated videolaryngoscope blades are thought to be superior [9, 11] – were underrepresented [8].

We aimed to determine if using a hyperangulated videolaryngoscope blade improves glottic view, success rates and tracheal intubation times compared with Macintosh videolaryngoscope blades in patients with expected difficult airways undergoing ear, nose and throat (ENT) or oral and maxillofacial surgery. We hypothesised that using a hyperangulated videolaryngoscope blade would enable the operator to visualise a higher percentage of glottic opening (POGO) compared with a Macintosh videolaryngoscope blade.

Methods

We performed the `Best LAryngoscope DEesign, Macintosh vs. hyperangulated SHAPEd videolaryngoscopes´ (BLADESHAPE) study, an open-label, single-blind, randomised controlled trial in a single university hospital in Hamburg, Germany. The trial was registered before recruitment of the first patient. The study was approved by the Ethics Committee of the Medical Association of Hamburg and is reported in accordance with the CONSORT guidelines [12]. All participants gave written informed consent.

Adults (aged ≥ 18 y) scheduled for elective ENT or oral and maxillofacial surgery during the study period were screened for eligibility. Patients were eligible if difficult tracheal intubation was expected and orotracheal intubation was planned. All patients underwent a structured airway risk evaluation in our pre-assessment clinic that included: medical history (e.g. radiotherapy, head and neck tumours or previous difficult tracheal intubation [3, 13]); upper lip bite test [14]; Wilson score [14, 15]; simplified airway risk index [16]; and nasendoscopy [17, 18] if appropriate. Expected difficult tracheal intubation was defined as one or more of: simplified airway risk index ≥ 4 points; Wilson score ≥ 2 points; positive upper lip bite test; expanding pharyngolaryngeal lesions (as assessed by the transnasal flexible videoendoscopy (TVE) score [17]); and reported previous difficult tracheal intubation, defined as a documented difficult airway alert and/or previous videolaryngoscopic intubation and difficult airway classification (VIDIAC) score ≥ 2 [3, 13–18].

Patients were screened for indicators for awake tracheal intubation using recognised decision-making tools [19, 20]. Patients in whom awake tracheal intubation was indicated, patients who required nasotracheal intubation or special tracheal tubes (i.e. laser or microlaryngoscopy tubes) and pregnant and breastfeeding women were not studied.

All participating airway operators were consultant anaesthetists with at least 5 y of professional work experience. In addition, all airway operators attended structured, hands-on training with both devices inspired by the `Bath C-MAC D blade guide´ [21] before the trial started. The sex, age and duration of professional work experience of the airway operators were collected.

Patients were assigned randomly using a 1:1 ratio to either hyperangulated videolaryngoscopy or Macintosh videolaryngoscopy. The randomisation sequence was generated before the study commencing: group allocations (91 in each) were concealed in 182 opaque envelopes. These were then sealed and shuffled into a random order before being numbered with sequential study identification numbers. The envelope corresponding to the allocated study identification number for the individual patient was then opened in the operating theatre immediately before induction of anaesthesia and after the anaesthetist had been assigned to the patient, and the tracheal tube size, anaesthesia induction strategy, drugs and targeted drug dosages had been determined. Patients were blinded to the allocation; however, because of the nature of the study, the airway operator could not be blinded. In patients allocated to the hyperangulated videolaryngoscopy group, tracheal intubation was facilitated by C-MAC D-BLADE™ (Karl Storz SE & Co. KG, Tuttlingen, Germany) whereas C-MAC™ with either a size 3 or 4 Macintosh blade (Karl Storz SE & Co. KG) was used in patients allocated to the Macintosh videolaryngoscopy group.

Cuffed reinforced tracheal tubes (Shiley™ Lo-Contour, Medtronic, Dublin, Ireland) with internal diameters between 6.0 and 8.0 mm were used in all patients. Hyperangulated blades were always used in conjunction with the corresponding hyperangulated stylet provided by the manufacturer (C-MAC Guide™, Karl Storz SE & Co. KG) while Macintosh videolaryngoscopes were always used in conjunction with a conventional malleable stylet (Shiley™ Intubation Stylet, Medtronic, Watford, UK); here, the tracheal tube containing the stylet was shaped by an independent member of the investigator group to be aligned exactly with the curvature of the corresponding

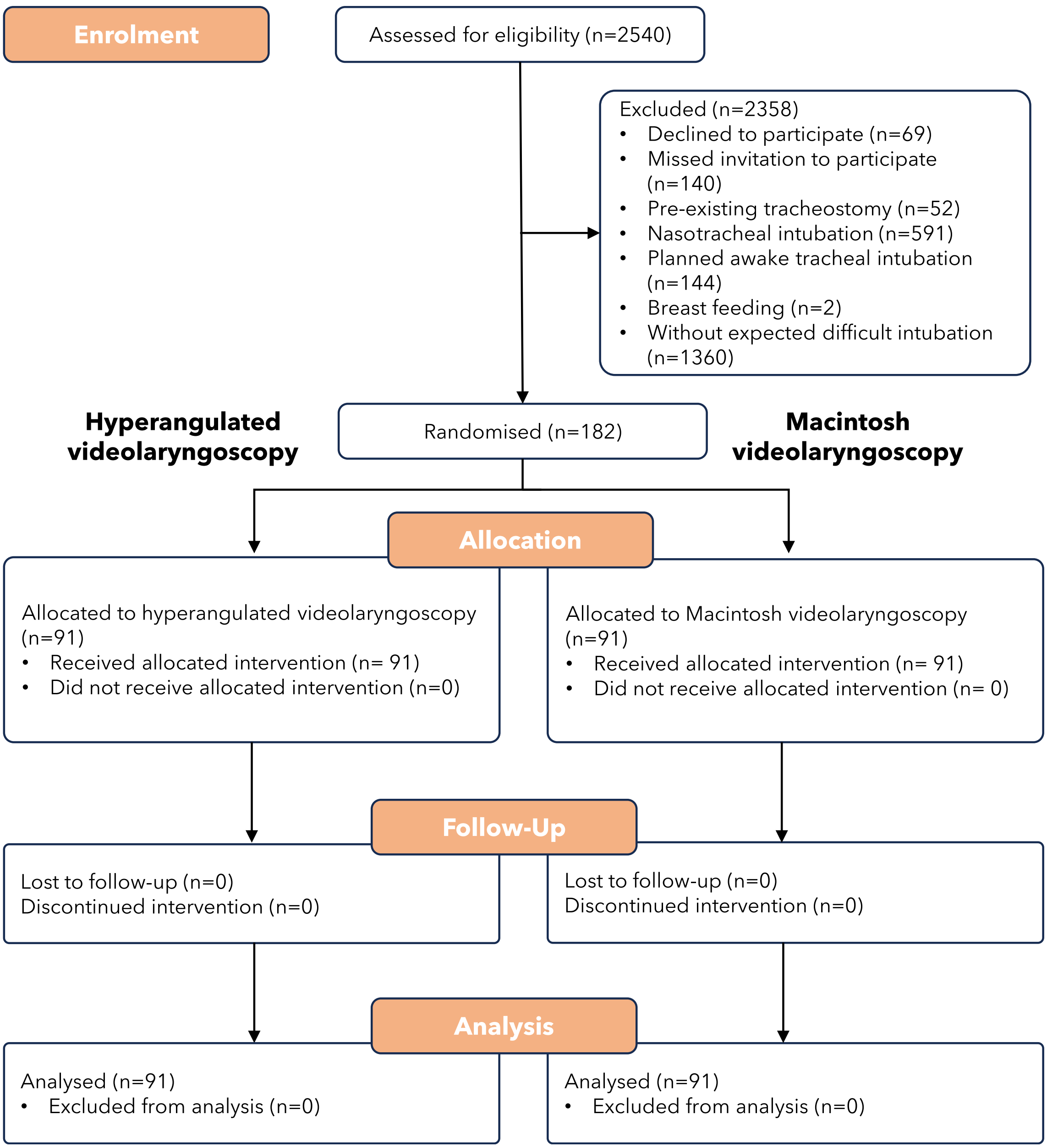

Figure 1 Study flowchart.

Table 1 Baseline patient characteristics. Values are mean (SD) or number (proportion).

	Overall n = 182	Hyperangulated videolaryngoscopy n = 91	Macintosh videolaryngoscopy n = 91
Age; y	64 (14.7)	62 (16.0)	66 (13.1)
Sex; male	120 (66%)	55 (60%)	65 (71%)
Weight; kg	79 (21.2)	75 (20.2)	82 (21.7)
ASA physical status			
1	10 (5%)	5 (5%)	5 (5%)
2	69 (38%)	39 (43%)	30 (33%)
3	97 (53%)	43 (47%)	54 (59%)
4	6 (3%)	4 (4%)	2 (2%)
Past medical history			
History of difficult tracheal intubation	80 (44%)	36 (40%)	44 (48%)
Previous awake tracheal intubation	20 (11%)	12 (13%)	8 (9%)
Existing anaesthesia alert card	16 (9%)	8 (9%)	8 (9%)
Pre-operative airway assessment			
Mouth opening; cm	4.0 (1.2)	3.9 (1.3)	4.2 (1.2)
Mallampati class 4	76 (42%)	42 (46%)	34 (37%)
Cannot bite upper lip	61 (34%)	36 (40%)	25 (27%)
Retrognathia	29 (16%)	14 (15%)	15 (16%)
Neck movement < 70°	27 (15%)	16 (18%)	11 (12%)
Expanding pharyngolaryngeal lesion	89 (49%)	45 (49%)	44 (48%)
History of neck radiotherapy	50 (27%)	26 (29%)	24 (26%)
Dysphagia	72 (40%)	34 (37%)	38 (42%)
Pre-operative transnasal videoendoscopy	110 (60%)	52 (57%)	58 (64%)
Simplified airway risk index	5.0 (2.3)	5.1 (2.2)	4.9 (2.4)
Wilson score	3.4 (1.9)	3.4 (2.0)	3.4 (1.8)
Surgical procedures			
Microlaryngoscopy	75 (41%)	36 (40%)	39 (43%)
Pharyngolaryngeal and tracheal	16 (9%)	10 (11%)	6 (7%)
Ear, nose and sinuses	16 (9%)	8 (9%)	8 (9%)
Endocrine glands	7 (4%)	5 (5%)	2 (2%)
Neck and maxillofacial	26 (14%)	12 (13%)	14 (15%)
Lower jaw	17 (9%)	10 (11%)	7 (8%)
Dentoalveolar	7 (4%)	3 (3%)	4 (4%)
Others	18 (10%)	7 (8%)	11 (12%)

Macintosh blade by means of a prefabricated template. However, the airway operator could reshape or adjust the tracheal tube at any time without giving a reason.

Anaesthesia management, anaesthesia induction, choice of drugs, blade size (in the Macintosh videolaryngoscopy group), tracheal tube size, head and neck position (either `sniffing´ or neutral position [22]), use of adjuncts like bougies (either Flextip™, P3 Medical Ltd, Bristol, UK or Frova™ airway intubation catheter Cook™ Medical Europ Ltd., Limerick, Ireland), forceps or airway optimisation manoeuvres (e.g. external laryngeal manipulation) were left to the discretion of the airway operator. Anaesthetists were encouraged to lift the epiglottis indirectly in the first instance by engaging the midline vallecular fold with the blade tip; direct lifting of the epiglottis was only employed as a rescue technique [3, 10]. Propofol combined with either sufentanil or remifentanil was used to induce anaesthesia. Rocuronium bromide was used for neuromuscular blockade in all patients and adequate neuromuscular blockade was verified with train-of-four measurements.

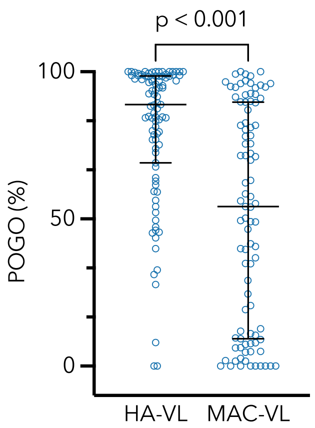

Figure 2 Percentage of glottic opening (POGO) values (blue dots) in the hyperangulated videolaryngoscopy (HA-VL) and Macintosh videolaryngoscopy (MAC-VL) groups. Values are median (whiskers represent the IQR).

Outcome measures were assessed by a research assistant not involved in patient care using a standardised case report form. Videos from all tracheal intubations were recorded for later review. The airway operators rated the POGO [23] and glottic view landmarks aided by the captured videos. Four additional assessors (VK, VW, MM, MP) who were blinded to the pre-operative airway assessments and ratings of the other assessors, analysed all stored videos independently post hoc and made quantitative measures using Datinf® Measure 3 (Datinf® GmbH, Tübingen, Germany). The mean POGO ratings of the five assessors (airway operator and four post hoc assessors) and median glottic view landmark ratings of the five assessors were used for further analysis. All assessors were instructed to rate the best POGO and best glottic view obtained with or without external laryngeal manipulation.

The primary outcome of the study was the POGO score. We further assessed the glottic view systematically using previously reported landmarks (vocal cords completely visible; part of the cords visible; posterior cords only just visible; arytenoids but not cords visible; epiglottis but no glottis visible; and laryngeal structures not visible) [3, 24, 25] and reported the incidence of impaired glottic view based on the modified Cormack–Lehane classification [24] and the difficulty of videolaryngoscopic tracheal intubation by means of the videolaryngoscopic intubation and difficult airway classification (VIDIAC) [3]. Further secondary outcomes were incidence of successful tracheal intubation; incidence of successful first-line technique (without conversion to a different laryngoscope or tracheal intubation technique); incidence of first attempt success (only one attempt at laryngoscopy and tracheal intubation [3]); tracheal intubation time (from device insertion to intubation of the trachea); time to successful first attempt tracheal intubation (tracheal intubation time in patients whose trachea was intubated in a single attempt); time to best view (from device insertion to best glottic view); time to tracheal tube placement (from best glottic view to intubation of the trachea); incidence of difficult airway alerts documented in patients' electronic health records after videolaryngoscopy [3, 18]; incidence of requirement for a bougie; number of tracheal intubation attempts; number of laryngoscopy attempts; and incidence of airway-related adverse events (defined in turn as one or more of: laryngospasm; aspiration; airway or oral trauma including bleeding and dental injury; glottic swelling; hypoxaemia ($SpO_2 < 90\%$); and hypotension (systolic blood pressure < 70 mmHg)). The quality of glottic view and ease of tracheal tube placement were rated by the airway operators using visual analogue scales (0–100, higher values better) immediately after tracheal intubation. We also analysed first attempt success without complications as a post hoc, exploratory outcome.

The minimum clinically important difference in POGO that would be needed to justify the use of hyperangulated rather than Macintosh videolaryngoscopes in patients with expected difficult airways is uncertain. Our sample size calculation relied on our own preliminary study data and existing literature [8–10]. The study was powered to detect a mean difference of 16% in POGO between groups. This difference was assumed to be clinically relevant, was considered to mark a turning point between a good and restricted laryngeal view in patients with difficult airways [3, 10, 19, 24] and was considered the smallest effect size worth detecting. A priori sample size calculations determined that 91 patients per group would yield 90% power to detect a mean difference of 16% in POGO between groups, assuming a standard deviation of 38% in the Macintosh and 27% in the hyperangulated group, with a significance level (α) of 0.05 using a two-sided, two-sample *t*-test.

Metric variables were checked for normal distribution by visual inspection of histograms. Fisher's exact test and Mann–Whitney U-test were used to compare variables between both groups, whichever was appropriate. The Wilcoxon test for paired samples was used for post hoc secondary analysis within the subgroup of patients in whom first-line Macintosh videolaryngoscopy failed. A two-tailed p-value < 0.05 was regarded as significant for the primary outcome. Secondary outcomes were analysed descriptively; p-values for secondary analyses are provided as descriptive summary measures and were not adjusted for

Table 2 Study outcome measures. Values are median (IQR [range]) or number (proportion).

Characteristic	Overall n = 182	Hyperangulated videolaryngoscopy n = 91	Macintosh videolaryngoscopy n = 91	p value
Percentage of glottic opening; %	79 (41–96 [0–100])	89 (69–99 [0–100])	54 (9–90 [0–100])	< 0.001
Glottic view*				< 0.001
Vocal cords completely visible	56 (31%)	39 (43%)	17 (19%)	
Part of the cords visible	48 (26%)	28 (31%)	20 (22%)	
Posterior cords only just visible	41 (23%)	19 (21%)	22 (24%)	
Arytenoids but not cords visible	22 (12%)	2 (2%)	20 (22%)	
Epiglottis but no glottis visible	14 (8%)	3 (3%)	11 (12%)	
Laryngeal structures not visible	1 (0.5%)	0	1 (1%)	
Vocal cords not visible**	37 (20%)	5 (5%)	32 (35%)	< 0.001
Attempts and success rates				
Successful tracheal intubation	181 (100%)	90 (99%)	91 (100%)	1.000
Successful first-line technique	169 (93%)	90 (99%)	79 (87%)	0.002
First attempt success	149 (82%)	88 (97%)	61 (67%)	< 0.001
First attempt success without complications	142 (78%)	84 (92%)	58 (64%)	< 0.001
Requirement for a bougie	17 (9%)	2 (2%)	15 (16%)	< 0.001
Tracheal intubation attempts				< 0.001
1	157 (86%)	88 (97%)	69 (76%)	
2	21 (12%)	2 (2%)	19 (21%)	
≥ 3	4 (2%)	1 (1%)	3 (3%)	
Laryngoscopy attempts				< 0.001
1	167 (92%)	90 (99%)	77 (85%)	
2	13 (7%)	1 (1%)	12 (13%)	
≥ 3	2 (1%)	0	2 (2%)	
Difficulty of videolaryngoscopic intubation				
Hard videolaryngoscopic intubation (VIDIAC score 2)	16 (9%)	8 (9%)	8 (9%)	1.000
Severe videolaryngoscopic intubation (VIDIAC score ≥ 3)	39 (21%)	9 (10%)	30 (33%)	< 0.001
Difficult airway alert after videolaryngoscopy††	66 (36%)	23 (25%)	43 (47%)	0.003
Time				
Time to best view; s	8 (6–14 [3–142])	7 (5–10 [3–52])	11 (7–24 [3–142])	< 0.001
Time to tracheal tube placement; s	12 (8–22 [3–200])§	11 (8–17 [3–200])†	14 (8–33 [4–197])	0.021
Tracheal intubation time; s	22 (15–39 [7–248])§	19 (13–25 [7–214])†	27 (17–62 [10–248])	< 0.001
Time to successful first attempt tracheal intubation; s‡	19 (14–25 [7–84])	19 (13–24 [7–84])	20 (14–27 [10–68])	0.210
Airway-related adverse events				
At least one	13 (7%)	6 (7%)	7 (8%)	1.000
SpO_2 < 90%	1 (1%)	0	1 (1%)	1.000
Dental or soft tissue injury	4 (2%)	2 (2%)	2 (2%)	1.000
Oral bleeding	6 (3%)	2 (2%)	4 (4%)	0.682
Systolic blood pressure < 70 mmHg	6 (3%)	3 (3%)	3 (3%)	1.000

Additional metric outcome variables are presented as mean (SD) in online Supporting Information Table S2.
VIDIAC, videolaryngoscopic intubation and difficult airway classification.
†Only for 90 patients with successful tracheal intubation.
‡Only for 149 patients with first attempt success (only one laryngoscopy and one tracheal intubation attempt).
§Only for 181 patients with successful tracheal intubation.
††Difficult airway alert after videolaryngoscopy documented in patients' electronic health records as reported previously [3, 18].
*Glottic view landmarks as reported previously [3, 24, 25].
**Cormack–Lehane grade 2b, 3 or 4 [24].

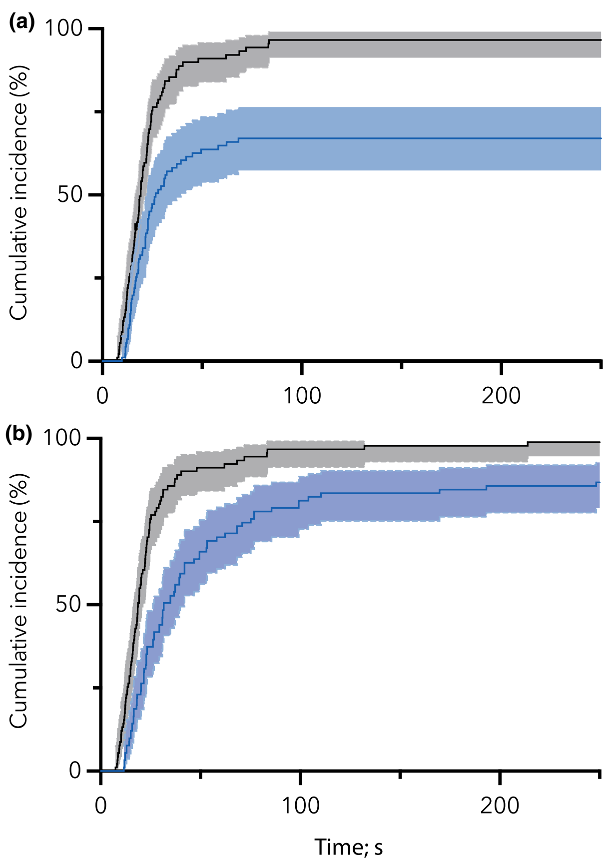

Figure 3 Cumulative incidence of the (a) first attempt success (black line: hyperangulated videolaryngoscopy; blue line: Macintosh videolaryngoscopy) and (b) successful first-line technique (black line: hyperangulated videolaryngoscopy; blue line: Macintosh videolaryngoscopy) as a function of time. Values are cumulative incidence (95%CI).

multiplicity. Statistical analysis was performed using SPSS 27 (IBM Inc., Armonk, NY, USA); figures were created using GraphPad Prism version 9.5.0 for Mac (GraphPad Software, Boston, MA, USA).

Results

We screened 2540 adults scheduled for elective ENT or oral and maxillofacial surgery requiring orotracheal intubation between 17 October 2022 and 31 July 2023. We included 182 individuals that fulfilled all eligibility criteria; 91 were assigned randomly to each study group and all patients were analysed (Fig. 1). Baseline characteristics are given in Table 1. The trial airway operators comprised 19 consultant anaesthetists: five women and 14 men, with a mean (SD) age of 41 (6) y and professional experience in anaesthesiology of 12 (5) y.

Median (IQR [range]) POGO was 89 (69–99 [0–100])% with hyperangulated videolaryngoscope blades and 54 (9–90 [0–100])% with Macintosh videolaryngoscope blades ($p < 0.001$; Fig. 2 and Table 2). Furthermore, the absolute rate of severe view impairments (i.e. vocal cords not visible [24]) was 30% lower with hyperangulated compared with Macintosh videolaryngoscope blades (5% vs. 35%, respectively; $p < 0.001$; Table 2). Moreover, the absolute rate of first attempt success was 30% higher with hyperangulated videolaryngoscope blades compared with Macintosh videolaryngoscope blades (97% vs. 67%, respectively; $p < 0.001$; Table 2). Figure 3 shows the cumulative incidence of the first attempt success and of successful first-line technique as a function of time in both groups.

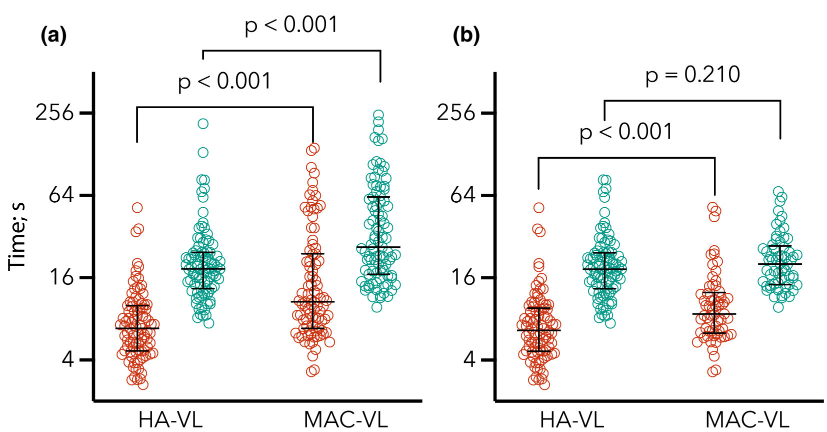

Figure 4 Time to best view (red dots) and tracheal intubation time (green dots) in the hyperangulated videolaryngoscopy (HA-VL) and Macintosh videolaryngoscopy (MAC-VL) group (a) in all patients (n = 182, left) and (b) in patients whose trachea was intubated in a single attempt (n = 149; right). Values are median (whiskers represent the IQR) illustrated on a logarithmic scale.

In the patients allocated to the hyperangulated videolaryngoscopy group, tracheal tube placement failed in one patient with an obstructive glottic tumour despite multiple attempts and tracheostomy was performed. In patients allocated to the Macintosh videolaryngoscopy group, the first-line technique failed in 12 patients (13%); in all cases hyperangulated videolaryngoscopy was used successfully as rescue technique. A secondary analysis of this subgroup revealed that the vocal cords were not visible with Macintosh videolaryngoscopy in all 12 patients but only in four after conversion to hyperangulated videolaryngoscopy. Here, the POGO with Macintosh videolaryngoscopy markedly increased after conversion to hyperangulated videolaryngoscopy (75% higher median POGO values after conversion, $p = 0.003$; online Supporting Information Table S1).

In the patients allocated to the hyperangulated videolaryngoscopy group, the best glottic view was achieved faster and tracheal intubation time was shorter compared with the Macintosh videolaryngoscope group (Table 2). In patients in whom only a single tracheal intubation attempt was necessary, between group time to successful first attempt tracheal intubation did not differ (Table 2 and Fig. 4).

Airway operators rated on a visual analogue scale that the quality of glottic view was better in patients allocated to the hyperangulated videolaryngoscope group compared with the Macintosh videolaryngoscope group, while there was no between group difference in ease of tube placement (online Supporting Information Figure S1 and Table S3).

Discussion

We performed a randomised controlled, single-centre trial, in which we compared hyperangulated with Macintosh videolaryngoscopy in elective patients undergoing ENT or maxillofacial surgery with an anticipated difficult airway who received care from an experienced consultant anaesthetist. The primary outcome, the POGO score, was significantly greater in patients allocated to the hyperangulated videolaryngoscopy group compared with the Macintosh videolaryngoscopy group. In this cohort, glottic view, success of the first-line technique and first attempt success rates were superior, and tracheal intubation was faster with hyperangulated videolaryngoscopes. However, the tracheal intubation time did not differ between devices in individuals in whom only a single intubation attempt was necessary, indicating that the time advantage obtained with hyperangulated blades was limited to the more difficult cases.

It has been reported that failure to achieve tracheal intubation at first attempt is associated with an increased incidence of complications [26]. Reducing the number of attempts is critical to increase the safety of airway management [19]. Furthermore, prolonged tracheal intubation time increases the risk of hypoxaemia; hence, the device that facilitates the fastest tracheal intubation with the lowest number of attempts is the optimal choice for the individual patient [26, 27].

Hyperangulated videolaryngoscopes are designed to improve glottic view beyond that achieved by devices with less pronounced angulation and may perform better in situations where the glottic view would be restricted severely with Macintosh videolaryngoscopes [10]. A subgroup analysis of a recent Cochrane review reported that hyperangulated videolaryngoscopes were more likely to reduce the incidence of failed tracheal intubation when used in patients with known or predicted difficult airways [9]. However, a recent pairwise meta-analysis of randomised clinical trials failed to identify differences between videolaryngoscope types for failed tracheal intubation, failed first attempt and glottic view assessed by the POGO score [8]. The only finding of note was increased tracheal intubation time with hyperangulated blades (mean difference 3.5 s (95%CI 0.4–6.7), $p = 0.028$), but the author did not consider this finding clinically relevant [8]. Importantly, the author of that meta-analysis concluded that the lack of significant differences was probably due to the low quality of evidence and did not indicate equivalence between the devices, noting that further well-designed studies are necessary to clarify whether any specific device is better and that most studies excluded patients with predictors for difficult tracheal intubation [8]. Since patients included in existing studies were most likely to have straightforward airway management, it was not possible to draw conclusions relevant to patients with more complex airways [8], where hyperangulated videolaryngoscopy could be superior [9, 11]. Hence, the current evidence was judged insufficient to support a personalised context-dependent choice of the optimal device and strategy, based on an individual patient risk profile and individual user skill level in daily clinical practice [8, 28].

It is not only the device geometry but also the use of adjuncts that differ between devices. Hyperangulated blades are intended to be used with stylets that match the curvature of the corresponding blade to enable tube delivery into the trachea [9, 21, 29], while Macintosh videolaryngoscopes can either be used with or without a stylet. Due to this prerequisite, hyperangulated videolaryngoscopy is often considered a more complex skill compared with Macintosh videolaryngoscopy as it requires distinct hand eye co-ordination and guidance of the tracheal tube; tube advancement; and stylet withdrawal at the level of the laryngeal inlet to allow gentle advancement through the vocal cords without impingement. These factors might slow an otherwise straightforward tracheal intubation [5, 21]. Notably, our study used preshaped stylets that followed exactly the curvature of the corresponding blade for both devices to avoid confounding [9, 21, 29].

Our findings show that better glottic view with hyperangulated videolaryngoscopy did translate into reduced tracheal intubation time, with higher success rates when used in patients with predicted difficult airways by experienced anaesthetists. Previous study findings [10], as well as the findings of our subgroup analysis show that the highest improvement in POGO occurred when hyperangulated videolaryngoscopy was used to rescue failed Macintosh videolaryngoscopy.

As a previous history of difficult airway management is the single biggest predictor for future difficulty [13], existing airway recordings should be screened for difficult airway alerts to identify individuals that require awake tracheal intubation. Many patients in our study could have been managed successfully using awake tracheal intubation and readers should not be encouraged to remove awake tracheal intubation from their armamentarium in favour of asleep videolaryngoscopy. Awake tracheal intubation either with a bronchoscope or videolaryngoscope is the current standard of care to assure patient safety in certain situations [30].

Our trial has some limitations. First, it is a single-centre study, and standards differ between departments. Accordingly, findings should not be generalised to other clinical settings, especially outside of the operating theatre or to non-anaesthetist airway operators. Second, this study only investigated the equipment of a single manufacturer; thus, these results should not be extrapolated to other devices without appropriate caution. Third, we used POGO as the primary outcome, although first attempt success rate is clinically more relevant, because pilot data for sample size calculation were very limited for first attempt success rates in the desired patient population. Finally, the effect of the blade geometry on the POGO (35%) was higher than predicted (16%), suggesting the observed difference in the study population was not reflected by the pilot populations used for the effect size calculation.

In conclusion, we have shown an improved glottic view, increased first attempt success, greater success with the first-line technique and a reduction in tracheal intubation times with hyperangulated videolaryngoscopy compared with Macintosh videolaryngoscopy when applied by experienced consultant anaesthetists in patients with expected difficult airways. The choice of the optimal videolaryngoscopy geometry should rely on contextual and patient-related factors as well as user skill level. Here, hyperangulated videolaryngoscopes should be considered as a first-line technique for experienced users on expected difficult airways and as a rescue technique for failed Macintosh videolaryngoscopy.

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Supporting Information

Additional supporting information may be found online via the journal website.

Figure S1. Ratings of the quality of glottic view and ease of tube placement on visual analogue scales for (a) all patients and (b) in patients with successful tracheal intubation with one attempt in patients allocated to the hyperangulated and Macintosh videolaryngoscopy groups.

Table S1. Secondary analysis of 12 patients in whom first-line Macintosh videolaryngoscopy failed.

Table S2. Metric study outcomes.

Table S3. Rating of the airway operators of the quality of glottic view and ease of tube placement for the entire cohort and for patients with successful tracheal intubation with one attempt.

