Equipment

Light intensity and area of illumination provided by various laryngoscope blades

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Several brands of laryngoscopes and commonly used blades are evaluated for differences in direct light intensity and area of illumination. The purpose of this study was to determine which laryngoscope/blade combination provided the best lighting conditions for tracheal intubation. The direct light intensity was assessed by directing various laryngoscope/blade combinations towards a multifunction exposure meter (Flash Meter III, Minolta Corp.). Light intensity expressed in Lux was calculated using the formula: $lux = 2.5 \times 2^{exposure\ index}$. *The area of illumination provided by the laryngoscopes was assessed by taking photographs when the laryngoscope blade tips were touching a wall. The widest diameter of bright illumination in the photograph was measured in centimeters (cm). The direct light intensity ranged from* $0.4\text{–}5.5 \times 10^3$ *lux. The field of illumination ranged from 3.2 to 8.8 cm. When fitted on regular size handles, blades with incandescent bulbs provided more intense light than blades using fibreoptic light sources (P = 0.0078). For blades using incandescent light, the use of a short handle laryngoscope resulted in a decrease in light intensity (P = 0.0117). The results of this study suggest that blades using incandescent light provide greater light intensity than blades using fibreoptics.*

Plusieurs marques de laryngoscope et de lames utilisées couramment sont évaluées au regard de l'intensité lumineuse directe et de la zone éclairée. L'objectif de cette étude consiste à déterminer quel assemblage laryngoscope/lame fournit les meilleures conditions d'éclairage en vue de l'intubation trachéale. L'intensité lumineuse directe est évaluée en orientant différentes combinaisons de laryngoscopes et de lames vers un photomètre à fonctions multiples (Flash Meter III, Minolta Corp.). L'intensité lumineuse exprimée en Lux est calculée avec la formule $Lux = 2,5 \times 2^{index\ d'exposition}$. *La zone éclairée émise par le laryngoscope est évaluée par photographie au moment où l'extrémité de la lame du laryngoscope touche un mur. Le diamètre le plus grand d'éclairage brillant obtenu sur la photographie est mesuré en centimètres (cm). L'intensité lumineuse directe varie de* $0,4 \text{ à } 5,5 \times 10^3$ *Lux. Le champ d'éclairage varie de 3,2 à 8,8 cm. Lorsque raccordée à des manches de grandeurs régulières, les lames à ampoules incandescentes produisent une lumière plus intense que les lames qui utilisent une source lumineuse à fibres optiques (P = 0,0078). Pour les lames à ampoules incandescentes, l'utilisation d'un laryngoscope à manche court produit une diminution de l'intensité lumineuse (P = 0,0117). Les résultats de cette étude suggèrent que les lames à ampoule incandescente procurent une intensité lumineuse plus grande que les lames à fibres optiques.*

Key words
EQUIPMENT: laryngoscopes;
INTUBATION: tracheal.

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Clinicians are often presented with claims from laryngoscope manufacturers that their product provides superior light characteristics. However, "detailed evaluations of the performance of any particular laryngoscope blade are extremely rare, and critical analysis is virtually non-existent."[1] We believe that light intensity and area of illumination from a laryngoscope may affect one's ability to visualize the larynx during tracheal intubation. We undertook this study to evaluate several brands of laryngoscopes available in Canada and various laryngoscope blades for differences in their direct light intensity and area of illumination.

Methods

We assessed non-single use laryngoscopes from Heine

Optotechnik, Penlon, Rusch and Welch-Allyn. We also evaluated disposable laryngoscopes from Penlon, Vital Signs and North American Medical Products Inc (See Table I). The tests were conducted on either new instruments, sample models, or used but thoroughly cleaned laryngoscopes. New 1.5 V batteries (Procell, alkaline battery, Duracell Inc. Bethel, CT) that were checked before and after use for full charge were our power sources.

Trials were performed in a photographer's dark room. There were two parts to the study. *Part 1 - Direct light intensity.* Each laryngoscope was inserted into a rigid clamp system that was set up to maintain the beam of light in a constant position. The laryngoscope was positioned such that its light was aimed directly (0 degree angle) into the middle of a Minolta Flash Meter III (Figure 1) with the tip of the blade resting on the centre of the Flash Meter III spherical diffuser. This was done to make the distance from the light source to the meter constant. In this position, the intensity of light falling on the Minolta Flash Meter III will approximate that which falls on the glottic opening during tracheal intubation.

The Minolta Flash Meter III is a photoelectric exposure meter that measures light intensity from continuous light sources with an accuracy of ±0.2 exposure value.[2] Its power source was confirmed to be adequate before starting and after all blades had been measured. The room lights were turned off to eliminate ambient light and an exposure index reading was obtained from the Minolta Flash Meter III. Each blade and laryngoscope handle were tested three times in this manner. The highest exposure index obtained for each handle and blade was recorded. This was done to avoid falsely low values of exposure index that could result from misdirection of the light source.

Light intensity was expressed in lux. One lux is the illumination of an area of one square meter produced by a luminous flux of one lumen[3] (see glossary). Exposure indices of the various laryngoscopes and blades obtained from the Minolta Flash Meter III were converted to lux by the formula:[2]

$$\text{lux} = 2.5 \times 2^{\text{exposure index}}$$

Lux values were rounded off to the nearest hundred.

GLOSSARY[11]

Candela: International unit of luminous intensity (strength of a light source). It is of such magnitude that the luminance of a perfectly radiating body at the melting point of platinum is 60 candelas per square centimeter.

Lumen: One lumen is the luminous flux or light flow that falls on a surface one meter away from a point source of one candela. If a uniform point source of one candela is placed at the centre of a hollow sphere of one meter radius, every square meter of the inside of the sphere - and there are 4π (12.57) of them - will receive one lumen. Thus a uniform source of one candela emits one lumen per unit solid angle and provides a total luminous flux of 12.57 lumens.

Lux: International unit of illumination (intensity of light falling on a subject). Luminous flux per unit area (lumens per square meter). The illumination on one square meter surface at one meter distant from a point source of one candela is one lumen per square meter = one lux.

TABLE I Laryngoscope models evaluated

Non-disposable
Fibreoptic light
- Heine Optotechnik
- Penlon
- Rusch
- Welch Allyn
Incandescent bulb
- Penlon
Disposable
Fibreoptic light
- Vital Signs
- North American Medical Products
Incandescent bulb
- Penlon

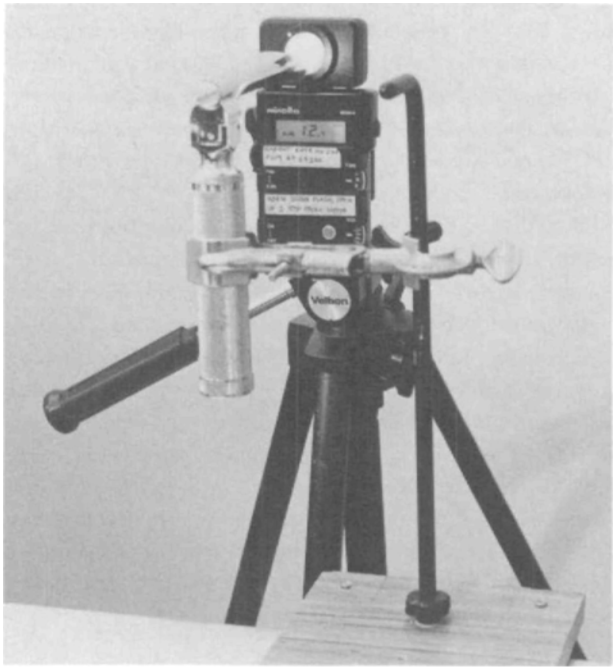

FIGURE 1 Rigid clamp system holding a nondisposable Penlon laryngoscope. The regular size handle is mounted on a Miller 3 blade. The tip of the blade is resting against the centre of the spherical diffuser of the Minolta Flash Meter III.

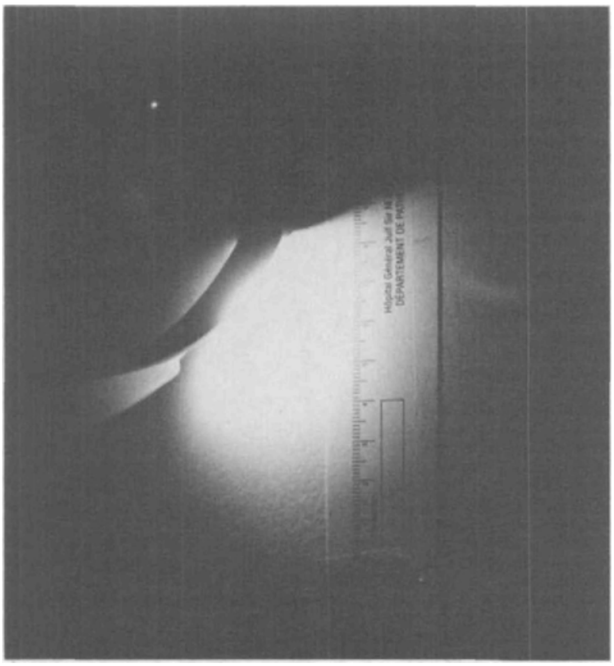

FIGURE 2 Area of illumination from the regular size nondisposable Heine Optotechnik fibreoptic laryngoscope mounted with a MacIntosh 4 blade. The tip of the blade is resting against the wall. The widest diameter of the bright area is 6 cm making it an average field of illumination (see methods).

The laryngoscopes/blades were divided into four groups: Group 1 were blades with incandescent bulbs mounted on a regular handle (IR); Group 2, blades with incandescent bulbs on a short handle (IS); Group 3, blades using fibreoptic light sources on a regular handle (FR); Group 4, blades using fibreoptic light sources on short or pencil handles (FS).

The groups were analyzed for differences in direct light intensity using an initial one-way analysis of variance (ANOVA) followed by the Bonferroni t procedure for multiple comparisons. Differences were considered significant at a P value < 0.05.

Part 2 – Area of illumination. The laryngoscope was placed in the clamp system and directed at a nonreflective cream-coloured wall. The tip of the laryngoscope blade touched the wall. A 10 cm ruler was placed within the field of illumination. Photographs were taken to illustrate the pattern of light illumination. We used an Ilford HP 5 Plus 400 ASA black and white film. This film was then processed in Kodak D 76 developer with a 1:1 ratio of D 76 stock solution to water for ten minutes. Callipers were used to measure the widest diameter of the bright area of illumination (Figure 2). The distance between the calliper tips was then read off the ruler in the field. A field of illumination was considered narrow (Na) if its diameter was less than 4 cm, average (A) if between 4 and 7 cm, and wide (W) if its diameter was greater than 7 cm.

Results

The results are summarized in Tables IIa, IIb and III. The laryngoscopes/blades tested had direct light intensities ranging from $0.4–5.5 \times 10^3$ lux. Blades with incandescent light bulbs provided greater illumination than blades using fibreoptic light sources when mounted on regular handles (Gp 1 vs Gp 3, $P < 0.01$) but not when mounted on short handles (Gp 2 vs Gp 4, P = NS).

The use of a short or pencil handle laryngoscope resulted in a decrease in direct light intensity compared with a regular handle for blades using incandescent bulbs (Gp 1 vs Gp 2, $P < 0.05$) but not for blades using fibreoptic light (Gp 3 vs Gp 4, P = NS).

Blades using fibreoptics were associated with either a narrow or average field of illumination (see Tables IIa, IIb). The exceptions were the disposible Vital Signs Fibreoptic (MacIntosh #3 and 4) blades which illuminated a wide area.

Discussion

We have found that, for regular size handles, blades with incandescent bulbs produced a greater illumination than blades using fibreoptic light sources. Also, for incandescent light, the use of a short handle laryngoscope resulted in a reduction in direct light intensity compared with a regular size handle.

Several comments need to be made about our experimental design. Our evaluation was conducted with laryngoscopes and blades having a variable degree of wear. The nondisposable Heine fibreoptic as well as the nondisposable Penlon incandescent laryngoscopes had been in use for some time and may have suffered from decreased direct light intensity. While batteries closely reflect the clinical situation, over time they are subject to small fluctuations in current output which may lead to variations in light intensity produced by the laryngoscope blade. The use of a steady state AC/DC transformer as a power source would have eliminated those small current fluctuations. Only the highest value of three exposure index measurements was recorded in order to represent the most intense light for all laryngoscope/blade combinations. We found that three trials gave ample opportunity to measure the highest exposure index without abusing the batteries.

Exposure is the effect of radiant energy, especially light, on a photographic emulsion.[4] An exposure value represents a given amount of light passing through a lens to reach the film.[5] Exposure values usually run from 2 to 18 and vary directly with the illumination of a subject. The Minolta Flash Meter III is a reliable multi-function

TABLE IIA Direct light intensity and field of illumination for non-disposible laryngoscopes

Laryngoscope model	*Status*	*ExI (±0.2 EV)*	*DLI (lux × 10^3)*	*FOI (cm)*	*FOI (Na, A, W)*
Heine Fibreoptic (RH)					
- MacIntosh 3	U	10.1	2.7	5.7	A
- MacIntosh 4	U	10.0	2.6	6.0	A
Penlon Incandescent					
- Regular handle					
- MacIntosh 3	U	10.4	3.4	7.8	W
- MacIntosh 4	U	9.9	2.4	8.2	W
- Miller 3	U	11.1	5.5	5.8	A
- Short handle					
- MacIntosh 3	U	9.1	1.4	5.9	A
- MacIntosh 4	U	7.5	0.5	6.6	A
- Miller 3	U	9.9	2.4	4.2	A
Penlon Fibreoptic (RH)					
- MacIntosh 3	N	9.4	1.7	4.5	A
- MacIntosh 4	N	9.4	1.7	4.6	A
Welch Allyn Fibreoptic					
- Regular handle					
- MacIntosh 3	N	9.1	1.4	3.4	Na
- MacIntosh 4	N	8.4	0.8	3.8	Na
- Miller 3	N	9.1	1.4	3.6	Na
- Miller 4	N	8.4	0.8	4.5	A
- Pencil handle					
- MacIntosh 3	N	8.8	1.1	3.6	Na
- MacIntosh 4	N	8.0	0.6	3.8	Na
- Miller 3	N	8.6	1.0	3.2	Na
- Miller 4	N	8.1	0.7	4.3	Na
Rusch Fibreoptic					
- Regular handle					
- MacIntosh 3	N	9.8	2.2	5.2	A
- Short handle					
- MacIntosh 3	N	7.4	0.4	N/D	N/D

Laryngscope model (RH = regular handle) Status (U = used, N = new); ExI = exposure index; EV = exposure value; DLI = direct light intensity; FOI = field of illumination (Na = narrow; A = average; W = wide; N/D = not determined).

TABLE IIB Direct light intensity and field of illumination for disposible laryngoscopes

Laryngoscope model	*Status*	*ExI (±0.2 EV)*	*DLI (lux × 10^3)*	*FOI (cm)*	*FOI (Na, A, W)*
Penlon Incandescent (RH)					
- MacIntosh 3	N	10.3	3.2	7.9	W
Vital Signs Fibreoptic (RH)					
- MacIntosh 3	N	10.9	4.8	8.3	W
- MacIntosh 4	N	10.0	2.6	8.8	W
North American Medical Products Fibreoptic (RH)					
- MacIntosh 3	N	8.5	0.9	6.5	A
- Miller 2	N	8.4	0.8	6.2	A

Laryngoscope model (RH = regular handle) Status (U = used, N = new); ExI = exposure index; EV = exposure value; DLI = direct light intensity; FOI = field of illumination (Na = narrow; A = average; W = wide).

TABLE III

Group		n	Mean (lux × 10^3)	SD (lux × 10^3)
1	IR	4	3.63	1.32
2	IS	3	1.43	0.95
3	FR	13	1.88	1.13
4	FS	5	0.76	0.29

IR = Incandescent bulb, regular size handle.
IS = Incandescent bulb, short or pencil handle.
FR = Fibreoptic light, regular handle.
FS = Fibreoptic light, short or pencil handle.
SD = Standard deviation.

exposure meter that has an accuracy of ±0.2 EV (exposure value).[2] This apparently small error in measurement will be greatly magnified by the application of the formula to determine illumination in lux from exposure indices (lux = $2.5 \times 2^{\text{exposure index}}$). With a true exposure index of 9.0, an error of ±0.2 EV would make the calculated lux number fall anywhere between 1114.3 and 1470.3, an error of about 15% on either side of the true value.

Successful tracheal intubation by direct laryngoscopy requires sufficient illumination of the glottic inlet. Laryngoscope design is one variable in determining glottic inlet illumination[6] while the intensity of illumination by the laryngoscope blade itself is another. Laryngoscope blades using fibreoptic light sources have advantages over blades with incandescent light bulbs. These include a cool light source[7,8] and the absence of a bulb that could fall off in the airway.[9] However, our results do not support the claimed advantage of a more intense light.[7]

While the use of pencil or short handle laryngoscopes may physically facilitate direct laryngoscopy in certain types of patients[10] (the obese, those with anatomical abnormalities), such light sources are associated with a considerable reduction in light output. In the clinical setting, where one is often using aging batteries as power sources, these handles could potentially generate inadequate light for direct laryngoscopy.

Finally, during a difficult intubation, when the glottic opening is not directly in front of the laryngoscope blade tip, blades with a narrow field of illumination may make intubation even more difficult. It is our clinical experience that the narrow focused light of most fibreoptic blades often makes recognition of clues to the location of the glottis more difficult. This necessitates searching movements of the laryngoscope/blade unit "looking for" the glottis. Such movements and the associated risk of trauma to the airway could be decreased or eliminated with the use of a laryngoscope/blade unit providing a wide area of illumination relative to the surface area of the periglottic region.

The measurement of light remains a difficult task as units of quantity and intensity of light cannot be put on an absolute physical basis because of the psychophysiological factors involved.[11] The units used depend upon the conditions under which measurement is being considered. In this paper, we reported the illumination (intensity of light falling on a subject) in lux provided by various laryngoscope/blade combinations. This photometric quantity is only one variable affecting the subjective visual sensation of brightness. Surface brightness, or luminance, depends also on the power of reflection of that surface. In the context of tracheal intubation, the reflection factor of laryngeal mucous membranes, which was not assessed in this study, is an important consideration.

McIntyre suggested that many factors affect the ability to intubate the trachea.[12] Differences in blade design can result in the laryngoscope light being directed away from the larynx.[6] We have shown that differences in direct light intensity and field of illumination exist among various laryngoscope/blade combinations. These differences may make tracheal intubation more difficult. We advise that anaesthetists consider the light intensity and the field of illumination provided by the laryngoscope/blade combination they select before tracheal intubation.

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