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Macintosh Videolaryngoscope for intubation in the operating room: a comparative quality improvement project

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UNIVERSITE DE MONTPELLIER
FACULTE DE MEDECINE MONTPELLIER-NÎMES

THESE

Pour obtenir le titre de

DOCTEUR EN MEDECINE

Présentée et soutenue publiquement

Par

Alexandre LAPLACE-BUILHÉ

Le 06 mars 2020

Titre :

**"Quel Vidéolaryngoscope Macintosh utiliser au bloc opératoire ?
Une évaluation prospective multicentrique"**

Directrice de thèse : Dr Audrey DE JONG

JURY :

Monsieur le Professeur Samir JABER, Président

Monsieur le Professeur Pascal COLSON, Assesseur

Monsieur le Professeur Gérald CHANQUES, Assesseur

Madame le Docteur Audrey DE JONG, Assesseur

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Aux chirurgiens, nos indispensables partenaires !

Aux équipes d'infirmiers anesthésistes, aux infirmiers en réanimation et aux aide-soignant !

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Macintosh Videolaryngoscope for intubation in the operating room: a comparative quality improvement project

Glossary:

VL = videolaryngoscopy

SpO₂ = peripheral oxygen saturation

CL = Cormack-Lehane

NRS = Numeric Rate Scale

SD = Standard deviation

CI = Confidence Interval

BMI = Body Mass index

INTRODUCTION

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(3–5) and un-anticipated(6–9) difficult intubation has been widely recognized. High-profile national guidelines(6,7) 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(10) by skilled providers declined significantly.(11,12) Furthermore, teaching with videolaryngoscopes can improve intubation skills in medical students.(9,13)

New devices, including APA™®, C-MAC-S® (single-use), C-MAC-S-PM® (pocket and single-use) and McGrath Mac®, are called “Macintosh” VLs.(5,14–17) They can be used both as direct and indirect-laryngoscopes. Two types of blades are available: first a Macintosh-style blade which integrates video capability and can be used to perform both indirect and direct-

laryngoscopy.(18) On the other hand a hyperangulated blade is available in order to further improve glottic visualization(19,20) for difficult laryngoscopy, which can be used only in indirect-laryngoscopy.(19)

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.

MATERIALS AND METHODS

A. 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 which 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(21). Requirement for written informed consent was waived by the Institutional Review Board.

The four Macintosh-videolaryngoscopes assessed were loaned to the anesthesia departments for the duration of the 5 month trial. Representatives of each company providing devices for the trial 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, NM), 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.

B. Population

Inclusion criteria

Patients aged ≥ 18 years that required oro-tracheal intubation during general anesthesia were included.

Exclusion criteria

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

C. Interventions

Four devices were used including the McGrath Mac[®] (Medtronic Covidien, USA), the C-MAC-S[®] (Karl Storz, Germany), the C-MAC-S Pocket Monitor[®] (PM) (Karl Storz, Germany) 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 were not available and only Glidescope[®] (Verathon, USA) VL was available and routinely used in case of difficult intubation.(1)

The anesthesiologists had no experience with the respective devices prior to participating in the study. In order to choose one Macintosh-VL for the institution, each of the four anesthesia departments assessed each of the four devices during one month in a randomized order: May (one period), June (one period), July- August together (due to the reduced number of patients undergoing anesthesia and surgery during the summer, one period) and September (one period).

One device was available for each anesthesia department (multiple patients could not be enrolled

simultaneously in the same anesthesia department, i.e. 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 (SpO₂) and arterial blood pressure (non-invasive or invasive as appropriate).

The anesthesia technique, including choice of drugs and order of administration,(22) size of blades and use of adjuvant airway device (ex, 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 TOF monitoring. For each Macintosh-VL, three 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, using the Cormack-Lehane (CL) scoring system,(23) using the Macintosh-VLs in direct-laryngoscopy with the Macintosh-style blade.

Step II: The second step was to rate the glottic visualization with the Macintosh-VLs in indirect-laryngoscopy (using the Macintosh-style blade); If the CL grade was \leq II, the operator made an intubation attempt, if the CL grade was \geq 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 \geq 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 Pocket Monitor[®], 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 peripheral oxygen saturation dropping below 90%. The choice of an alternative technique after two failed intubation attempts was recommended by the study protocol and was in accordance with clinical standard.(7,8,24) The alternative technique was left at the discretion of the physician.

D. 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, inter-incisor 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 (ex, stylet, Bougie). The decision to use a stylet for intubation at Step II was made by the operator before performing the first attempt.
- Vital signs (SpO₂, heart rate, blood pressure)

- Degree of ease or difficulty of tracheal intubation based on the Numeric Rate Scale (NRS) (0=easy to 10=difficult)
- Degree of user-friendliness (0= not user friendly to 10= totally user friendly) and quality of the image (0=bad to 10=perfect) based on NRS

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 in direct-laryngoscopy with the Macintosh-style blade, the Macintosh-VL in indirect-laryngoscopy with the Macintosh-style blade and if step III was reached the Macintosh-VL in indirect-laryngoscopy with the hyperangulated blade
- Cormack I and II scores with the Macintosh-VL in indirect-laryngoscopy with the Macintosh-style blade (step II)
- Number of laryngoscopy attempts
- Adverse effects (hypoxemia defined by SpO₂<90%, bradycardia defined by heart rate <50 bpm, hypotension defined by systolic arterial pressure <90mmHg)
- Degree of ease or difficulty of tracheal intubation based on the NRS (0=easy to 10=difficult)
- Degree of user-friendliness (0= not user friendly to 10= totally user friendly) and quality of the image (0=bad to 10=perfect) based on NRS. No free text was accompanying this assessment, only an NRS was provided to the assessor.

Exploratory outcomes

- Proportion of successful attempts at tracheal intubation with the Macintosh-style blade in indirect-laryngoscopy (step II)

- Proportion of successful attempts at tracheal intubation with the hyperangulated blade (Step III)
- Failures/crossovers to other rescue techniques

E. Statistical analysis

Quantitative variables were expressed as means \pm standard deviation (SD) and qualitative variables were expressed as numbers (percentage). Comparison of means for unpaired data was performed using analysis of variance and Tukey's test for multiple comparisons. Comparison of percentages was performed using a Chi square test with Bonferroni correction for 6 comparisons (a P value < 0.008 was considered significant). Confidence intervals (CI) were computed for associations of interest (99.2% CI after adjustment). For paired repeated data (Differences in CL score between steps), comparison was performed using a linear mixed effect model, for each VL group, including the subject as a random effect. 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. All variables with p-value less than 0.20 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. The center was taken into account as a random effect. Pre-specified interactions between BMI and group, and age and group were tested.

All P values were two-tailed and exact. A P value < 0.008 was considered statistically significant after Bonferroni correction for 6 comparisons. 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 two of the four Macintosh-VLs (from 30% to 10%),⁽²⁵⁾ we calculated the sample size as 97 per device, using a chi square test, with α level of 0.008 (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 four 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 four Macintosh-VLs (Table 1, Supplemental Table 1). 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 one predictive factor of difficult intubation did not significantly differ between Macintosh-VLs (Table 1).

A. Primary outcome

The hyperangulated blade was used in 22/180 patients (12%) for the McGrath Mac[®], in 29/139 patients (21%) for the C-MAC-S-PM[®], in 39/132 patients (30%) for the C-MAC-S[®] and in 35/138 patients (25%) for the APA[™] (Table 2, Supplemental Figure 1). 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 C-MAC-S[®] (OR, 99.2% CI of 0.34 (0.16, 0.77), p=0.0005), or APA[™] (OR, 99.2% CI of 0.42 (0.19, 0.93), p=0.004), but not C-MAC-S-PM[®] (OR, 99.2% CI of 0.53 (0.23, 1.2), p=0.04, Figure 3).

B. 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 I and II grades was significantly higher for the McGrath Mac[®] than for the C-MAC-S[®] and the APA[™] (Table 2, Figure 4). 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, Figure 4). Thirty-seven percent (37%) 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 and Supplemental Figure 1. Glottic visualization and alternative devices used in patients who reached step III in the four Macintosh-VLs are presented in Supplemental Table 2.

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 Table 3).

The subjective appreciation 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 Table 3 and Figure 4). The subjective assessment of image quality showed higher NRS scores for the C-MAC-S[®] and C-MAC-S-PM[®] compared to the APA[™] or McGrath Mac[®] (Supplemental Table 3).

DISCUSSION

In this quality improvement project aiming to select one Macintosh-VL, the McGrath Mac[®] showed better performances than others Macintosh-VLs, reduced 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 four 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 (Figure 3), and the number of overall attempts were reduced with the McGrath Mac[®]. The McGrath Mac[®] was the only device which had a lower CI limit of first-attempt success rate higher than 90%, main criterion in a recent study by Kleine-Brueggeney et al.(25). Previous studies performed by Kleine-Brueggeney et al.(25)²⁵ in simulated difficult airway and by Shin et al.(26) in manikin which 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 are that, as required by French law, all the Macintosh-VLs devices used in the current study had single-use blade, whereas the reusable C-MAC[®] was assessed in the two other studies.(25,26) 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's study(26) was a manikin study so the results cannot be fully extrapolated to human subjects, and Kleine et al.(25) excluded all subjects with known or predicted difficult airway (BMI>35 kg.m⁻², Mallampati score>III, thyromental distance>3.5cm, known difficult mask ventilation/laryngoscopy and planned or previous history of awake tracheal intubation). It is also worth nothing that whereas the main aim of our pragmatic study was to assess the Macintosh-style blade in indirect-laryngoscopy, Kleine et al.(25) focused on the hyperangulated blade dedicated to difficult airway.

Despite its relatively poor image quality (Supplemental Table 3), the McGrath Mac[®] was chosen by most operators as the most “user friendly” device providing the easiest intubation (Figure 4). 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 one device was available for each anesthesia department, and the anesthesiologists strongly encouraged to use the device as often as possible, it is likely that the more the Macintosh-VL was considered 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,(26) 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,(27) may be more strongly associated with the quality of image and warrants further studies. Moreover, the difficulties assessed by the user-friendliness NRS may 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.(1,28)

The aim of this quality improvement project was in line with recent guidelines.(6,29) All anesthesiologists should be trained to use, and have immediate access to, a videolaryngoscope. Proficiency with videolaryngoscope intubation is unlikely to be achieved if there are several different devices across one hospital.(30–32) Developing expertise requires frequent rather than exceptional use,(2) in operating room(6) as in ICU(29,33,34) or emergency settings.(35) Cook et al.(18) 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.(18) The use of a single effective device for easy and difficult intubation may decrease the number of intubation attempts and by extension the complications related to the number of intubation attempts.(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.(16,38) 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 non-blinded non-randomized 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 Cormack–Lehane 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 to capture indices of difficulty common to 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 be interpreted descriptively and with caution. Fifth, the study was powered for a very large effect (10% versus 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 patients' 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 may have resulted in improved laryngeal exposure with a reduced 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 one 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).

CONCLUSION

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 may be the preferred VL and eventually become the standard VL.

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FIGURE LEGENDS

Figure 1. Methodology of the quality improvement project

Three steps were performed:

- **Step I:** After preoxygenation for 3 minutes according to the institution protocol and anesthesia induction, the first step was to rate the glottic visualization, using the Macintosh-VLs in direct-laryngoscopy with the Macintosh-style blade.
- **Step II:** The second step was to rate the glottic visualization (third rating) with the Macintosh-VLs in indirect-laryngoscopy (using the Macintosh-style blade); If the CL grade was \leq II, the operator made an intubation attempt, if the CL grade was \geq III, the operator moved to the third step without attempting intubation.
- **Step III:** The third step was performed only in case of CL grade \geq 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 two intubation attempts was recommended by the study protocol and was in accordance with clinical standard.^{7,8,24} The alternative technique was left at the appreciation of the physician.

VL = videolaryngoscope

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.

Figure 3. Main outcome (need of a hyperangulated blade) for each Macintosh videolaryngoscope after multivariable analysis

The hyperangulated blade was used in 22/180 patients (12%) for the McGrath Mac[®], in 29/139 patients (21%) for the C-MAC-S-PM[®], in 39/132 patients (30%) for the C-MAC-S[®] and in 35/138 patients (25%) for the APA[™]. By multivariable analysis, the following variables were entered in the model: age, body mass index (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 C-MAC-S[®] (OR, 99.2% CI of 0.34 (0.16, 0.77), p=0.0005), or APA[™] (OR, 99.2% CI of 0.42 (0.19, 0.93), p=0.004), but not C-MAC-S-PM[®] OR, 99.2% CI of 0.53 (0.23, 1.2), p=0.04, Figure 3).

Figure 4. Subjective evaluation for each Macintosh videolaryngoscope

The subjective appreciation of difficulty of intubation and user friendliness of devices respectively showed lower and higher numeric rating scale (NRS) scores for the McGrath Mac[®] device compared to the other devices.

* Significantly differ from McGrath Mac[®]

FIGURE 1. Methodology of the quality improvement project

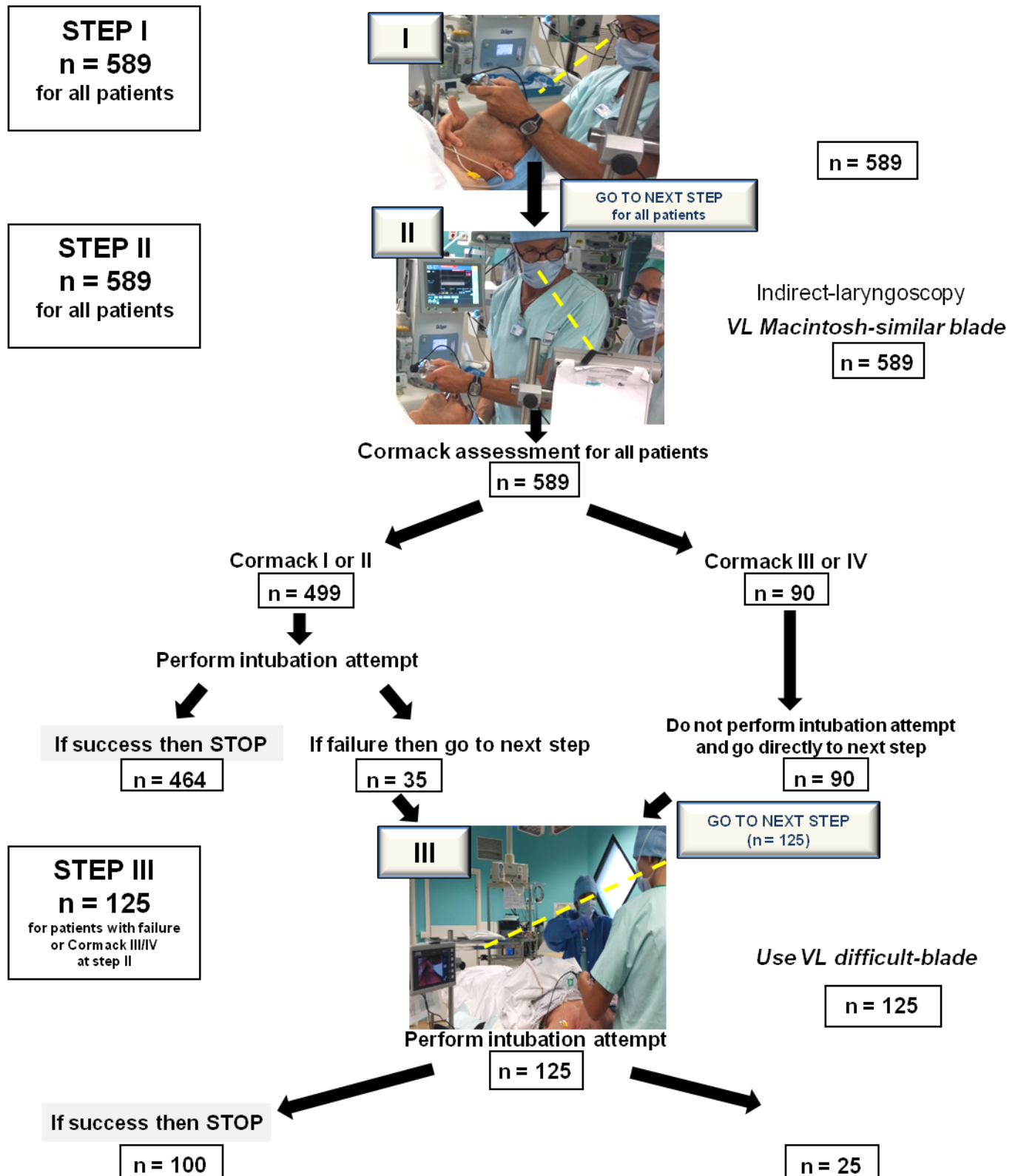


FIGURE 2. Flow chart of the study

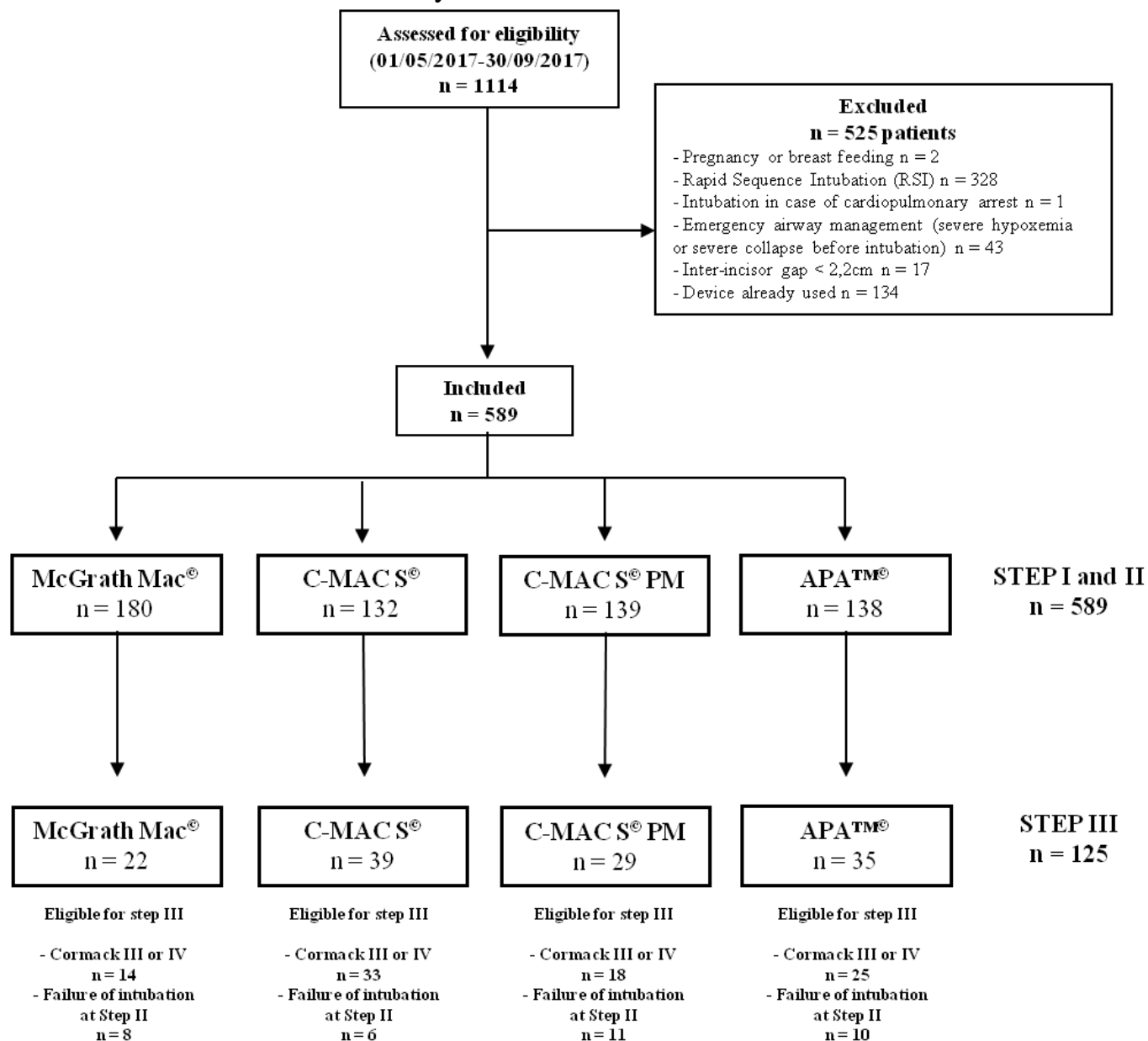


FIGURE 3. Main outcome (need of a hyperangulated blade) for each Macintosh videolaryngoscope after multivariable analysis

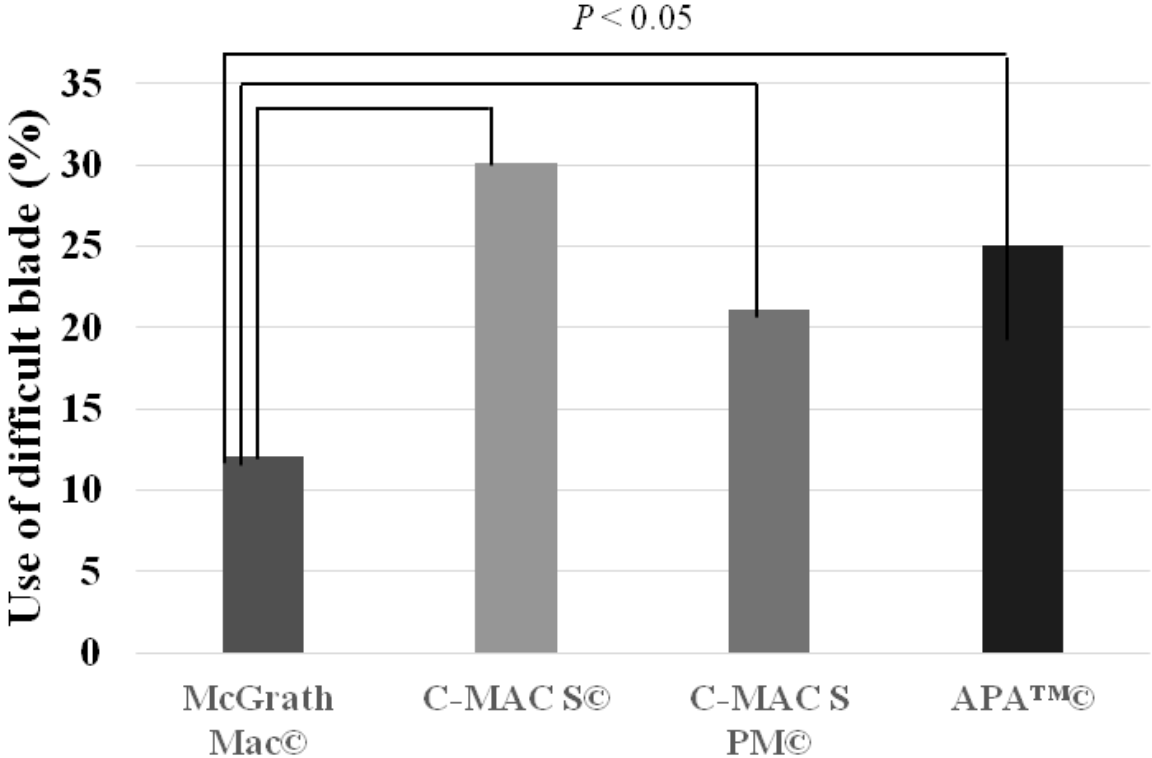


FIGURE 4. Subjective evaluation for each Macintosh videolaryngoscope

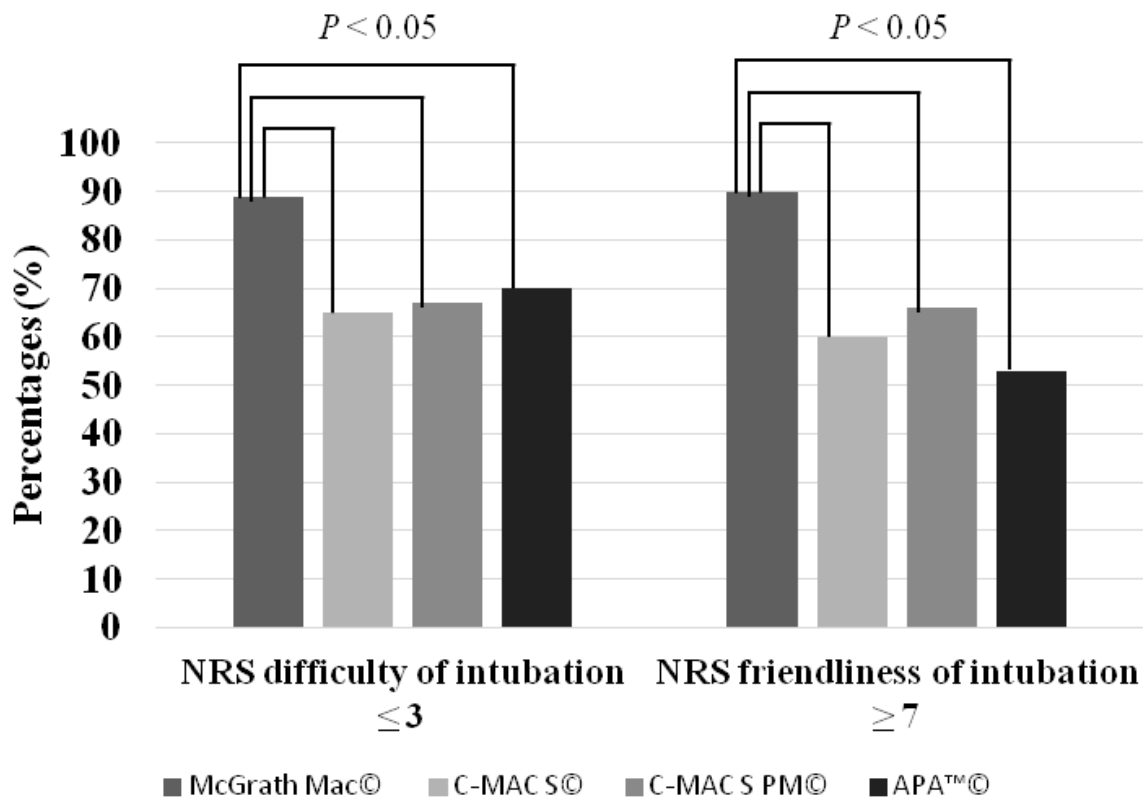


TABLE 1. Patients; airway and operator characteristics in the four Macintosh videolaryngoscopes groups

Characteristics	McGrath Mac [©]	C-MAC-S [©]	C-MAC-S-PM [©]	APA TM [©]	<i>P</i> Values
General characteristics	(n = 180)	(n = 132)	(n = 139)	(n = 138)	
Age (years)	56 ± 18	55 ± 18	58 ± 18	56 ± 18	0.58
Weight (kg)	74 ± 21	79 ± 19	76 ± 17	75 ± 19	0.08
Height (cm)	168 ± 10	168 ± 10	169 ± 9	169 ± 10	0.68
BMI (kg/m ²)	26 ± 7	28 ± 7	26 ± 6	26 ± 6	0.24
Airway assessment					
Thyromental distance < 6cm	8/180 (4%)	5/128 (4%)	20/138 (14%)** ^{\$}	18/138 (13%)* ^{***\$}	0.0008
Inter-incisor distance < 3cm	21/180 (12%)	18/128 (14%)	21/138 (15%)	15/138 (11%)	0.67
Limited cervical spine extension	21/180 (12%)	19/128 (15%)	19/138 (14%)	23/138 (17%)	0.63
No cervical spine extension	7/180 (4%)	2/128 (2%)	0/138 (0%)	1/138 (1%)	0.04
Mallampati score					0.52
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 one predictive criteria of difficult intubation	73/180 (41%)	54/128 (41%)	55/138 (40%)	43/138 (31%)	0.28
Operator status					
Physician (senior anesthesiologist)	51/176 (29%)	49/129 (38%)	43/135 (32%)	47/136 (35%)	0.40
Resident	30/176 (17%)	26/129 (20%)	33/135 (24%)	26/136 (19%)	0.44
Anesthetist nurse	95/176 (54%)	54/129 (42%)	59/135 (44%)	63/136 (46%)	0.14

Data are summarized as mean ± SD or n (%). NA = Not Available. * C-MAC-S[©] ≠ McGrath Mac[©]; ** C-MAC-S-PM[©] ≠ McGrath Mac[©]; *** APATM[©] ≠ McGrath Mac[©].

TABLE 2. Outcomes according to step I, II and III in the four Macintosh videolaryngoscope groups

Outcomes	McGrath Mac [®] N = 180	C-MAC S [®] N = 132	C-MAC S PM [®] N = 139	APA [™] [®] N = 138	P Values
<i>CL score at step I (Videolaryngoscope, DL, Macintosh-style blade)</i>					
1	104/180 (58%)	50/132 (38%)*	72/139 (52%)	61/138 (44%)	0.003
2	39/180 (22%)	31/132 (24%)	29/139 (21%)	37/138 (27%)	0.64
3	28/180 (15%)	40/132 (30%)	29/139 (21%)	26/138 (19%)	0.01
4	9/180 (5%)	11/132 (8%)	9/139 (6%)	14/138 (10%)	0.33
CL score 3 or 4	37/180 (20%)	51/132 (38%)*	38/139 (27%)	40/138 (29%)	0.006
Mean CL score at step I (Macintosh-style blade)	1.68 ± 0.91	2.10 ± 1.01*	1.82 ± 0.98	1.95 ± 1.02	0.001
<i>CL score at step II (Videolaryngoscope, IL, Macintosh-style blade)</i>					
1	146/180 (81%)	67/132 (51%)*	89/139 (64%)**	80/138 (58%)***	<0.0001
2	20/180 (11%)	32/132 (24%)*	32/139 (23%)	33/138 (24%)***	0.006
3	12/180 (7%)	27/132 (20%)*	12/139 (9%)	16/138 (12%)	0.002
4	2/180 (1%)	6/132 (5%)	6/139 (4%)	9/138 (6%)	0.09
CL score 3 or 4	14/180 (8%)	33/132 (25%)*	18/139 (13%)	25/138 (18%)***	0.0002
Mean CL score at step II	1.28 ± 0.64	1.79 ± 0.93*	1.54 ± 0.84**	1.67 ± 0.92***	<0.0001
Difference CL score Step I - Step II ^h	0.40 ± 0.67	0.30 ± 0.68	0.28 ± 0.66	0.28 ± 0.63	0.20
Successful intubation at step II	158/166 (95%)	93/99 (94%)	110/121 (91%)	103/113 (91%)	0.43
Stylet use	56/159 (35%)	43/100 (43%)	46/104 (44%)	32/112 (29%)	0.06
Malleable stylet	30/49 (61%)	30/43 (70%)	20/37 (54%)	18/29 (62%)	0.67
Rigid stylet	18/49 (37%)	13/43 (30%)	13/37 (35%)	8/29 (28%)	0.81
Eschmann stylet	1/49 (2%)	0/43 (0%)	4/37 (11%)	3/29 (10%)	0.06

Step III rate (primary outcome)	22/180 (12%)	39/132 (30%)*	29/139 (21%)	35/138 (25%)***	0.001
<i>CL score at step III (Videolaryngoscope, IL, hyperangulated blade and senior anesthetist as operator)</i>					
1	17/22 (77%)	23/39 (59%)	17/29 (59%)	19/35 (54%)	ND
2	0/22 (0%)	12/39 (31%)	5/29 (17%)	8/35 (23%)	ND
3	4/22 (18%)	4/39 (10%)	4/29 (14%)	6/35 (17%)	ND
4	1/22 (5%)	0/39 (0%)	3/29 (10%)	2/35 (6%)	ND
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
Difference CL score Step II - Step III	1.09 ± 0.97	1.46 ± 0.85	0.93 ± 0.92	1.03 ± 0.99	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%)	ND
Rigid stylet	5/18 (28%)	8/27 (30%)	3/16 (19%)	1/5 (20%)	ND
Eschmann stylet	0/18 (0%)	4/27 (15%)	3/16 (19%)	0/5 (0%)	ND
Successful intubation at step III	19/22 (86%)	36/39 (92%)	21/29 (72%)	24/35 (69%)	ND
Successful intubation at step II and III	177/180 (98%)	129/132 (98%)	131/139 (94%)	127/138 (92%)	0.02
Number of attempts	1.14 ± 0.42	1.32 ± 0.71*	1.31 ± 0.58**	1.27 ± 0.63	0.005

Data are summarized as mean ± SD or n (%). CL = Cormack-Lehane. ND = Not Done (as the sample size for each group here is conditional on requiring step III, no statistical testing was done). DL = Direct Laryngoscopy. IL = Indirect Laryngoscopy

[#] The difference between Cormack-Lehane score obtained using the videolaryngoscope in direct vision and the Cormack-Lehane score obtained using videolaryngoscope in indirect vision differs significantly from 0 in the overall population and in all the videolaryngoscopes ($P < 0.008$).

* C-MAC-S[®] ≠ McGrath Mac[®] ** C-MAC S PM[®] ≠ McGrath Mac[®] *** APA[™] ≠ McGrath Mac[®] [§] C-MAC S PM[®] ≠ C-MAC-S[®] ^{§§} APA[™] ≠ C-MAC-S[®] [£] APA[™] ≠ C-MAC S PM[®] ($P < 0.008$)

SUPPLEMENTAL MATERIAL

Macintosh Videolaryngoscopes for intubation in the operating room:

A comparative quality improvement project

SUPPLEMENTAL TABLE 1. Drugs characteristics in the four Macintosh videolaryngoscopes groups

	McGrath Mac [®]	C-MAC S [®]	C-MAC S PM [®]	APA [™]	P Values
Drugs at induction					
Propofol	146/174 (84%)	99/128 (77%)	103/136 (76%)	108/133 (81%)	0.28
Propofol posology (mg)	304 ± 153	303 ± 136	271 ± 134	271 ± 130	0.14
Ketamine	25/174 (14%)	20/128 (16%)	23/136 (17%)	20/132 (15%)	0.94
Ketamine posology (mg)	22 ± 7	23 ± 12	19 ± 8	18 ± 7	0.17
Thiopentone	1/174 (1%)	0/128 (0%)	0/136 (0%)	0/132 (0%)	1.00
Thiopentone posology (mg)	NA	0	0	0	-
Etomidate	10/174 (6%)	3/128 (2%)	5/136 (4%)	2/132 (2%)	0.23
Etomidate posology (mg)	26 ± 9	20 ± 0	28 ± 9	20 ± 0	0.55
Sufentanil	132/174 (76%)	78/128 (61%)*	93/136 (68%)	95/132 (72%)	0.04
Sufentanil posology (mcg)	14 ± 4	15 ± 5	16 ± 7	15 ± 5	0.12
Remifentanil	2/174 (1%)	7/128 (5%)	6/136 (4%)	8/132 (6%)	0.12
Remifentanil posology (mcg)	70 ± 0	144 ± 96	67 ± 34	110 ± 17	0.41
Cisatracurium	85/174 (49%)	79/128 (62%)	59/136 (43%)	62/132 (47%)	0.02
Cisatracurium posology (mg)	13 ± 3	13 ± 3	12 ± 5	12 ± 3	0.21
Atracurium	5/174 (3%)	3/128 (2%)	5/136 (4%)	4/135 (3%)	0.95
Atracurium posology (mg)	31 ± 6	40 ± 5	35 ± 10	34 ± 11	0.66
Succinylcholine	0/174 (0%)	2/128 (2%)	0/136 (0%)	0/132 (0%)	0.05
Succinylcholine posology (mg)	0	53 ± 66	0	0	-
Rocuronium	0/174 (0%)	0/128 (0%)	1/136 (1%)	0/132 (0%)	0.95
Rocuronium posology (mg)	0	0	50 ± 0	0	-
Midazolam	0/174 (0%)	3/128 (2%)	3/136 (2%)	4/132 (3%)	0.08
Midazolam posology (mg)	0	1 ± 0	1 ± 1	8 ± 8	0.14
Propofol TIVA	24/174 (14%)	29/128 (23%)	31/136 (23%)	24/132 (18%)	0.14
Sufentanil TIVA	1/174 (1%)	15/128 (12%)*	4/136 (3%) [§]	2/132 (2%) ^{§§}	<0.0001
Remifentanil TIVA	31/174 (18%)	23/128 (18%)	29/136 (21%)	24/132 (18%)	0.86

Data are summarized as mean ± SD or n (%). NA = Not Available. TIVA = Total intravenous anesthesia

* C-MAC ≠ MacGrath ** C-MAC pocket ≠ MacGrath *** APA ≠ MacGrath

SUPPLEMENTAL TABLE 2. Glottis visualization and alternative devices used in patients who reached step 3 in the four Macintosh videolaryngoscopes groups

	McGrath Mac [®]	C-MAC S [®]	C-MAC S PM [®]	APA [™]	P Values
<i>CL score at step 2 (Videolaryngoscope, Macintosh blade)</i>					
1	3/22 (14%)	1/39 (3%)	4/29 (14%)	7/35 (20%)	0.09
2	5/22 (23%)	5/39 (13%)	7/29 (24%)	3/35 (8%)	0.26
3	12/22 (54%)	27/39 (69%)	12/29 (41%)	16/35 (46%)	0.09
4	2/22 (9%)	6/39 (15%)	6/29 (21%)	9/35 (26%)	0.44
Mean CL score at step 2	2.59 ± 0.85	2.97 ± 0.63	2.69 ± 0.97	2.77 ± 1.06	0.41
<i>Macintosh blade size</i>					
3 (n)	27/137 (20%)	17/92 (18%)	18/93 (19%)	20/101 (20%)	0.7670
4 (n)	110/137 (80%)	75/92 (82%)	75/93 (81%)	81/101 (80%)	0.7670
<i>CL score at step 3 of patients who were CL score 3 or 4 at step 2 (Videolaryngoscope, hyperangulated blade and senior anesthetist as operator)</i>					
1	9/14 (64%)	18/33 (55%)	9/18 (50%)	11/25 (44%)	ND
2	0/14 (0%)	11/33 (33%)	2/18 (11%)	6/25 (24%)	ND
3	4/14 (29%)	4/33 (12%)	4/18 (22%)	6/25 (24%)	ND
4	1/14 (7%)	0/33 (0%)	3/18 (17%)	2/25 (8%)	ND
Mean CL score	1.79 ± 1.12	1.58 ± 0.71	2.06 ± 1.21	1.96 ± 1.02	ND
Difference CL score Step 2 vs Step 3 ^u	1.36 ± 1.08	1.61 ± 0.83	1.28 ± 0.96	1.40 ± 0.91	ND

CL score at **step 3** of patients who were CL score 1 or 2 at **step 2** (*Videolaryngoscope, hyperangulated blade and senior anesthetist as operator*)

1	8/8 (100%)	5/6 (83%)	8/11 (73%)	8/10 (80%)	ND
2	0/8 (0%)	1/6 (17%)	3/11 (27%)	2/10 (20%)	ND
3	0/8 (0%)	0/6 (0%)	0/11 (0%)	0/10 (0%)	ND
4	0/8 (0%)	0/6 (0%)	0/11 (0%)	0/10 (0%)	ND
Mean CL score	1.00 ± 0.00	1.17 ± 0.41	1.27 ± 0.47	1.20 ± 0.42	ND
Difference CL score Step 2 - Step 3 ^{¶¶}	0.63 ± 0.52	0.67 ± 0.52	0.36 ± 0.50	0.10 ± 0.32	ND
Failure of intubation at Step III	3/22 (14%)	3/39 (8%)	8/29 (28%)	11/35 (31%)	ND
Alternatives techniques used in case of failure at Step III					
Standard Macintosh Laryngoscope		1/3 (33%)	5/8 (63%)	5/11 (45%)	-
Other VL dedicated to difficult intubation	3/3 (100%)	1/3 (33%)		6/11 (55%)	-
Same VL used in DL		1/3 (34%)			-
Straight blade			1/8 (12%)		-
Spontaneous ventilation without intubation			1/8 (12%)		-
Laryngeal mask			1/8 (13%)		-

Data are summarized as mean ± SD or n (%).

NA = Not Available. CL = Cormack-Lehane. ND = Not Done (as the sample size for each group here is conditional on requiring step III, no statistical testing was done).

[¶] The difference between Cormack-Lehane score obtained using the videolaryngoscope in indirect vision with the Macintosh blade and the Cormack-Lehane score obtained using videolaryngoscope in indirect vision with the hyperangulated blade differs significantly from 0 in the overall population and in all the videolaryngoscopes.

^{¶¶} The difference between Cormack-Lehane score obtained using the videolaryngoscope in indirect vision with the Macintosh blade and the Cormack-Lehane score obtained using videolaryngoscope in indirect vision with the hyperangulated blade did not differ significantly from 0.

* C-MAC ≠ MacGrath ** C-MAC pocket ≠ MacGrath *** APA ≠ MacGrath \$ C-MAC Pocket ≠ C-MAC \$\$ APA ≠ C-MAC

£ APA ≠ C-MAC Pocket

SUPPLEMENTAL TABLE 3. Complications, subjective appreciation and quality of image in the four Macintosh videolaryngoscope groups

	McGrath Mac [®]	C-MAC S [®]	C-MAC S PM [®]	APA [™] [®]	P Values
Complications					
Hypoxemia	6/177 (3%)	14/130 (11%)*	6/134 (5%)	8/134 (6%)	0.0452
Bradycardia	1/177 (1%)	3/130 (2%)	4/135 (3%)	5/135 (4%)	0.2799
Hypotension	6/177 (3%)	5/129 (4%)	7/134 (5%)	7/135 (5%)	0.8184
At least one	12/176 (7%)	20/129 (16%)	15/132 (11%)	18/134 (13%)	0.0953
Subjective appreciation					
Easy	159/170 (94%)	96/123 (78%)*	104/127 (82%)**	109/129 (84%)	0.0013
Difficult	9/170 (5%)	23/123 (19%)*	15/127 (12%)	10/129 (8%)	0.0016
Impossible	2/170 (1%)	4/123 (3%)	8/127 (6%)	10/129 (8%)	0.0442
NRS difficulty of intubation	1 ± 2	3 ± 3*	3 ± 3**	3 ± 3***	< 0.0001
NRS ≤ 3	144/161 (89%)	80/124 (65%)*	85/126 (67%)**	89/127 (70%***)	< 0.0001
4 ≤ NRS ≤ 6	13/161 (8%)	34/124 (27%)*	25/126 (20%)**	19/127 (15%)	0.0002
7 ≤ NRS	4/161 (2%)	10/124 (8%)	16/126 (13%)**	19/127 (15%***)	0.0011
NRS conviviality for devices	9 ± 2	7 ± 2*	7 ± 3**	6 ± 3***	< 0.0001
NRS ≤ 3	5/163 (3%)	13/123 (11%)	16/128 (13%)**	24/129 (19%***)	0.0003
4 ≤ NRS ≤ 6	12/163 (7%)	36/123 (29%)*	27/128 (21%)**	36/129 (28%***)	< 0.0001
7 ≤ NRS	146/163 (90%)	74/123 (60%)*	85/128 (66%)**	69/129 (53%***)	< 0.0001
Quality of image					
Bad	20/175 (11%)	2/126 (2%)*	5/135 (4%)	19/133 (15%)	< 0.0001
Passable	59/175 (34%)	7/126 (5%)*	15/135 (11%)**	44/133 (33%)	< 0.0001
Good	54/175 (31%)	42/126 (33%)	52/135 (39%)	52/133 (39%)	0.3665
Very good	33/175 (19%)	59/126 (47%)*	45/135 (33%)**	15/133 (11%) ^{\$\$}	< 0.0001
Excellent	9/175 (5%)	16/126 (13%)	18/135 (13%)**	3/133 (2%) ^{\$\$}	0.0007

Data are summarized as mean ± SD or n (%).

NA = Not Available. NRS = Numeric Rating Scale

* C-MAC ≠ MacGrath ** C-MAC pocket ≠ MacGrath *** APA ≠ MacGrath § C-MAC Pocket ≠ C-MAC \$\$ APA ≠ C-MAC

£ APA ≠ C-MAC Pocket

SERMENT

- En présence des Maîtres de cette école, de mes chers condisciples et devant l'effigie d'Hippocrate, je promets et je jure, au nom de l'Être suprême, d'être fidèle aux lois de l'honneur et de la probité dans l'exercice de la médecine.

- Je donnerai mes soins gratuits à l'indigent et n'exigerai jamais un salaire au-dessus de mon travail.

- Admis (e) dans l'intérieur des maisons, mes yeux ne verront pas ce qui s'y passe, ma langue taira les secrets qui me seront confiés, et mon état ne servira pas à corrompre les mœurs, ni à favoriser le crime.

- Respectueux (se) et reconnaissant (e) envers mes Maîtres, je rendrai à leurs enfants l'instruction que j'ai reçue de leurs pères.

- Que les hommes m'accordent leur estime si je suis fidèle à mes promesses.
Que je sois couvert (e) d'opprobre et méprisé (e) de mes confrères si j'y manque.

RÉSUMÉ

Introduction : Les Vidéolaryngoscopes (VLs) “Macintosh” sont des dispositifs utilisés pour l’intubation permettant de réaliser à la fois une laryngoscopie directe et indirecte. Dans le cadre d’une évaluation prospective multicentrique au CHRU de Montpellier, nous avons comparé les performances de 4 VLs Macintosh en vision directe et indirecte.

Méthodes: Il s’agit d’un projet-qualité visant à généraliser au bloc opératoire l’utilisation des VLs Macintosh pour toutes les intubations afin d’améliorer la gestion des voies aériennes. Les 4 VLs Macintosh testés étaient : le McGrath-Mac[®], le C-MAC-S[®], le C-MAC-S-Pocket-Monitor[®] (PM) et l’APA[™]. L’évaluation se déroulait en 3 étapes consécutives : I) une laryngoscopie directe avec le VL Macintosh, II) une laryngoscopie indirecte avec le VL Macintosh (en cas de Cormack I ou II, une tentative d’intubation avait lieu), III) Tentative d’intubation en ayant recours à la lame hyperangulée, toujours en vision indirecte, en cas de Cormack III/IV ou échec à l’étape précédente. Le critère de jugement principal était le besoin de recourir à la lame hyperangulée (étape III). Une analyse multivariée avec régression logistique a été réalisée, une valeur de p-value<0.008 était considérée comme statistiquement significative.

Résultats : De Mai à Septembre 2017, 589 patients ont été inclus. L’utilisation du McGrath-Mac[®] (22/180 (12%)) était associée à moins de recours à la lame hyperangulée que l’utilisation du C-MAC-S[®] (39/132 (30%), odds ratio (OR) = 0.34 avec un intervalle de confiance (IC) à 99.2% [0.16-0.77], p=0.005 et de l’APA[®] (35/138 (25%), OR=0.42, IC 99.2% [0.19-0.93], p=0.004, contrairement à l’utilisation du C-MAC-S-PM[®] (29/139 (21%), OR=0.53, IC99.2% [0.23-1.2], p=0.04). Globalement le nombre de tentatives d’intubation était significativement moins important en utilisant le McGrath-Mac[®] que les autres vidéolaryngoscopes. Le McGrath-Mac[®] obtenait également les meilleures appréciations subjectives en termes de facilité d’intubation et de convivialité-ergonomie. Cependant l’évaluation subjective concernant la qualité de l’image montrait des scores sur l’échelle visuelle numérique meilleurs pour le C-MAC-S[®] et le C-MAC-S-PM[®] que ceux du McGrath Mac[®] et de l’APA[®].

Conclusion: Parmi les quatre VLs Macintosh à usage unique testés, le McGrath Mac[®] améliorait de manière significative la visualisation directe et indirecte de la glotte, réduisant à la fois le recours à la lame hyperangulée et le nombre de tentatives d’intubation.

Mots clés : Voies aériennes, Vidéolaryngoscope Macintosh, Intubation, Bloc opératoire, Vidéolaryngoscopes