Design evaluation of commonly used rigid and levering laryngoscope blades

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Background: The shape of a laryngoscope blade affects the exposition of the larynx. This study evaluates and compares some rigid and levering blade designs based on previous investigative X-ray laryngoscopic studies.

Methods: Five rigid laryngoscope blades (Miller #3, Standard Macintosh #3, Classical Macintosh #4 and English-Macintosh #3 and #4) and two levering laryngoscope blades (McCoy in neutral and maximally elevated positions and Flexiblade in three basic positions: straight, neutral, and maximally curved) were evaluated. This study assesses two parameters derived from the depth of insertion: the eye line deviation from the ideal straight view line to the vocal cords, and the space occupied by the blade behind the mandible, which affects the contact of the blade tip with the base of the tongue.

Results: The best results on larynx exposition were produced by the English-Macintosh #4 at all insertion depths between 5 and 14 cm. It surpassed the Classical Macintosh #4 and both the English and Standard Macintosh #3. Although the Miller and the Flexiblade in a straight position afford a nearly ideal view line, both blades reduce the space reserved for the tongue behind the mandible. The McCoy with its tip maximally elevated provides limited view, while activation of the Flexiblade provides various ranges of larynx exposition.

Conclusion: The difference in shape and design of Macintosh blades affects their performance. The distal portion of a large-sized curved blade is more effective than the full length of a shorter blade. The #4 English Macintosh is a better choice for routine clinical use. The Flexiblade performs as a multiblade device and can therefore be used for both routine and difficult intubations.

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Successful direct laryngoscopy requires the fulfilment of two essential conditions: (a) elevation of the epiglottis by compression of the laryngoscope blade tip, and (b) a clear view into the vocal cords. Intubating conditions, apart from varying anatomic structures, are highly dependent on the shape and length of the laryngoscope blade. A Macintosh blade is generally regarded as the preferred blade whenever there is a little upper airway room, and a Miller blade is considered convenient for use in patients with small mandibular space, large incisors, or a long and floppy epiglottis (1, 2).

During difficult endotracheal intubation with a Macintosh laryngoscope, the application of increased lifting force combined with a levering movement of the blade is inevitable. In this case, the patient is exposed to potential damage, and the upper teeth may be inadvertently used as a fulcrum (3). The engineering design of the McCoy levering laryngoscope was one of the first attempts to address these difficulties. Having its fulcrum at a lower point within the pharynx, it was expected to simplify the elevation of the epiglottis and the exposure of the larynx, reducing contact with the upper incisor teeth (4).

The ‘Flexiblade’ is a new laryngoscope with the same concept of an internal levering blade but with a wider range of movements (5, 6) (Fig. 1F).

Marks et al. (1993) suggested criteria for laryngoscope evaluation (7). This criteria is based upon measurements of two angular parameters representing (a) the eye line deviation from the straight ideal line of view to the laryngeal inlet, and (b) the amount of space occupied by the blade behind the mandible (Fig. 2). The available space behind the mandible was shown by several investigators to be correlated with the difficulty of laryngoscopy and tracheal intubation (8–10). If the tongue is not compressible, there may be difficulty in exploring the vocal cords. It follows that the amount of space the laryngoscope blade itself occupies behind the mandible is an important factor when space is already limited. Failure of a blade tip to put tension on the hyoepiglottic ligament when
using a Macintosh or inability to trap the epiglottis against the tongue when using a Miller because of compression of soft tissues between the blade and the buccal surface of the mandible, has been described in cases of difficult laryngoscopy (1, 11–15).

A reproducible laboratory method to evaluate blade design was derived from X-ray observations of laryngoscopy during general anesthesia in normal individuals. Using this method, the influence of the laryngoscope’s blade shape is outlined by depth-of-insertion profiles, which are quantified by the two angular parameters mentioned earlier (7,8). The eye line deviation angle from the ideal line of view is termed EIT (Fig. 2): I is one of many points on the blade flange that may have contact with the incisor teeth of the patient during laryngoscopy. This point represents insertion depths; IT is the ideal straight line of view to the vocal cords (it is also referred to as the anterior airway line); IE is the real line of view, which is limited by the lower lingual surface of the blade. The second parameter is termed MIT (Fig. 2). It is the angle representing the amount of space occupied by the blade behind the mandible (space that normally is housed by the tongue): M is set on the upper lingual surface of the blade, and it is crossed by a line perpendicular to the IT line; J is a point mid-way between the mandibular condyles; S is the internal mid-point of the symphysis menti; the line JS is at the level of the

Fig. 1. Various shapes of rigid and levering laryngoscope blades: (A) Standard Macintosh; (B) Classical Macintosh, (C) Miller blade, (D) English Macintosh, (E) McCoy with blade maximally elevated, and (F) Flexiblade in various positions.
Design evaluation of laryngoscope BLADES

Fig. 2. X-ray laryngoscopy showing the contact point of the upper incisor teeth with the blade (marking the depth of insertion), and the hyoid points of contact with the blade’s tip, forming the line IT (the ideal straight line of view). The eye line deviation, IE, which is the actual real line of view, is a tangent line from I to the lower lingual surface of the blade. SJ is the line from the internal mid-point of the mandibular symphisis menti S to the mid-point of the mandibular condyles J. The point of intersection of IT and SJ is C. M lies on the upper lingual surface of the blade at the level of the mandible, and is perpendicular to IT (see text).

mandible, the same level at which space restriction occurs; the line JS crosses IT at an angle of approximately 90° when the mouth is closed around the blade; the point of intersection of IT and JS is C, which lies at approximately one-third of the length of IT from point I. Hence, a line perpendicular to IC marks the level of the mandible relative to IT. MIT thus influences how close the laryngoscope blade can move toward the mandible, and thus indicates either forward space encroachment or forward space enhancement. When point M lies in front of the line IT, the derived angle is positive and the blade is then said to encroach/occupy part of the available forward space. This is an important factor when space is already limited. The MIT angle can be negative when the point M lies behind the line IT. The space between the blade and the mandible is then either increased or enhanced (8, 11).

Marks et al. examined two types of rigid laryngoscope blades (7): (a) the classical curved Macintosh blades, and (b) the straight-shaped Soper and Miller blades. Their study tested only the classical Macintosh blades (the levering laryngoscopes were not available at that time).

In the present study, we reproduced the design evaluation of various laryngoscope blades, while adding two other Macintosh blades to the classical one, i.e. the Standard Macintosh and the English Macintosh. Two levering laryngoscopes, the McCoy in two basic positions, and the Flexiblade in three basic positions were also evaluated (Fig. 1).

Methods

In the present study, we evaluated the seven blade models most frequently used in our institutions. These blade models are divided into rigid and levering blade types. (Fig. 1 and Table 1)

The group of rigid blades included four Macintosh blades and one Miller blade. There were two Macintosh #3: a Standard Macintosh marked 69063 (SM3) and an English Macintosh E-MAC 69213 (EM3), both from Welch Allyn (Welch Allyn Inc., Skaneatills Falls, NY USA), and two Macintosh #4: a ‘Classical’ Macintosh Shucman 5643 (SM4) (Shucman Truphatek, Netanya, Israel) and an English Macintosh, Welch Allyn E-MAC 69214 (EM4). The only Miller blade was a #3, Welch Allyn 68063 (MIL).

Table 1 Various blades and their parameters.

<table>
<thead>
<tr>
<th>Blade model</th>
<th>Length (mm)*</th>
<th>Web width at 10 cm from tip</th>
<th>Web width at 12 cm from tip</th>
<th>Deviation from X-axis</th>
<th>Distance of deviation**</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-Macintosh (SM3)</td>
<td>126</td>
<td>25 mm</td>
<td>–</td>
<td>32°</td>
<td>40 mm</td>
</tr>
<tr>
<td>E-Macintosh (EM3)</td>
<td>135</td>
<td>15</td>
<td>–</td>
<td>30°</td>
<td>40</td>
</tr>
<tr>
<td>C-Macintosh (SM4)</td>
<td>155</td>
<td>18</td>
<td>21</td>
<td>30°</td>
<td>52</td>
</tr>
<tr>
<td>E-Macintosh (EM4)</td>
<td>156</td>
<td>16</td>
<td>20</td>
<td>35°</td>
<td>60</td>
</tr>
<tr>
<td>Miller #3 (MIL)</td>
<td>172</td>
<td>15</td>
<td>15</td>
<td>12°</td>
<td>150</td>
</tr>
<tr>
<td>McCoy rest (MCN)</td>
<td>150</td>
<td>18</td>
<td>25</td>
<td>35°</td>
<td>50</td>
</tr>
<tr>
<td>McCoy elevated (MCM)</td>
<td>140</td>
<td>18</td>
<td>25</td>
<td>49°</td>
<td>50</td>
</tr>
<tr>
<td>Flexiblade rest (FLN)</td>
<td>167</td>
<td>14</td>
<td>15.5</td>
<td>13°</td>
<td>92</td>
</tr>
<tr>
<td>Flexiblade elevated (FLM)</td>
<td>156</td>
<td>14</td>
<td>15.5</td>
<td>32°</td>
<td>83</td>
</tr>
<tr>
<td>Flexiblade straight (FLD)</td>
<td>170</td>
<td>14</td>
<td>15.5</td>
<td>8°</td>
<td>105</td>
</tr>
</tbody>
</table>

*Overall length, and **Distance measured from the proximal end of the blade web. Rest = neutral position.
The group of levering laryngoscopes blades included a McCoy blade #4 (Mercury Medical, Clearwater, FL, USA, CLM 4 s/s) and a larger sized Flexiblade (similar to the Macintosh #4) made by Arco-Medic (Arco-Medic Ltd, Omen, Israel). The McCoy was studied in two basic positions: the neutral resting position (35° from the X-axis of the blade base; MCN), and with the tip maximally elevated (49° from the X-axis; MCM). The Flexiblade was studied in three basic positions: the neutral resting position (13° from the X-axis; FLN), the maximal curvature position (32° from the X-axis; FLM), and the straight position, which is achieved when the blade is maximally pulled backward (8° from the X-axis; FLD).

The performances of the Flexiblade and the McCoy laryngoscopes were analyzed in comparison with various rigid blade types whose blade could be held at a comparable position. For example, the Flexiblade at its straight position is comparable to the Miller blade while in a neutral or maximally curved/elevated position; both the Flexiblade and the McCoy can be compared with the curved Macintosh blades. These positions are all standard, and are easy to reproduce using both the Flexiblade and the McCoy laryngoscopes.

The two angular parameters, EIT and MIT, were measured from the blade’s photographs, and can be acquired as the blade is placed on a Cartesian graph paper. Angles were drawn on the photographs at various insertion depths starting from a depth of 5 cm, as measurements are based on the anatomy of an adult. Measurements of the McCoy with the tip maximally elevated were performed from the same points of insertion depths as at the neutral position in order to simulate real intubating conditions. The same was applied to the Flexiblade at the straight and maximal curvature positions.

A combination score was produced in order to compare the performance of the various blade types in terms of the eye line deviation and the forward space encroachment/enhancement. This number is the sum of the value of the EIT and MIT angles for each depth of insertion. This scoring method is based on the assumption that an increase in magnitude of the eye line deviation or the forward space encroachment for a certain insertion depth represents deterioration in the performance of the blade (7).

The acquired images were enlarged to enhance the accuracy of the measurements. Highly accurate angle calculations with a resolution of less than 0.5° were made possible through the use of an optical/digital 3-D coordinate measurement system (Bh706, Mitutoyo, Mitutoyo corporation, Japan) and image processing software (Mitutoyo 3D beopak, vs. 3.11, Mitutoyo).

Results

The results of the EIT/MIT performance analysis are summarized in Figs 3 and 4.

The MIL provided a very small eye line deviation from the ideal direct line of view (EIT), as would be expected from its straight design (Fig. 3). Values of less than 2.5° were recorded through all the insertion depth ranges of 5–14 cm. Like the MIL, the FLD presented very similar eye line deviation values, starting from 7-cm insertion depth. The SM4 and the FLN also
demonstrated a small deviation from the ideal line of view (less than 4° for insertion depths lower than 11 cm). Although these blades were shown to provide an adequate EIT, their MIT maintained relatively high values (Fig. 4). For instance, the MIT values of the MIL ranged from 16.5° to 6.5° at all insertion depths between 5 and 13 cm. While the SM4 provided a high initial MIT of 17° at 6 cm, decreasing to 6° at 9-cm insertion depth, and enhancing to −2.7° (negative value) at the deeper insertion depth of 13 cm. The deviation from the ideal straight line of view (EIT) increased for the remainder of the blades: the SM3, the EM3 and EM4, the MCN, and the FLM. As for the MCM, deviations from the ideal line of sight were extremely high at all insertion depths (approximately 12°).

MIT, which is the angle representing the space occupied by the blades behind the mandible, afforded a large variability for most of the blades (Fig. 4). For example, the MIT values at 5-cm insertion depth for the SM3, EM3, EM4, MCN, MCM, and FLM started with 15.3° for the SM3 and ended with 4.2° for the EM4. The above plots then converged toward 8-cm depth of insertion, reached values of approximately 2.7° ± 1.4, and continued to enhance with deeper insertion. The MIT plots indicate that the two blades that minimally affected the space behind the mandible were the MCM and the EM4.

The combined EIT and MIT scores of the rigid and levering blades are presented in Figs 5 and 6. The lowest combination score that integrates a small deviation from the ideal straight line of view with a small degree of space occupied by the blade behind the mandible and covers wider insertion depths can be considered as the ‘best blade’. Hence, the EM4 provided the best performance. Its combined score was the lowest throughout all insertion depths from 5 to 14 cm. The SM3 and the EM3 presented less favorable scores, although better than the other blades. The web width of the curved blades was also apparently important in a clinical context. The web of the EM4 is narrower than that of the Standard and the Classical Macintosh, and this may have had an effect on the space behind the mandible (Table 1).

Careful analysis of the plots describing the combined scores of the levering laryngoscope blades (Fig. 6) reveals that major differences exist between the McCoy and the Flexiblade. The McCoy’s two plots, MCN and MCM, are nearly supra positioned. There are only two points of insertion depth where the lines diverge: at 5 cm and 8 cm. The Flexiblade on the other hand yielded three totally different plots. In the maximally elevated position, the Flexiblade behaved like the McCoy, and both the English and Standard Macintosh blades. In the straight position, the combined plot of the Flexiblade resembled that of the Miller, while in the neutral position, there were elements that resembled the #4 Classical Macintosh at insertion depths between 5 and 8 cm and those of the Miller at deeper insertion depths. The space between these three plots is a space where innumerable variants can be drawn while pulling or liberating the trigger.

**Discussion**

In the present study we employed quantitative performance evaluation of different rigid and levering
laryngoscope blades. The best results were produced by the #4 English Macintosh at all insertion depths between 5 and 14 cm. It surpassed the #4 Classical Macintosh and both the English and Standard Macintosh size 3, which are frequently used by most anesthetists. The results of our study on curved blades were only in partial agreement with those of Marks et al. (1993), probably because of some variations in the design and shape of blade models, even when from the same manufacturer.

Although the Miller blade and the Flexiblade in the straight position provide nearly ideal eye view lines, both blades reduce the space reserved for the tongue behind the mandible. Such functional restriction involves the application of excessive upward force and maximal extension of the head at the atlanto-occipital joint in order to align the oral axis with the pharyngeal axis and with the laryngeal axis (16). This limitation of the straight Miller blade is not definitive when it comes to the Flexiblade. Once the tip of the Flexiblade lies in the vallecula, its blade can be reshaped by simply pulling or releasing the control trigger. Thus, the performance of the Flexiblade may be analyzed in respect to various blade types, provided that its blade is held at a comparable position. The same applies to the McCoy blade.

Cook and Tuckey stated that the McCoy blade, when held in the neutral position, provides a limited view field in comparison with the Macintosh blade (17). In our study it was the McCoy at the maximally elevated position that provided a very limited view in comparison with any of the other tested blades.

This finding can be explained on geometric and mechanic bases. The levering system of the McCoy laryngoscope does not allow movement of the blade except for the last 2.5 cm (measured from the tip). This means that during tip elevation, the real line of view does not change from the view in the neutral position at any insertion depth (starting from 3 cm). On the other hand, activation of the Flexiblade’s trigger may cause as much as 10-cm flexion of the blade because of its six intermediate slots. This design allows both a larger range of motion forward and backward and a better exposition of the larynx by the parallel modification of the line of view (Figs 1 and 3).

The levering blades also present variations in range of movement. These variations are the product of length differences of the intersystem levers, rods, shafts, or wires. For example, adding a few millimeters to the rod of a Flexiblade will result in a larger degree of the blade curvature because of widening of the slots and thus prolongation of the blade. The McCoy levering system is more prone to this kind of variation because it includes six components in comparison with only two components of the Flexiblade (5). We found various degrees of maximal tip elevations that ranged from 22 to 30° among different McCoy laryngoscopes.

A clinical study conducted in Cardiff by Perera et al. showed that activation of the Flexiblade’s trigger during laryngoscopy caused a reduction of one or even two grades in the Cormack and Lehane larynx view classification in 93% of cases (18). Such changes in the Cormack and Lehane classification are barely achieved using the Macintosh blade without applying selected maneuvers and forces (2, 19).

As a result of its versatility, the Flexiblade laryngoscope can be considered as a multiblade device, as its trigger activation causes changes in blade shape, curvature, and length, as well as various eye line deviations and forward space displacements (Figs 3, 4 and 6, and Table 1). These changes are not restricted to the three positions that were tested in the current study. The free movement of the trigger affords many interim positions. We believe Flexiblade to be well suited for use in routine and difficult intubations because it obviates the need to change blades when encountering difficulties.

The present study compares rigid and levering blade types by using the same specific quantitative criteria. Despite the efficiency and the relative simplicity of this methodology, its in vitro conditions impose several limitations. While deviation from the ideal line of view is determined by the geometry of the blade and thus can be absolutely measured, forward space encroachment is only a derivation from geometric measurements of the blade, and should be considered as an approximation. The anatomo-geometric reference points in Marks et al.’s study are based upon 10 normal X-ray laryngoscopies (of European patients) using a constant intubating position of 35° neck flexion and 15° head extension relative to horizontal (7). They are detached from patient’s variant anatomic characteristics and external larynx manipulation during laryngoscopy (7, 8, 13–15).

Obviously, mathematic models for a biologic system are not applicable for all possible values, but they can provide quantitative evaluation of basic device performances upon which several conclusions can be made: (i) intubation procedures should be approached with great care to select a suitable blade rather than using any available laryngoscope found at the time in the intubation tray; (ii) the English Macintosh (size 4) blade is a good choice for routine clinical use; (iii) it is advisable to compare the length of the blades and to opt for a larger size, even if there is no
intention to insert it to its entire length; (iv) the web width of a curved blade is apparently also important in a clinical context; and (v) the Flexiblade may be a good option for both routine and difficult intubations.

The #4 English-Macintosh provided the best results, even in small insertion depths, compared with the #3 English-Macintosh and the #3 Standard Macintosh. The results of this study confirm the contention that the distal portion of a large and curved blade is more effective than the full length of a shorter blade (20).

Marks et al. selected a specifically European population for his anatomic measurements; it is necessary to repeat the protocol of the present study for other population types. Additional research will also be required to evaluate levering blades based on other parameters, including clinical practice, ease, cost of maintenance, illumination performances, and others.

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References


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