Macintosh Videolaryngoscope for Intubation in the Operating Room

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Macintosh Videolaryngoscope for Intubation in the Operating Room: A Comparative Quality Improvement Project

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BACKGROUND: "Macintosh"-videolaryngoscopes (VLs) are VLs that allow both direct and indirect laryngoscopy for intubation. We describe the decision-making and implementation-processes that our hospital used regarding the choice of device. We compared the performances of 4 Macintosh-VLs both in direct and indirect laryngoscopy.

METHODS: A quality-improvement-project for airway management aiming at implementing Macintosh-VL for all intubation procedures performed in the operating room, involving 4 Macintosh-VLs (McGrath-Mac, C-MAC-S, C-MAC-S-Pocket-Monitor [PM], and APA). Three consecutive steps were described: (1) direct laryngoscopy with Macintosh-VL, (2) indirect laryngoscopy with Macintosh-VL (intubation attempt with Macintosh-style blade in case of Cormack I or II), (3) intubation attempt with hyperangulated blade in case of Cormack III/IV or failure of Macintosh-style blade. The main end point was the need to move to step III and use a hyperangulated blade. A mixed-effects multivariable logistic regression analysis was performed to compare devices on the main end point while considering site as a random effect. Comparison of means was performed using analysis of variance and Tukey's test for multiple comparisons (number of laryngoscopy attempts, numeric rate scale [NRS] difficulty of intubation and NRS user-friendliness). Comparison of percentages was performed using a χ^2 test for the need to move to step III and a Kruskal-Wallis test for the quality of image (bad, passable, good, very good, excellent). A P value ≤.008 was considered statistically significant.

RESULTS: From May to September 2017, 589 patients were included. Using the McGrath-Mac (22/180 [12%]) was associated with less use of hyperangulated blade than using the C-MAC-S (39/132 [30%], odds ratio [OR] [99.2% confidence interval {CI}] 0.34 [0.16–0.77], P = .0005), the APA (35/138 [25%], OR [99.2% CI] 0.42 [0.19–0.93]; P = .004), but not the C-MAC-S-PM (29/139 [21%], OR [99.2% CI] 0.53 [0.23–1.2]; P = .04).

Overall, the number of intubation attempts was significantly lower using the McGrath Mac than the C-MAC-S or the C-MAC-S-PMVLs. Subjective appreciation of intubation difficulty and user-friendliness of the devices showed respectively lower and higher NRS scores for the McGrath-Mac compared to the other devices, whereas subjective assessment of image quality showed higher quality for the C-MAC-S and C-MAC-S-PM compared to the APA or McGrath-Mac.

CONCLUSIONS: Among 4 single-use Macintosh-VLs, glottic visualization in direct and indirect laryngoscopy with the Macintosh-style blade was significantly improved with the McGrath-Mac compared to other Macintosh-VLs, leading to a less frequent need to resort to the hyperangulated blade and reduced overall number of intubation attempts.

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Conflicts of Interest: See Disclosures at the end of the article.

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The 4 Macintosh-videolaryngoscopes assessed were lent to the anesthesia departments for the duration of the 5-month trial. A representative of each company provided training in the use of the devices and support throughout the trial. The companies were otherwise not involved in this clinical assessment. The clinical evaluations were performed without funding, or involved in the decisions to perform the trial, in analysis of the results, or in subsequent decision-making. The anesthesia departments had received free or at cost equipment for research and evaluation from several airway companies. No individual author has made any profit of any sort from such donations. No author (nor any of their families) has, to the best of our knowledge, any financial involvement in airway companies.

Reprints will not be available from the authors.

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KEY POINTS

- **Question:** Does 1 Macintosh-videolaryngoscope (VL) used as primary intubation device perform better than others?
- **Findings:** In this quality improvement project aiming to select 1 Macintosh-VL, the McGrath Mac showed less frequent resort to "hyperangulated blade" than the C-MAC-S or the APA and higher user-friendliness than other devices.
- **Meaning:** The McGrath Mac outperformed the other Macintosh VLs tested in terms of direct and indirect glottic visualization obtained resulting in an increase in first-attempt success and less need to resort to a hyperangulated VL blade.

GLOSSARY

BMI = body mass index; **CI** = confidence interval; **CL** = Cormack-Lehane; **DAB** = difficult airway blade; **DL** = direct laryngoscopy; **ICU** = intensive care unit; **IL** = indirect laryngoscopy; **ND** = not done; **NRS** = numeric rate scale; **OR** = odds ratio; **SD** = standard deviation; **SpO_2** = peripheral oxygen saturation; **TOF** = train of four; **VL** = videolaryngoscopy

Standard Macintosh direct laryngoscopy, which requires a direct line of sight to align airway axes, remains the first airway management device for most anesthesiologists.[1,2]

Recently, the role of videolaryngoscopy (VL) in anticipated[3,4] and un-anticipated[5–8] difficult intubation has been widely recognized. High-profile national guidelines[5,6] have stated that all anesthesiologists should be trained to use and have immediate access to a VL. Following large implementation, difficult and failed intubation rates[9] by skilled providers declined significantly.[10,11] Furthermore, teaching with VL can improve intubation skills in medical students.[8,12]

New devices, including APA (Advanced Airway Management Healthcare, Venner Medical International, Jersey, UK), C-MAC-S (Karl Storz, Tuttlingen, Germany; single-use), C-MAC-S-PM (pocket and single-use), and McGrath Mac (Medtronic Covidien, Minneapolis, MN), are called "Macintosh" VLs.[4,13–16] They can be used both as direct and indirect-laryngoscopes. Two types of blades are available: first, a Macintosh-style blade that integrates video capability can be used to perform both indirect and direct laryngoscopy.[17] On the other hand, a hyperangulated blade is available to further improve glottic visualization[18,19] for difficult laryngoscopy, which can be used only in indirect laryngoscopy.[18]

To our knowledge, very limited data are available regarding the use of Macintosh-VLs as the first-intention devices for all intubation procedures performed in the operating room, no matter how difficult.

We performed a pragmatic study included in a quality improvement project aiming to compare the glottic visualization of different Macintosh-VLs used as the primary intubation device. The main hypothesis was that one of the Macintosh-VLs might show less frequent need to use the hyperangulated blade. The secondary hypotheses were that the Macintosh-VLs might differ regarding successful first attempt intubation, number of intubation attempts, glottic visualization in direct and indirect laryngoscopy, adverse-effects, subjective assessment of difficulty of intubation, user-friendliness, and image quality.

METHODS

Study Design

We conducted a quality improvement project from May 2017 to September 2017 in the 4 anesthesia departments of Montpellier Teaching Hospital, aiming at implementing Macintosh-VL for all intubations procedures in the operating room.

This study was part of an institutional assessment of airway management that evaluated single-use Macintosh-VLs. We obtained approval from the local scientific (Comité d'Organisation et de Gestion de l'Anesthésie Réanimation) and ethics committee (Institutional Review Board, Comité Locale d'Ethique Recherche, agreement number: 2017_CLER-MPT_11-04) of Montpellier University Hospital.[20] Requirement for written informed consent was waived by the institutional review board.

The 4 Macintosh-VLs assessed were loaned to the anesthesia departments for the duration of the 5-month trial. Representatives of each company provided devices for the trial and afforded training in the use of the devices and support throughout the trial. The companies (including Medtronic) were otherwise not involved in this clinical assessment. The clinical evaluations were performed without funding or involvement in the decision to perform the trial, in the analysis of the results (performed by an independent statistician, N.M.), or in the subsequent decision-making. The departments of anesthesia had received free or at cost equipment for research and evaluation from all the airway companies providing single-use Macintosh VL at the time where the study was performed.

Inclusion Criteria

Patients aged ≥18 years who required orotracheal intubation during general anesthesia were included.

Exclusion Criteria

Patients were not included if they met one or more of the following criteria: pregnancy or breastfeeding, rapid sequence intubation, intubation in case of cardiopulmonary arrest, emergency airway management (severe hypoxemia or severe collapse before intubation), or interincisor gap <2.2 cm.

Interventions

Four devices were used including the McGrath Mac (Medtronic Covidien), the C-MAC-S (Karl Storz; Tuttlingen, Germany), the C-MAC-S-Pocket Monitor (PM; Karl Storz), and the APA (Advanced Airway Management Health Care, United Kingdom). All the Macintosh-VLs were single-use and had both Macintosh-style blades and hyperangulated blades. Before the beginning of the quality improvement project, Macintosh-VL was not available and only Glidescope (Verathon, Bothell, WA) VL was available and routinely used in case of difficult intubation.[1] The anesthesiologists had no experience with the respective devices before participating in the study. To choose 1 Macintosh-VL for the institution, each of the 4 anesthesia departments assessed each of the 4 devices during 1 month in a randomized order: May (1 period), June (1 period), July–August together (due to the reduced number of patients undergoing anesthesia and surgery during the summer, 1 period), and September (1 period). One device was available for each anesthesia department (multiple patients could not be enrolled simultaneously in the same anesthesia department, ie, not consecutive included patients), and the anesthesiologists were encouraged to use the device whenever available. All patients requiring tracheal intubation and without exclusion criteria could be included in the study. All the anesthesia providers at the participating institutions took part in the study.

All patients were monitored as usual with electrocardiogram, peripheral oxygen saturation (Spo_2), and arterial blood pressure (noninvasive or invasive as appropriate).

The anesthesia technique, including choice of drugs and order of administration,[21] size of blades, and use of adjuvant airway device (eg, stylet, Bougie), was at the discretion of the anesthesia provider providing patient care. In case of use of neuromuscular blockers, cisatracurium was universally used and muscle relaxation was assessed using a train of four (TOF) monitoring.

For each Macintosh-VL, 3 consecutive steps were performed in the same order and are summarized in Figure 1.

Step I. After preoxygenation for 3 minutes according to the institution protocol followed by anesthesia induction, the first step was to rate the glottic visualization with the Cormack-Lehane (CL) scoring system[23] using the Macintosh-VLs by direct laryngoscopy with the Macintosh-style blade.

Step II. The second step was to rate the glottic visualization with the Macintosh-VLs by indirect laryngoscopy (using the Macintosh-style blade); if the CL grade was ≤II, the operator made an intubation attempt; if the CL grade was ≥III, the operator moved to the third step without attempting intubation. Head repositioning or backward upward rightward pressure/external laryngeal pressure was permitted at this step. Intubation using a Bougie was not permitted with a CL III/IV view. The need to go to the third step was the primary outcome variable.

Step III. The third step was performed only in case of CL grade ≥III (III or IV) or if the intubation attempt at the second step failed. This step was mandatorily performed by a senior anesthesiologist (defined as a physician, attending anesthesiologist). The Macintosh-style blade was switched to the hyperangulated blade—X blade for the McGrath Mac, D Blade for the C-MAC-S and the C-MAC-S-PM, Difficult Airway Blade (DAB) for the APA—using the same device. After rating the new glottic visualization (fourth rating) using the hyperangulated blade, the operator made an intubation attempt.

An intubation attempt was defined as the insertion of the laryngoscope blade into the mouth of the patient and the attempt to insert an endotracheal tube. At our institution, usual practice is to stop the laryngoscopy and to resort to bag-mask ventilation in case of Spo_2 dropping below 90%. The choice of an alternative technique after 2 failed intubation attempts was recommended by the study protocol and was in accordance with clinical standard.[6,7,22] The alternative technique was left at the discretion of the physician.

Data Collection

The perioperative data collected by the operator consisted of

- Demographic information (height, weight, age).
- Airway evaluation (Mallampati class, mouth opening, thyromental distance, neck range of motion, interincisor gap, medical history of difficult intubation).
- Type and amount of drugs administered during induction.
- Operator status: physician, resident, or anesthetic nurse.
- Assessment of the glottic visualization using the CL scoring system.
- Number of intubation attempt(s).
- Need to change to a different intubation device, and use of adjuvant airway devices (eg, stylet,

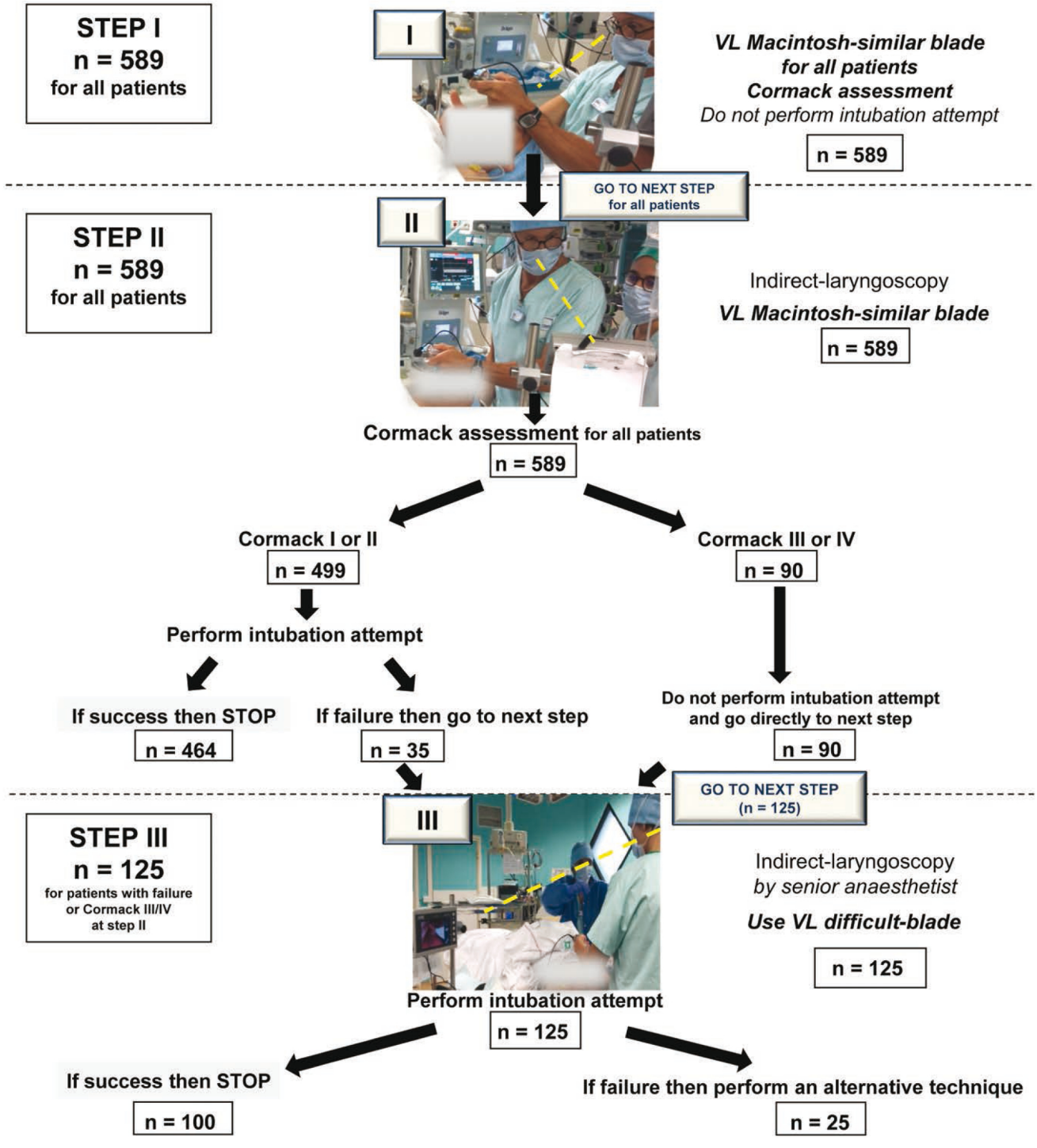

Figure 1. Methodology of the quality improvement project. Three steps were performed. Step I: After preoxygenation for 3 min according to the institution protocol and anesthesia induction, the first step was to rate the glottic visualization, using the Macintosh-VLs by direct laryngoscopy with the Macintosh-style blade. Step II: The second step was to rate the glottic visualization (third rating) with the Macintosh-VLs by indirect laryngoscopy (using the Macintosh-style blade); if the CL grade was ≤II, the operator made an intubation attempt; if the CL grade was ≥III, the operator moved to the third step without attempting intubation. Step III: The third step was performed only in case of CL grade ≥III (III or IV) or if the intubation attempt at the second step failed. This step was mandatorily performed by a senior anesthesiologist. The Macintosh-style blade was switched to the hyperangulated blade, using the same device. After rating the new glottic visualization (fourth rating) using the hyperangulated blade, the operator made an intubation attempt. An intubation attempt was defined as the insertion of the laryngoscope blade into the mouth of the patient and the attempt to insert a tracheal tube. The choice of an alternative technique after 2 intubation attempts was recommended by the study protocol and was in accordance with clinical standard.[6,7,22] The alternative technique was left to the appreciation of the physician. CL indicates Cormack-Lehane; VL, videolaryngoscope.

Bougie). The decision to use a stylet for intubation at step II was made by the operator before performing the first attempt.
- Vital signs (Spo_2, heart rate, blood pressure).
- Subjective appreciation of the use of the device (easy, difficult, impossible).
- Degree of ease or difficulty of tracheal intubation based on the numeric rate scale (NRS; 0 = easy to 10 = difficult) and of user-friendliness (0 = not user friendly to 10 = totally user friendly) based on NRS. No free text was accompanying this assessment, only an NRS was provided to the assessor.
- Quality of the image (bad, passable, good, very good, excellent).

Primary Outcome

The primary outcome was the need to move to step III (using a hyperangulated blade because of failure to intubate at step II or CL grade III/IV at step III).

Secondary Outcomes

- Glottic visualization assessed by CL score using the Macintosh-VL by direct laryngoscopy with the Macintosh-style blade, the Macintosh-VL by indirect laryngoscopy with the Macintosh-style blade, and if step III was reached, the Macintosh-VL by indirect laryngoscopy with the hyperangulated blade.
- CL III and IV scores with the Macintosh-VL by indirect laryngoscopy with the Macintosh-style blade (step II).
- Number of laryngoscopy attempts.
- Adverse effects (hypoxemia defined by Spo_2 <90%, bradycardia defined by heart rate <50 bpm, hypotension defined by systolic arterial pressure <90 mm Hg).
- Subjective appreciation of the use of the device.
- Degree of ease or difficulty of tracheal intubation and of user-friendliness.
- Quality of the image.

Exploratory Outcomes

- Successful tracheal intubation with the Macintosh-style blade by indirect laryngoscopy (step II).
- Successful tracheal intubation with the hyperangulated blade (step III).
- Successful tracheal intubation at step II and step III.
- Failures/crossovers to other rescue techniques.

Statistical Analysis

Quantitative variables were expressed as means ± standard deviation (SD) and qualitative variables were expressed as numbers (percentage). Comparison of means was performed using analysis of variance and Tukey's test for multiple comparisons in quantitative outcomes (number of laryngoscopy attempts, NRS difficulty of intubation, and NRS user-friendliness).

Comparison of device groups was made using a χ^2 test for binary outcomes (the need to move to step III, CL III and IV scores, successful intubation at step II, successful intubation at step II and step III, adverse effects) and a Kruskal-Wallis test for ordinal qualitative outcomes (CL scores [I–IV], subjective appreciation of the use of the device [easy, difficult, impossible], and quality of image [bad, passable, good, very good, excellent]). Regarding outcomes recorded in step III, conditional nature of step III makes comparisons here well confounded by the primary outcome results and results of this conditional phase will be descriptive.

For the main outcome (use of a hyperangulated blade), a mixed effect multivariable logistic regression model was performed to assess the relation between the main outcome and the VL group, and adjust for confounding and considering center as a random effect. All variables with P value <.20 in the univariate analysis (as presented in Table 1), age (defined a priori), and body mass index (BMI, defined a priori) were entered into the model. Prespecified interactions between BMI and group, and age and group were tested.

All P values were 2-tailed. A P value ≤.008 (0.05/6) was considered statistically significant after Bonferroni correction for 6 comparisons between devices. Confidence intervals (CI) were computed for associations of interest (99.2% CI after adjustment). Statistical analysis was performed using SAS software version 9.4 (SAS Institute, Cary, NC).

Expecting a difference of use of the hyperangulated blade of 20% between 2 of the 4 Macintosh-VLs (from 30% to 10%),[24] we calculated the sample size as 97 per device, using a χ^2 test, with α level of .008 (taking into account multiple comparisons) and a power of 0.80. We decided to include 125 patients per device (total of 500 patients) to compensate for dropouts and missing data, and calculated that 4 months would allow to include at least the required number of subjects.

RESULTS

From May 2017 to September 2017, 589 patients were included (Figure 2). The demographic variables, operator characteristics, and the choice of drugs did not differ between the 4 Macintosh-VLs (Table 1; Supplemental Digital Content, Table 1, http://links.lww.com/AA/D127). Among airway characteristics, thyromental distance <6 cm was significantly more frequent in the C-MAC-S-PM and APA than in the McGrath Mac and the C-MAC-S, whereas the presence of at least 1 predictive factor of difficult intubation did not significantly differ between Macintosh-VLs (Table 1).

Table 1. Patient's Airway and Operator Characteristics in the 4 Macintosh Videolaryngoscopes Groups

Characteristics	McGrath Mac	C-MAC-S	C-MAC-S-PM	APA	*P*
General characteristics	(n = 180)	(n = 132)	(n = 139)	(n = 138)	
Age (y)	56 ± 18	55 ± 18	58 ± 18	56 ± 18	.58
Weight (kg)	74 ± 21	79 ± 19	76 ± 17	75 ± 19	.08
Height (cm)	168 ± 10	168 ± 10	169 ± 9	169 ± 10	.68
BMI (kg/m^2)	26 ± 7	28 ± 7	26 ± 6	26 ± 6	.24
Airway assessment					
Thyromental distance <6 cm	8/180 (4%)	5/128 (4%)	20/138 (14%)[a,b]	18/138 (13%)[c,d]	.0008
Interincisor distance <3 cm	21/180 (12%)	18/128 (14%)	21/138 (15%)	15/138 (11%)	.67
Limited cervical spine extension	21/180 (12%)	19/128 (15%)	19/138 (14%)	23/138 (17%)	.63
No cervical spine extension	7/180 (4%)	2/128 (2%)	0/138 (0%)	1/138 (1%)	.04
Mallampati score					.52
Mallampati score 1	85/177 (48%)	52/125 (22%)	73/135 (22%)	63/134 (47%)	
Mallampati score 2	45/177 (25%)	44/125 (42%)	32/135 (54%)	43/134 (32%)	
Mallampati score 3	33/177 (19%)	22/125 (18%)	23/135 (17%)	21/134 (16%)	
Mallampati score 4	14/177 (8%)	7/125 (6%)	7/135 (5%)	7/134 (5%)	
Previous difficult intubation	23/179 (13%)	11/125 (9%)	14/138 (10%)	9/133 (7%)	
At least 1 predictive criteria of difficult intubation	73/180 (41%)	54/128 (41%)	55/138 (40%)	43/138 (31%)	.28
Operator status					
Physician (senior anesthesiologist)	51/176 (29%)	49/129 (38%)	43/135 (32%)	47/136 (35%)	.40
Resident	30/176 (17%)	26/129 (20%)	33/135 (24%)	26/136 (19%)	.44
Anesthetist nurse	95/176 (54%)	54/129 (42%)	59/135 (44%)	63/136 (46%)	.14

Data are summarized as mean ± SD or n (%).
Abbreviations: BMI, body mass index; SD, standard deviation.
[a]C-MAC-S-PM ≠ McGrath Mac.
[b]C-MAC-S-PM ≠ C-MAC-S.
[c]APA ≠ McGrath Mac.
[d]APA ≠ C-MAC-S.

Primary Outcome

The hyperangulated blade was used in 22 of 180 patients (12%) for the McGrath Mac, in 29 of 139 patients (21%) for the C-MAC-S-PM, in 39 of 132 patients (30%) for the C-MAC-S, and in 35 of 138 patients (25%) for the APA (Table 2). By multivariable analysis, the following variables were entered in the model: age, BMI, center, thyromental distance <6 cm, no cervical spine extension. After adjustment for BMI, the McGrath Mac was associated with less frequent use of hyperangulated blade than the C-MAC-S (odds ratio [OR] [99.2% CI] 0.34 [0.16–0.77]; P = .0005), the APA (OR [99.2% CI] 0.42 [0.19–0.93]; P = .004), but not the C-MAC-S-PM (OR [99.2% CI] 0.53 [0.23–1.2]; P = .04, Figure 3).

Secondary and Exploratory Outcomes

Step I. In direct laryngoscopy using the Macintosh-VLs (Macintosh-style blade), the CL scores were significantly lower with the McGrath Mac than with the other Macintosh-VLs.

Step II. The glottic visualization with the Macintosh-VL was significantly better using indirect laryngoscopy than using direct laryngoscopy for all Macintosh-VLs (Table 2).

The number of Cormack III and IV grades was significantly lower for the McGrath Mac than for the C-MAC-S and the APA (Table 2). The rates of successful intubation at step II were the following: n = 158/166 (95.2% [90.8–99.6]) for the McGrath Mac, n = 93/99 (93.9% [87.6–1.00]) for the C-MAC-S, n = 110/121 (90.9% [84.0–97.8]) for the C-MAC-S-PM, n = 103/113 (91.2% [84.1–98.2]) for the APA (Table 2). Thirty-seven percent of intubation attempts were performed using a stylet (Table 2).

Step III. The rates of successful intubation at step III are presented in Table 2. Glottic visualization and alternative devices used in patients who reached step III in the 4 Macintosh-VLs are presented in Supplemental Digital Content, Table 2, http://links.lww.com/AA/D127.

For All Steps. Overall, the number of intubation attempts was significantly lower using the McGrath Mac than the C-MAC-S or the C-MAC-S-PM VLs (Table 2). Intubation was successful in more than 90% of attempts, whatever the device used.

No serious adverse events occurred during the assessment period, and the rate of complications did not differ between Macintosh-VLs (Supplemental Digital Content, Table 3, http://links.lww.com/AA/D127).

The assessment of difficulty of intubation and user-friendliness of devices, respectively, showed lower and higher NRS scores for the McGrath Mac device compared to the other devices (Supplemental Digital Content, Table 3, http://links.lww.com/AA/D127).

The subjective assessment of image quality showed higher quality for the C-MAC-S and C-MAC-S-PM

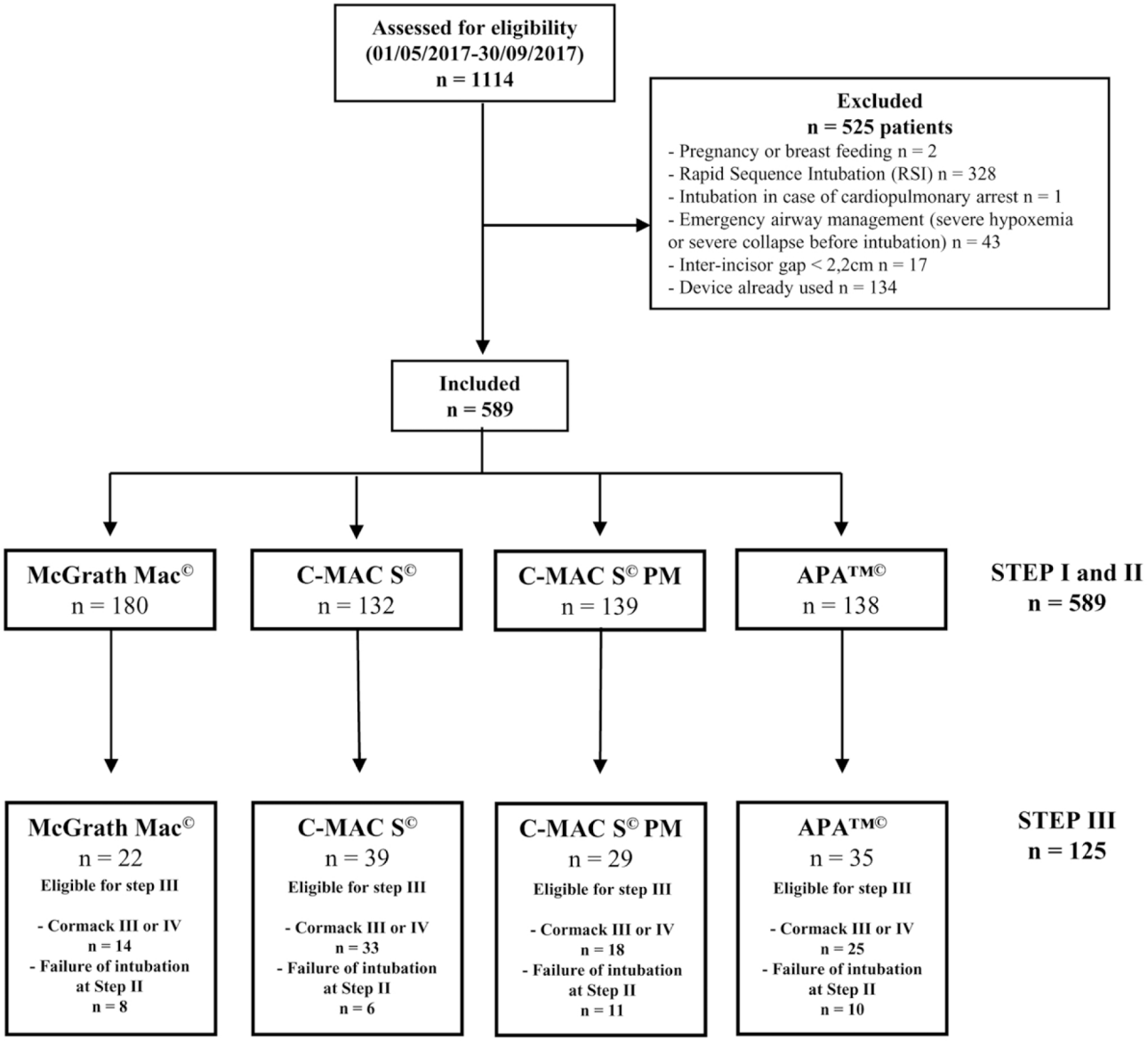

Figure 2. Flow chart of the study. Among 1114 patients assessed for eligibility, 589 patients were included, 180 in the McGrath Mac group, 132 in the C-MAC-S group, 139 in the C-MAC S PM group, and 138 in the APA group. The use of a hyperangulated blade was required in 22/180 (12%) in the McGrath Mac group, 39/132 (30%) in the C-MAC-S group, 29/139 (21%) in the C-MAC-S-PM group, and 35/138 (25%) in the APA group.

compared to the APA or McGrath Mac (Supplemental Digital Content, Table 3, http://links.lww.com/AA/D127).

DISCUSSION

In this quality improvement project aiming to select 1 Macintosh-VL, the McGrath Mac showed better performances than other Macintosh-VLs, was associated with less need to resort to a hyperangulated blade, and showed greater user-friendliness than other devices. However, C-MAC-S and C-MAC-S-PM showed better image quality than APA or McGrath Mac.

To our knowledge, this is the first time that the 4 single-use Macintosh-VLs on the market are assessed in a pragmatic human study. Laryngeal exposure was better with the McGrath Mac though the image quality was not as good as the other devices, and the number of overall attempts was reduced with the McGrath Mac. The McGrath Mac was the only device that had a lower CI limit of first-attempt success rate higher than 90%, main criterion in a recent study by Kleine-Brueggeney et al.[24] Previous studies performed by Kleine-Brueggeney et al[24] in a simulated difficult airway and by Shin et al[25] in a manikin that compared the McGrath Mac and the reusable C-MAC found no significant differences between the devices in terms of successful intubation rate and glottic visualization. One explanation to these apparent discrepancies is that, as required by French law, all the Macintosh-VLs devices used in the current study had single-use

Table 2. Outcomes According to Steps I, II, and III in the 4 Macintosh Videolaryngoscope Groups

Outcomes	McGrath Mac N = 180	C-MAC-S N = 132	C-MAC-S-PM N = 139	APA N = 138	*P*
CL score at step I (Videolaryngoscope, DL, Macintosh-style blade)					.001
1	104/180 (58%)	50/132 (38%)	72/139 (52%)	61/138 (44%)	
2	39/180 (22%)	31/132 (24%)	29/139 (21%)	37/138 (27%)	
3	28/180 (15%)	40/132 (30%)	29/139 (21%)	26/138 (19%)	
4	9/180 (5%)	11/132 (8%)	9/139 (6%)	14/138 (10%)	
CL score 3 or 4	37/180 (20%)	51/132 (38%)[a]	38/139 (27%)	40/138 (29%)	.006
Mean CL score at step I (Macintosh-style blade)	1.68 ± 0.91	2.10 ± 1.01[a]	1.82 ± 0.98	1.95 ± 1.02	.001
CL score at step II (Videolaryngoscope, IL, Macintosh-style blade)					<.0001
1	146/180 (81%)	67/132 (51%)	89/139 (64%)	80/138 (58%)	
2	20/180 (11%)	32/132 (24%)	32/139 (23%)	33/138 (24%)	
3	12/180 (7%)	27/132 (20%)	12/139 (9%)	16/138 (12%)	
4	2/180 (1%)	6/132 (5%)	6/139 (4%)	9/138 (6%)	
CL score 3 or 4	14/180 (8%)	33/132 (25%)[a]	18/139 (13%)	25/138 (18%)[b]	.0002
Mean CL score at step II	1.28 ± 0.64	1.79 ± 0.93[a]	1.54 ± 0.84[c]	1.67 ± 0.92[b]	<.0001
Successful intubation at step II	158/166 (95%)	93/99 (94%)	110/121 (91%)	103/113 (91%)	.43
Stylet use	56/159 (35%)	43/100 (43%)	46/104 (44%)	32/112 (29%)	ND
Malleable stylet	30/49 (61%)	30/43 (70%)	20/37 (54%)	18/29 (62%)	
Rigid stylet	18/49 (37%)	13/43 (30%)	13/37 (35%)	8/29 (28%)	
Eschmann stylet	1/49 (2%)	0/43 (0%)	4/37 (11%)	3/29 (10%)	
Step III rate (primary outcome)	22/180 (12%)	39/132 (30%)[a]	29/139 (21%)	35/138 (25%)[b]	.001
CL score at step III (Videolaryngoscope, IL, hyperangulated blade, and senior anesthetist as operator)					ND
1	17/22 (77%)	23/39 (59%)	17/29 (59%)	19/35 (54%)	
2	0/22 (0%)	12/39 (31%)	5/29 (17%)	8/35 (23%)	
3	4/22 (18%)	4/39 (10%)	4/29 (14%)	6/35 (17%)	
4	1/22 (5%)	0/39 (0%)	3/29 (10%)	2/35 (6%)	
CL score 3 or 4	5/22 (23%)	4/39 (10%)	7/29 (24%)	8/35 (23%)	ND
Mean CL score at step III	1.50 ± 0.96	1.51 ± 0.68	1.76 ± 1.06	1.74 ± 0.95	ND
Stylet use	18/20 (90%)	33/39 (85%)	17/22 (77%)	6/28 (21%)	ND
Malleable stylet	13/18 (72%)	15/27 (55%)	10/16 (62%)	4/5 (80%)	
Rigid stylet	5/18 (28%)	8/27 (30%)	3/16 (19%)	1/5 (20%)	
Eschmann stylet	0/18 (0%)	4/27 (15%)	3/16 (19%)	0/5 (0%)	
Successful intubation at step III	19/22 (86%)	36/39 (92%)	21/29 (72%)	24/35 (69%)	ND
Successful intubation at steps II and III	177/180 (98%)	129/132 (98%)	131/139 (94%)	127/138 (92%)	.02
Number of attempts	1.14 ± 0.42	1.32 ± 0.71[a]	1.31 ± 0.58[c]	1.27 ± 0.63	.005

Data are summarized as mean ± SD or n (%). Comparison of means was performed using analysis of variance and Tukey's test for multiple comparisons. Comparison of percentages was performed using a χ^2 test for nonordinal outcomes and a Kruskal-Wallis test for ordinal outcomes (CL scores). A *P* value ≤.008 (0.05/6) was considered statistically significant after Bonferroni correction for 6 pairwise comparisons among the 4 Macintosh videolaryngoscope groups for each outcome variable.

Abbreviations: CL, Cormack-Lehane; DL, direct laryngoscopy; IL, indirect laryngoscopy; ND, not done (as the sample size for each group here is conditional on requiring step III, no statistical testing was done); SD, standard deviation.

[a]C-MAC-S value > McGrath Mac value.

[b]APA value > McGrath Mac value.

[c]C-MAC S PM value > McGrath Mac value.

blade, whereas the reusable C-MAC was assessed in the 2 other studies.[24,25] The blade used in the reusable C-MAC differs from the blade used in the C-MAC S and the C-MAC S PM, being less thick in the reusable C-MAC. Moreover, Shin et al's[25] study was a manikin study so the results cannot be fully extrapolated to human subjects, and Kleine-Brueggeney et al[24] excluded all subjects with known or predicted difficult airway (BMI >35 kg·m^{-2}, Mallampati score >III, thyromental distance >3.5 cm, known difficult mask ventilation/laryngoscopy, and planned or history of awake tracheal intubation). It is also worth noting that whereas the main aim of our pragmatic study was to assess the Macintosh-style blade in indirect laryngoscopy, Kleine-Brueggeney et al[24] focused on the hyperangulated blade dedicated to difficult airway.

Despite its relatively poor image quality (Supplemental Digital Content, Table 3, http://links.lww.com/AA/D127), the McGrath Mac was chosen by most operators as the most "user-friendly" device providing the easiest intubation (Supplemental Digital Content, Table 3, http://links.lww.com/AA/D127). These results are in line with the more frequent use of the McGrath Mac device than others (n = 180 compared to n = 132, 139, and 138 for other devices). Even if 1 device was available for each anesthesia department, and the anesthesiologists were strongly encouraged to use the device as often as possible, it is likely that the more the Macintosh-VL was considered

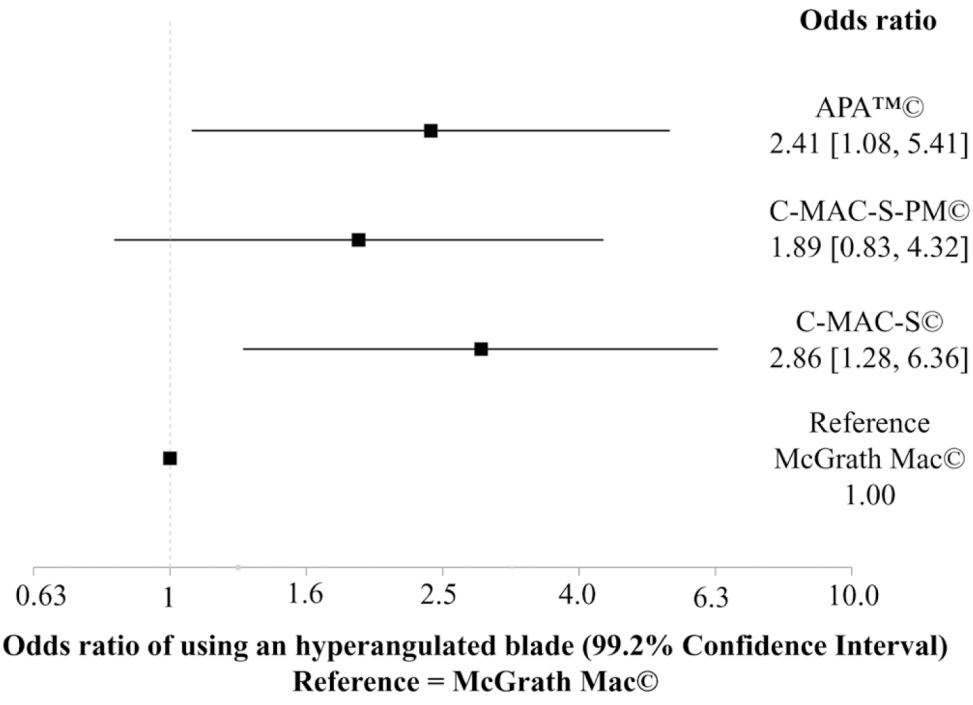

Figure 3. Main outcome (need of a hyperangulated blade) for each Macintosh videolaryngoscope after multivariable analysis. The hyperangulated blade was used in 22 of 180 patients (12%) for the McGrath Mac, in 29 of 139 patients (21%) for the C-MAC-S-PM, in 39 of 132 patients (30%) for the C-MAC-S, and in 35 of 138 patients (25%) for the APA. By multivariable analysis, the following variables were entered in the model: age, BMI, center, thyromental distance <6 cm, no cervical spine extension. After adjustment for BMI, the McGrath Mac was associated with less frequent use of hyperangulated blade than the C-MAC-S (OR [99.2% CI] 0.34 [0.16–0.77]; *P* = .0005), the APA (OR [99.2% CI] 0.42 [0.19–0.93]; *P* = .004), but not the C-MAC-S-PM (OR [99.2% CI] 0.53 [0.23–1.2]; *P* = .04). BMI indicates body mass index; CI, confidence interval; OR, odds ratio.

effective, the more it was used in this quality improvement project. As the operators were not experienced with the McGrath Mac, it is unlikely that the more frequent use of the McGrath MAC results from greater familiarity. By contrast, the C-MAC-S delivered the best quality image but was not deemed the most user-friendly device. As in previous studies,[25] image quality does not seem to affect the proportion of successful attempts. However, the teaching quality of the VL, making it possible for a supervisor to observe the trainee's actions during direct laryngoscopy and give advice,[26] might be more strongly associated with the quality of image and warrants further studies. Moreover, the difficulties assessed by the user-friendliness NRS might have resulted from insufficient familiarity with or training on the devices used.

Finally, it is worth noting that higher BMI was significantly associated with more use of a hyperangulated blade. These results are consistent with the findings of recent studies showing higher odds of difficult intubation in case of higher BMI.[1,27]

The aim of this quality improvement project was in line with recent guidelines.[5,28] All anesthesiologists should be trained to use, and have immediate access to, a VL. Proficiency with VL intubation is unlikely to be achieved if there are several different devices across 1 hospital.[29–31] Developing expertise requires frequent rather than exceptional use,[2] in operating room[5] as in intensive care unit (ICU)[28,32,33] or emergency settings.[34] Cook et al[17] reported the conversion to VL as a routine first-choice option throughout a hospital's anesthetic and ICU practice. Consistent with this study, the results observed in the current study suggest that a single device to be used for easy and difficult intubation can be successfully implemented in operating room. One could suggest that these devices could even replace the standard-Macintosh laryngoscope in operating rooms.[17,35] The use of a single effective device for easy and difficult intubation might decrease the number of intubation attempts and by extension the complications related to the number of intubation attempts.[29,36,37] An abundant literature shows that delayed, difficult, or failed intubation is a major risk factor of harm and death in the patient with difficult airway.[15,38] However, although the McGrath MAC may have outperformed the other Macintosh-VL devices, none performed well enough to be advocated as a "universal" method, with a failure rate of 125/589 (21%) for the proposed universal VL. An alternative strategy would be to retain Macintosh laryngoscope and resort to a hyperangulated VL as a routine or rescue technique. There is evidence, though no prospective study, that the latter strategy is highly effective.[36] Indeed, regular use of a hyperangulated blade would increase familiarity, providing improved laryngeal visualization and fewer conversions to alternative techniques.

There are some limitations to discuss. First, this is a nonblinded nonrandomized quality improvement project, which weakens the conclusions. Providers had a choice as to whom to include in the study, so the trial was not purely randomized, which is a major confounding factor. However, the order of testing each Macintosh-VL in each center was randomly selected and the data were prospectively collected. Second, operator experience with the use of VL varied from new users to experienced users. However, as the groups did not differ regarding operator characteristics, it is unlikely that the comparison between groups could have been biased. As the name of the operator was not systematically recorded, we were not able to assess the improvement of their performance. Third, concerns have been raised about the use of the CL grading system during videolaryngoscopy. Although many studies have demonstrated that videolaryngoscopy improves the view, this does not always translate into easier tracheal intubation. Alternatives like the intubation difficulty scale[39] could have been used as an index of difficulty for both direct and indirect laryngoscopes. Fourth, since step III was a conditional step depending on the results of step II, results for step III should interpreted descriptively and with caution. Fifth, the study was powered for a very large effect (10% vs 30% with the primary outcome). Power was moderate/low for smaller differences that would still be clinically important for the binary outcomes. Negative results on binary outcomes cannot be taken as definitive. Sixth, even after further adjusting for confounding as recommended, there is a potential for residual confounding bias, which is a main concern in this study. The patient's positioning was not standardized, whereas positioning impacts laryngoscopy (and VL) view. The use of head repositioning and backward upward rightward pressure/external laryngeal pressure have not been recorded and might have resulted in improved laryngeal exposure with less need to convert to a hyperangulated blade. Thyromental distance <6 cm appeared more frequently in the patients in whom the CMAC-S was used, introducing the possibility of bias. However, the thyromental distance <6 cm was not significant in the final multivariable model. Moreover, the presence of at least 1 factor for difficult intubation did not differ between groups. Seventh, the CL score does not reflect the ease or difficulty of tracheal intubation. However, the CL score provides a reasonable description of the quality of laryngoscopy (for both direct and indirect methods) but does not equate with the ease of intubation (by either direct or indirect methods).

In conclusion, the glottic visualization in direct and indirect laryngoscopy with the Macintosh-style blade was significantly improved with the McGrath Mac compared to other Macintosh-VLs, leading to a decreased resort to the hyperangulated blade and overall number of intubation attempts. Among VLs, MacGrath-Mac might be the preferred VL and eventually become the standard VL.

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