Equipment

An analysis of laryngoscope blade shape and design: new criteria for laryngoscope evaluation

Rex R.D. Marks MB ChB BSc (Hons.),*
Richard Hancock RMIP LBIPP,†
Peter Charters MD MRCP FFRCS BA*

Laryngoscope blade design has tended to be relatively arbitrary and so far scientific analysis has not allowed useful comparisons between blade shapes. A new theoretical method of analysing laryngoscope blades is introduced and uses the depth of insertion profiles of two angular measurements. One represents eyelid displacement and the other the forward space that the blade occupies at the level of the mandible. Photographs of straight and curved blades were studied on Cartesian graphs with the tip T, at the origin and handle fittings parallel to the x-axis of the graph. Then, IT is any line from the origin to the incisor surface and represents a point of contact with the upper incisors for a given depth of blade insertion. Angle EIT (eyelid displacement) is to a tangent from I along the lower lingual surface of the blade. Point M is on the upper lingual surface of the blade, at right angles to IT, 1/3 of the distance from I along IT. Angle MIT (forward space) may be positive or negative depending on whether M is in front of or behind IT. The angles EIT, MIT and their additive combination are used in blade analysis. Negative MIT compensates for eyelid displacement as Macintosh size 3 and 4 blades have better combination scores than Miller size 3. All three are superior to the straight Soper size 3 blade. The Macintosh size 1 and 2 blades are quite different from the larger Macintosh blades. This theoretical basis for blade analysis is consistent with commonly expressed clinical opinions and may influence blade design in the future.

Key words

ANATOMY: airway, larynx;
EQUIPMENT: laryngoscopes;
INTUBATION: tracheal.

From the Department of Anaesthesia*, and the Department of Medical Illustration†, Walton Hospital, Rice Lane, Liverpool L9 1AE, England UK.

Address correspondence to: Dr. P. Charters.

Accepted for publication 9th November, 1992.

La conception des lames de laryngoscope tient de l'arbitraire et a jusqu'à maintenant a défié toute analyse scientifique comparative. Les auteurs présentent une nouvelle méthode analytique basée sur le profil de la lame vue sous deux angles différents après son insertion. Le premier montre la déviation de la ligne de vision et l'autre l'espace rétro-mandibulaire que la lame occupe. Des photographies de lames droites et courbes sont transposées sur des coordonnées cartésiennes avec la pointe T à l'origine et le point d'attache du manche parallèle à l'abscisse du graphique. IT devient la ligne qui naît de la surface des incisives et représente le point de contact avec les incisives supérieures pour une profondeur donnée d'insertion. L'angle EIT (déplacement de la ligne de vision) est la tangente de I avec la surface linguale inférieure de la lame. Le point M se situe sur la surface linguale supérieure de la lame, à angle droit avec IT, au tiers de la distance entre I et IT. L'angle MIT (espace antérieur) peut être positif ou négatif selon que M est en avant ou en arrière de IT. Les angles EIT et MIT et leur combinaisons additives sont utilisés pour l'analyse des lames. Un angle MIT négatif compense pour le déplacement de la ligne de vision: les lames Macintosh 3 et 4 ont une meilleure cote que la Miller 3. Les trois sont supérieures à la lame droite Soper 3. Les Macintosh 1 et 2 sont tout à fait différentes des Macintosh plus longues. Cette analyse théorique est consistante avec les impressions cliniques courantes et pourrait dans l'avenir influencer la conception des lames.

Since the advent of tracheal intubation in anaesthesia, at least 50 descriptions of laryngoscope blade designs have been published, and many more designs exist unpublished. Despite this, only a small number of blades has passed beyond the prototype stage to enjoy widespread clinical use. In a recent review, McIntyre classified different designs in terms of addressing specific problems of difficult intubation; however, he concluded that "detailed evaluations of the performance of any particular

laryngoscope blade are extremely rare and critical analysis virtually nonexistent."¹ Attempted practical methods of laryngoscope evaluation include: clinical trial,^{2,3} radiographs at laryngoscopy ("x-ray laryngoscopy"),³ and the use of an animal model.⁴ Theoretical analysis of laryngoscope blade shape has been alluded to as a means of evaluation by comparison of lateral blade projections⁵⁻⁷ and by estimation of the line of vision.^{2,3,8,9} The majority of laryngoscope designers make no attempt at scientific evaluation but instead resort to subjective anecdotal recommendations ranging from modest claims; "Over a period of six months it has given satisfactory results ... and has been of value in children with cleft-lips and cleft palate,"¹⁰ to bold generalizations: "Intubation is easier and more successful with this blade, in conjunction with a Sanders catheter than with any other blade."¹¹ A number of problems of standardization and reproducibility arises from practical methods of laryngoscope evaluation. Reproducibility among individual anaesthetists has been shown to be poor.¹² For this reason, a standard intubating position has been proposed for use in intubation studies.¹³ Despite this, the evident limitations of standardizing clinical studies convinced us that a successful evaluation of laryngoscope blades must initially derive from a theoretical basis.

This paper outlines theoretical criteria for blade analysis and comparison based on previous investigative x-ray laryngoscopy studies. The most important observation from this preceding work was that difficulty or otherwise correlated well with a single "ease of intubation" angle. This midline angle is the connection of three points – from the internal mid-point of the symphysis menti to the tip of the upper incisors and from there to an anterior airway point (just behind the thyroid cartilage).¹⁴ This measurement was considered to represent the space available behind the mandible into which the tongue volume which was not amenable to displacement would be compressed during laryngoscopy to permit laryngeal exposure.

Theory

Measurements derived from ten normal x-ray laryngoscopies in the standardized intubating position of 35° neck flexion and 15° face plane extension show that during normal laryngoscopy the blade contacts the upper incisors proximally whilst the blade tip engages the hyoid bone.¹⁵ The mouth tends to close around the blade at the time of epiglottic elevation and visualization of the glottis. Figures 1 and 2 show normal laryngoscopy with x-ray derived body points. Point I represents the upper incisors, T the hyoid, J a point mid-way between mandibular condyles and S the mid-point of the mandibular symphysis menti. The line IT represents the ideal straight line view

FIGURE 1 Normal laryngoscopy with the mouth closed around the blade. The incisor surface of the laryngoscope blade contacts the upper incisors at I. The blade tip contacts the hyoid at T. The two points are connected as the anterior airway line IT. JS is the line from the internal mid-point of the mandibular symphysis menti (S) to the mid-point of the mandibular condyles (J). IT and JS cross at C and previous work has shown that SCT is almost 90°, and C is 1/3 of the distance along IT from I.

FIGURE 2 X-ray laryngoscopy in the standard intubating position showing incisor and hyoid point contact. The mouth is not completely closed around the blade in this example and thus a line joining J and S makes an angle of 85 degrees to a line joining points I and T. The angle approximates to 90 degrees when the mouth is fully closed around the blade. (The Macintosh blade shown was not necessarily the same as those analysed in the present study.)

to the laryngeal inlet and is the reference line for our angular measurements. It will be referred to as the *anterior airway line*. The line JS crosses IT at an angle of approximately 90° (mean 91.6°, $\pm 5.34^\circ$ Sd) when the mouth is closed around the blade. The line JS being

at the level of the mandible, this is the level at which space restriction occurs. This may result directly from a receding mandible, or indirectly from an anterior larynx or prominent incisors. In the latter two cases the line IT would lie closer to S so that space behind the mandible is reduced in spite of a normal mandible. The point of intersection of IT and JS is C, which lies at approximately $1/3$ (mean $32.2\% \pm 2.4\%$ Sd) of the length of IT from point I. Hence, a perpendicular to IC marks the level of the mandible relative to IT. Throughout our analysis we refer to blades in the position of incisor and hyoid contact. Measurements of blade shape relative to the anterior airway line thus reflect blade positioning at laryngoscopy, and also provide a reproducible system of comparison for different blade shapes in the same position.

Whilst it is appreciated that the mouth is not completely closed around the blade in every normal laryngoscopy, this position has been adopted for the purpose of blade shape analysis, since, in this position, the available space behind the mandible is maximized. When the jaw is already pulled well forward by a laryngoscope, further mouth opening will be simulated by simple rotation of the line JS about the point J. Since S starts at right angles to IT, such rotation will inevitably mean S gets closer to IT and further restricts the forward space.

Our analysis consists of two aspects of blade shape and we have used the angular displacement values as this preserves the flexibility of size independence. However, the equivalent linear displacement values for eyeline and forward space are easily derived.

The mechanism of direct laryngoscopy

The two essentials for successful direct laryngoscopy are: (1) movement of the hyoid bone by the laryngoscope blade tip (epiglottic elevation), and (2) a clear line of view to the exposed larynx.

1 Blade tip – hyoid bone contact

Chevalier Jackson appeared to recognize the importance of blade tip–hyoid bone contact in his important 1913 publication on direct laryngoscopy.¹⁶ Recent x-ray laryngoscopy confirms the mechanism of epiglottic elevation by downward and forward displacement of the hyoid bone by the laryngoscope blade tip. Failure of blade tip–hyoid bone contact due to compression of soft tissue between the laryngoscope blade and the buccal surface of the mandible was recognized in cases of difficult laryngoscopy.^{14,17} An index of difficult intubation based on the amount of space available behind the mandible shows a highly significant correlation with degree of difficulty.¹⁸ It follows that the amount of space that the laryngoscope blade itself occupies behind the mandible is an important factor when space is already limited. Compression of soft

FIGURE 3 Measurement of the angle MIT. M is on the perpendicular to IT from C (Figure 1), where this line meets the upper lingual surface of the blade. Two arbitrary curved blade shapes are shown to indicate that MIT may be positive or negative, i.e., above or below IT (right and left hand diagrams respectively). MIT thus influences how close the laryngoscope blade can move toward the mandible and so indicates forward space encroachment or forward space enhancement accordingly.

tissue between the blade and the mandible causing failure to contact the hyoid bone will occur more readily if the blade itself occupies more of this available space.

The angle MIT in Figure 3 is a measure of the blade shape effect on available forward space. Point M lies on the blade surface at the level of the mandible, that is, along the line JS. When the blade lies in front of the line IT, the angle MIT is taken as positive and the blade is said to encroach on available forward space. When the blade point M lies behind the line IT then the angle MIT is taken as a negative value and the increased space between the blade and the mandible is described as forward space enhancement. Our current work outlines a measure of the space occupied by the blade shape behind the mandible at laryngoscopy.

2 Eyeline

A direct line of view to the exposed glottis is an obvious requirement of direct laryngoscopy. Previous attempts at laryngoscope evaluation have compared eyelines showing how a particular blade shape might affect the view down the blade's long axis visualizing the glottis.^{2,3,8,9} This approach to laryngoscope evaluation has failed to be of value for two reasons; firstly, there has been no agreed standard method of eyeline measurement and secondly, the eyeline was not always measured relative to the likely position of the laryngoscope blade at laryngoscopy and, as a result, is of limited meaning. Our current work measures angular deviation of the eyeline from the glottis based on blade positioning at laryngoscopy.

Figure 4 shows measurement of the eyeline relative to the anterior airway line, IT. When the laryngoscope

FIGURE 4 Measurement of eyelid deviation from the anterior airway line by the angle EIT. E lies on a tangent from I to the lower lingual surface of the blade.

blade shape impinges on the direct, unobstructed view (i.e., IT), then the best eyelid is from the upper incisors along a tangent to the curved under-surface of the blade. The point E lies along this tangent. EIT is thus an angular measure of deviation of the eyelid from the ideal.

Method

Accurate photographs of laryngoscope blades with a super-imposed measuring scale were produced according to the method of Hancock and Patel.¹⁹ In an attempt to standardize measurements, blade images were positioned with the tip at the origin of a graph and the blade's handle mounting block parallel with $y = 0$ (see Figure 5). The position of T is fixed at $x = 0, y = 0$ and the anterior airway line IT projected from the origin to the outline of the blade incisor surface. To simulate the effect of the blade being inserted to different depths (i.e., airways of different incisor to hyoid length) the line IT was increased by 1 cm increments which effectively moved the point I progressively along the blade incisor surface. For each new IT line, angles EIT and MIT were measured for values of IT from 5 cm to the upper limit of each blade's length, as indicated in Figures 3 and 4. In order to increase the accuracy of measurement, the images were enlarged. Angular measurement to better than 0.5 degrees is then possible with the Linex 720 circular protractor.

New unused Penlon Laryngoscopes were used throughout. The "British" Macintosh blade was used as an example of a curved shape, and the Soper 3 adult blade used as the best approximation of a pure straight shape. The adult size Miller 3 was also studied as this blade has some properties of both a curved and straight shape.

FIGURE 5 Photograph of laryngoscope blade. The blade (in this case a size 4 Macintosh) is positioned with its handle mounting block parallel to the x-axis and the blade tip at the origin of the graph ($x = 0, y = 0$).

Results

The maximum values of IT for the Soper 3 and Miller 3 blades are about 17 cm and 19 cm. (These depend solely on blade length overall.) Maximum values of IT for the Macintosh series of blades are 15 cm, 12 cm, 10 cm, and 9 cm for the four blades in decreasing order of size. Measurement of MIT and EIT for values of IT less than 5 cm was associated with artifacts on some blades due to the position of the light source: IT values less than 5 cm, were considered unlikely to be clinically relevant except in extremely small children and so were not studied.

In general we should expect that blade curvature causes greater eyelid deviation (i.e., EIT increases as the curve itself blocks the view). This apparent disadvantage might, however, be balanced by increased forward space enhancement (i.e., MIT could be less with a curved blade), and it would be the combined effect that mattered.

Measurement of MIT and EIT for the Soper 3 laryngoscope blade is shown in Figure 6. When IT is increased from 5 cm the eyelid deviation, EIT, initially zero, increases to 0.5° by 9 cm, and thereafter remains at 0.5° . Measurement of forward space encroachment by the Soper 3 with increasing length of IT shows a reduction in MIT from 28.25° at 5 cm to 14.5° at 17 cm.

The Miller 3 eyelid (Figure 7) shows little variation from 2.75° at 5 cm to 2° at 19 cm. Forward space encroachment, MIT, for this blade decreases progressively from 13.0° at 5 cm to 2.8° at 19 cm.

By contrast, EIT (eyelid deviation) for the Macintosh 4 laryngoscope (Figure 8), is initially zero, like that of

FIGURE 6 Soper 3 laryngoscope straight blade. The flat eyeline trace (eyeline angle EIT) is shown. Forward space encroachment (positive MIT) remains high at all values of IT.

FIGURE 8 Macintosh 4 curved blade. Progressive deviation of the eyeline angle EIT at greater than IT = 7 cm is shown. There is compensation of the eyeline deviation by negative MIT angle with forward space enhancement at greater than IT = 11 cm.

FIGURE 7 Miller 3 straight blade with distal curve. The straight blade flat eyeline trace, EIT, and forward space encroachment (positive MIT) are shown.

FIGURE 9 Macintosh 3 curved blade. Progressive increase in eyeline deviation angle EIT at greater than IT = 7 cm and forward space enhancement, negative MIT at greater than IT = 11 cm.

the Soper 3 and Miller 3 blades, but unlike these blades, beyond 7 cm of IT there is a progressive increase in EIT to a maximum of 9.5° at the blade's maximum IT value of 15 cm. On the other hand, the initial value for forward space encroachment, MIT, is 17.4° at 5 cm, but lessens progressively with increasing IT, becoming zero at 11 cm and -7° by 15 cm.

Analysis of the Macintosh 3 (Figure 9) also shows an EIT of zero until after 7 cm, increasing to a maximum value of 5.9° at 12 cm. There is a similar pattern of reduction in forward space encroachment to the Macintosh 4, in that MIT decreases from 19° at 5 cm, to -0.9° by 12 cm.

Eyeline for the Macintosh 2 blade (Figure 10) as for the larger blades, is zero until 7 cm of IT. The maximum EIT is 6.6° at 10 cm. The pattern of forward space encroachment is unusual because MIT first decreases from

22° at 5 cm to a minimum of 3.5° at 8 cm but then increases again to 6.1° by 10 cm. This late rise in MIT is peculiar to the Macintosh 2 blade.

The Macintosh 1 eyeline (Figure 11) is initially zero, the progressive increase after 5 cm reaching a maximum of 5.6° at 9 cm. The forward space encroachment value for this blade falls progressively from 17° at 5 cm to 11.2° at 9 cm.

Both Soper 3 (Figure 6) and Miller 3 (Figure 7) blades show a distinctive flat eyeline trace. This is in contrast to the curved Macintosh blades which after an initial flat trace show a progressive increase in EIT with increasing length of IT. The Soper 3 exhibits the lowest EIT values of all the blades tested. The Miller 3 shows higher EIT values than the Soper 3, but lower than any EIT for curved blades. The Macintosh 4 blade (Figure 8) has the highest EIT values of all the blades tested.

FIGURE 10 Macintosh 2 curved blade. Progressive increase in eyeline deviation angle at greater than IT = 7 cm. Forward space encroachment angle MIT falls progressively to IT = 8 cm but rises again after IT = 9 cm.

The other three curved blades share a similar range of values which are intermediate between the straight blades and the Macintosh 4.

The lowest MIT values are shown by the two larger curved blades which are the only ones achieving negative MIT values with forward space enhancement. The Macintosh 4 exhibits the lowest MIT values of all the blades analyzed. Neither of the small curved blades achieve negative MIT values. The Soper 3 blade fairs worst in terms of forward space encroachment with the highest MIT values of all the blades tested.

In order to interpret the measurements of the eyeline deviation and forward space encroachment (or enhancement) a combination score was produced from simple addition of EIT and MIT on the basis that an increase in magnitude of either angle represents a deterioration in performance of the laryngoscope blade for any given value of IT. Figure 12 compares the Soper 3 straight blade, Miller 3 straight blade with distal curve, and the Macintosh 4 curved blade in terms of their combination scores. The Macintosh curved blade shows the lowest overall range of combination scores. The Miller 3 combination score lies between the curved blade and the straight Soper 3 blade. Combination score for the Macintosh series of blades are shown in Figure 13. Both the Macintosh 3 and 4 blades show progressive reduction in combination score with increasing IT. The longer Macintosh 4 blade has the lowest combination scores. The deterioration in performance of the Macintosh 2 blade in terms of increasing combination score at IT values greater than 8 cm is well shown. The Macintosh 1 combination score is a remarkably flat trace with little improvement as IT increases.

FIGURE 11 Macintosh 1 curved blade. Progressive rise in eyeline deviation angle EIT from IT = 5 cm. Forward space encroachment angle MIT remains high with little improvement against increasing IT.

FIGURE 12 Combination scores for the Soper 3, Miller 3, and Macintosh 4 laryngoscope blades.

FIGURE 13 Combination scores for the Macintosh series of blades. The smaller size 1 and 2 blades are quite different from the larger size 3 and 4 blades.

Discussion

Despite possessing the lowest eyeline deviation score of all, the straight Soper 3 blade has the highest MIT and therefore worst combination score on account of the high values for forward space encroachment. The significance of high forward space encroachment is that in difficult intubating situations where forward space is limiting, it may be impossible for the blade to be positioned with the tip in contact with the hyoid point. As a result, although the eyeline to the Soper blade tip is excellent, elevation of the epiglottis with laryngeal exposure may be prevented. Clearly, when forward space is not limiting, the Soper blade achieves minimal eyeline deviation with a straight line view of the vocal cords. Soper uses the same Z-shaped cross-section as the Macintosh blade. Soper considered this to be superior to the C-shaped cross-section of other "orthodox" straight blades used at the time. Soper's justification for a straight blade was that, with a curved shape, a "stiffener" was sometimes needed in order to pass the endotracheal tube around the curve and into the larynx.²⁰ This advantage of a straight shape claimed by Soper now seems tenuous with the advent of modern endotracheal tubes not requiring a "stiffener."

Miller's blade shows an improvement in combination score over the pure straight shape. There is a small eyeline deviation (maximum of 4.5°) which results from the distal curved part of the shape. The distal curve also contributes to the lesser forward space encroachment when compared with the Soper. This is because the blade tip extends beyond the rest of the shape. This means that when the blade tip contacts the hyoid point, less of the blade is forward of the anterior airway line and hence the lower MIT angle. The fact that the blade is narrower than the Soper also contributes to its lower forward space encroachment. Miller claimed that his narrower blade allowed the mouth to be open less widely at laryngoscopy. He remarked, "This allows freer anterior movement of the mandible which in itself is an aid in obtaining better exposure."²¹ The implication of "freer anterior movement of the mandible" is that available forward space (the space between the blade and the mandible) is increased by the Miller blade compared with other straight blades that were available in 1941.

The lowest and best combination scores are achieved by the Macintosh size 3 and 4 curved blades. Both exhibit higher eyeline deviation than either the Soper or Miller blades but possess low combination scores on account of low forward space encroachment. The high eyeline deviation of Macintosh blades is a direct effect of the curved shape. When the blade tip contacts the hyoid point the bend of the blade is clearly in the way of a direct

view of the tip. Apparently the original Macintosh design had a "slight but distinct flattening near the mid-point ... On the principle that one cannot see through the crest of a hill."²² This would appear to be an attempt to reduce eyeline deviation caused by the curved shape. Unfortunately when stainless steel was first used for blade manufacture in 1956 it was not possible to press a shape with mid-point flattening due to the more springy property of steel compared with previously used chromium plated brass,²² and the flat mid-point now seems to have disappeared from the curve.

The two larger Macintosh blades are distinct in exhibiting forward space enhancement with negative MIT values. Forward space enhancement is an effect attributable to the curve. It occurs when the concavity of the curve passes behind the anterior airway line at the level of the mandible. It is not possible for either the Soper or Miller shapes to achieve forward space enhancement since both are flat at the level of the anterior airway line. With Macintosh 3 and 4 blades, forward space enhancement occurs for values of IT greater than 11 cm. Eyeline deviation with these blades does not begin until after 7 cm IT, and only exceeds that of the straight blades after 9 cm. The increased eyeline deviation of the curved shape is offset by forward space enhancement with negative MIT after 11 cm. The forward space enhancement after 11 cm of IT is clinically relevant since the range of values obtained for IT from our accumulated data in adults is from 9.5 to 14.5 cm. The Macintosh 4 blade shows the greatest degree of forward space enhancement and this may represent an advantage over the Macintosh 3 blade when IT is greater than 12 cm. There is little difference between the two shapes for IT lengths of less than 12 cm.

Macintosh remarked on two occasions that "the precise shape or curve of the blade does not seem to matter much provided the tip does not go beyond the epiglottis."^{23,24} The curve of the Macintosh blade was designed with the intention of positioning the tip "into the angle made by the epiglottis with the base of the tongue."²³ Such a placement does achieve blade tip-hyoid contact as described in this paper. Macintosh did not allude to the forward space enhancing property of his blade other than to say "I find a curved blade easy to introduce" without any further qualification.²⁴ However, he did cite the curved shape as being advantageous for passage of the curved Magill-type endotracheal tube.²⁴ Cassels appeared to recognize the potentially greater laryngeal exposure possible with a curved blade when space is restricted, but he considered the gap between the upper and lower teeth to be the important space restriction rather than forward space at the level of the mandible.⁸

Furthermore, the "curved" blade illustrated in Cassels' 1942 paper, which pre-dates the Macintosh design, is a predominantly straight shape with a distal curve.

The Macintosh 2 combination score graph is interesting (Figure 13). Whilst the blade shows some advantage over the larger blades for IT values of 8 cm and less, there is a marked deterioration in score at IT greater than 8 cm such that it is inferior to the larger Macintosh 3 and 4 size blades. The increase in score at > 8 cm of IT with the Macintosh 2 blade is because forward space enhancement does not occur with this blade and MIT increases after 9 cm. This means that the characteristic curved blade eyelid deviation is not compensated.

The Macintosh 1 blade shows the worst performance and highest combination score of all the curved blades (Figure 13). The blade does not have the advantage of a curved shape in that MIT shows very little improvement with increasing IT, yet the blade still possesses the eyelid deviation of a curved shape. In other words the Macintosh 1 has the disadvantageous eyelid deviation of a curved blade and also the high MIT values more in keeping with a straight blade. The designer of the size 1 Macintosh blade is not known, but the shape was apparently condemned by Macintosh as "anatomically wrong."²² Robertshaw observes that the larger Macintosh blades could be used "even in the newborn" but that the smaller sized blades were "much too curved."²⁵ We have no information on the clinical range of IT for children but a value of 8 cm or greater would mean that the Macintosh 2 blade is inferior to the larger curved blades according to our criteria. The concept of available forward space limiting laryngoscopy was derived from adult data and hence the significance of forward space encroachment by the paediatric size Macintosh blades remains unclear. Despite this, it is relevant that the two smaller blades are quite different in shape, in terms of MIT and EIT, than the larger size 3 and 4 blades. Our own subjective experience is that the smaller size Macintosh blades are inferior to the two larger sizes for paediatric anaesthesia. It is interesting that Miller initially advocated only one size of laryngoscope for tracheal intubation in patients of all ages.²¹

Theoretical prediction of laryngoscope blade performance in terms of eyelid deviation and forward space enhancement and encroachment supports the view that a curved blade is superior to a straight one,⁸ and that the smaller Macintosh blades are comparatively poor performers.^{22,25} Whilst our method produces MIT and EIT values for comparison of different blades, it is not possible to say what the absolute numerical value is for a bad MIT or EIT unless the anatomical values of IT JS and IC are known in a particular circumstance. Eyelid de-

viation has been calculated with the blade tip as the zero reference point. The laryngeal opening is actually some distance behind the blade tip at laryngoscopy and hence EIT measurement may overestimate eyelid deviation from the laryngeal opening. The combination score is produced by simple addition of EIT and MIT. This may prove to be an over-simplification, although each angle influences laryngoscopy such that an increase in its magnitude predicts a worse view. Measurement of MIT was from the anterior airway line. The position of the mandible (where forward space effects are thought to be most important) has been assumed to be along a perpendicular from C on IT such that $IC = IT/3$. Angle MIT is measured along this line. The value of $IC = IT/3$ has been derived from measurements of x-ray laryngoscopy. The ratio IC:IT may well be altered in difficult intubation. This will result in different MIT values.

Throughout our work we have assumed that positioning of the blade along the IT axis was possible and thus our measurements are a reflection of the properties intrinsic to laryngoscope blade shape. We have not attempted to predict the view when there are limitations on mouth opening or restricted neck movement, although both would be likely to restrict forward space.

It is important to point out that the Soper and Miller blades were designed for direct elevation of the epiglottis whilst the Macintosh blade is intended for indirect epiglottic elevation. Forward space restriction is likely to effect both mechanisms in a similar fashion since both direct and indirect epiglottic elevation require similar blade tip positioning and similar epiglottic elevation for laryngeal exposure. Furthermore, the straight blades may be used for indirect epiglottic elevation.

Over the years, many promising laryngoscope designs have fallen by the wayside without any objective evaluation. In our view simple comparative clinical trials, in the present state of knowledge, would require stringent conditions, be time consuming and might still give uncertain results. It should be noted that curved blades even of the same generic type and size from different manufacturers are not necessarily exactly the same shape. Our information from Penlon Ltd was that the original Macintosh designs were from simple pencil line drawings which are not now available. This study underlines the relevance of laryngoscope blade shape and establishes a theoretical reproducible method for performance analysis. The values obtained for standard straight and curved blades may be considered as yardsticks against which future developments in blade design can be compared. It would appear reasonable to suggest even on the basis of the limited information available thus far that the blades studied can probably be improved on. A blade

with a combination score close to zero for its whole length would seem feasible.

Acknowledgement

We are grateful to Penlon UK Limited for making available a complete range of unused laryngoscopes.

References

- 1 *McIntyre JWR*. Laryngoscope design and the difficult adult tracheal intubation. *Can J Anaesth* 1989; 36: 1: 94-8.
- 2 *Phillips OC, Duerksen RL*. Endotracheal intubation: a new blade for direct laryngoscopy. *Anesth Analg* 1973; 52: 4: 691-8.
- 3 *Gabuya R, Orkin LR*. Design and utility of a new curved laryngoscope blade. *Anesth Analg* 1959; 38: 5: 364-9.
- 4 *Bainton CR*. A new laryngoscope blade to overcome pharyngeal obstruction. *Anesthesiology* 1987; 67: 767-70.
- 5 *Portzer M, Wasmuth CE*. Endotracheal anesthesia using a modified Wis-Foregger laryngoscope blade. *Cleve Clin Q* 1959; 26: 140-3.
- 6 *Schapira M*. A modified straight laryngoscope blade designed to facilitate endotracheal intubation. *Anesth Analg* 1973; 52: 553-4.
- 7 *Bizzarri DV, Giuffrida JG*. Improved laryngoscope blade designed for ease of manipulation and reduction of trauma. *Anesth Analg* 1958; 37: 231-2.
- 8 *Cassels WH*. Advantages of a curved laryngoscope. *Anesthesiology* 1942; 3: 580-1.
- 9 *Racz GB*. Improved vision modification of the Macintosh laryngoscope (Correspondence). *Anaesthesia* 1984; 39: 1249-50.
- 10 *Bryce-Smith R*. A laryngoscope blade for infants. *BMJ* 1952; 1: 217.
- 11 *Snow JC*. Modification of laryngoscope blade. *Anesthesiology* 1962; 23: 394.
- 12 *Williams KN, Carli F, Cormack RS*. Unexpected, difficult laryngoscopy: a prospective survey in routine general surgery. *Br J Anaesth* 1991; 66: 38-44.
- 13 *Horton WA, Fahy L, Charters P*. Defining a standard intubating position using "angle finder." *Br J Anaesth* 1989; 62: 6-12.
- 14 *Horton WA, Fahy L, Charters P*. Factor analysis in difficult tracheal intubation: laryngoscopy-induced airway obstruction. *Br J Anaesth* 1990; 65: 801-5.
- 15 *Horton WA, Fahy L, Charters P*. Disposition of cervical vertebrae, atlanto-axial joint, hyoid and mandible during x-ray laryngoscopy. *Br J Anaesth* 1989; 63: 435-8.
- 16 *Jackson C*. The technique of insertion of intratracheal insufflation tubes. *Surg Gynecol Obstet* 1913; 17: 507-9.
- 17 *Fahy L, Horton WA, Charters P*. Factor analysis in patients with a history of failed tracheal intubation during pregnancy. *Br J Anaesth* 1990; 65: 813-5.
- 18 *Horton WA, Fahy L, Charters P*. Towards a single index for quantifying osseous factors in difficult laryngoscopy. *Br J Anaesth* 1990; 65: 583-4P.
- 19 *Hancock R, Patel BC*. Clinical photography: a method of accurate documentation. *J Audiov Media Med* 1989; 12: 154-5.
- 20 *Soper RL*. A new laryngoscope for anaesthetists. *BMJ* 1947; 1: 265.
- 21 *Miller RA*. A new laryngoscope. *Anesthesiology* 1941; 2: 318-20.
- 22 *Jephcott A*. The Macintosh laryngoscope. A historical note on its clinical and commercial development. *Anaesthesia* 1984; 39: 474-9.
- 23 *Macintosh RR*. A new laryngoscope. *Lancet* 1943; 1: 205.
- 24 *Macintosh RR*. Laryngoscope blades (Correspondence). *Lancet* 1944; 1: 485.
- 25 *Robertshaw FL*. A new laryngoscope for infants and children. *Lancet* 1962; 2: 1034.