Technical Report

An assessment of the luminance and light field characteristics of used direct laryngoscopes

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Purpose: To determine luminance and light field characteristics and the effect of residual battery potential and luminance on light colour temperature in our used Macintosh #3 and #4 fibre-light (FLB) and bulb-light (BLB) laryngoscopes.

Methods: We used a power supply to provide laryngoscopes with potentials equivalent to those most commonly measured in the handles in use in our OR. Measurements were made under controlled, constant, conditions using a Pentax digital spotmeter (luminance) or a Minolta Color III colour temperature meter (light colour). Colour measurements were made while increasing the power source potential from 2-3 volts (v) in increments of 0.1 v. Light field measurements were made with a mm increment ruler mounted on the base of the test fixture.

Results: At 2.5 and 2.8 v respectively, the #3 FLB produced luminance values of 23.9 ± 11.4 and 41.7 ± 17.2 $cd \cdot m^{-2}$ (mean ± SD), and the #4 FLB produced 58.6 ± 21.4 and 90.9 ± 32.2 $cd \cdot m^{-2}$. Increasing potential increased luminance values ($P < 0.001$) and the #4FLB produced higher luminance values ($P < 0.001$). BLB produced higher luminance values than did FLB across all comparisons ($P < 0.001$). As potentials and luminance values decreased, light temperature was reduced ($P < 0.001$). There were no differences in light field dimensions noted in any comparison.

Conclusion: Fifteen percent of the BLB did not meet the minimum luminance for laryngoscopy of 100 $cd \cdot m^{-2}$, 92% of the FLB did not meet that same standard.

Objectif : Déterminer les caractéristiques de la luminance et du champ lumineux, ainsi que l'effet de la luminance et de l'énergie de la pile résiduels sur la thermocolorimétrie des laryngoscopes Macintosh n^os^ 3 et 4 avec fibre optique (LFO) et ampoule (LA).

Méthode : Nous avons utilisé une alimentation électrique pour fournir aux laryngoscopes l'énergie équivalente à celle qui est la plus communément utilisée dans les appareils en usage dans nos salles d'opération. Les mesures ont été faites dans des conditions contrôlées et constantes à l'aide d'un photomètre digital Pentax (luminance) ou d'un thermocolorimètre Minolta Color III (couleur de la lumière). L'enregistrement des couleurs a été réalisé tout en augmentant le potentiel de la source énergétique de 2-3 volts (v) par incréments de 0,1 v. Les mesures du champ lumineux ont été obtenues avec une règle millimétrique montée sur la base de l'appareil testé.

Résultats : À 2,5 et 2,8 v respectivement, le LFO n° 3 a produit une luminance de 23,9 ± 11,4 et 41,7 ± 17,2 $cd \cdot m^{-2}$ (moyenne ± écart type), et le LFO n° 4 a produit une luminance de 58,6 ± 21,4 et 90,9 ± 32,2 $cd \cdot m^{-2}$. L'augmentation de potentiel énergétique a entraîné une hausse de la luminance ($P < 0,001$) et le LFO n° 4 a produit une luminance plus importante ($P < 0,001$). Le LA a produit des valeurs de luminance plus élevées que le LFO pour toutes les comparaisons réalisées ($P < 0,001$). La température lumineuse a baissé en accord avec les diminutions d'énergie et de luminance ($P < 0,001$). Aucune différence de dimensions des champs lumineux n'a été notée lors des comparaisons.

Conclusion : On a constaté que 15 % des mesures LA et 92 % des LFO n'ont pu atteindre la luminance minimale nécessaire à la laryngoscopie, soit 100 $cd \cdot m^{-2}$.

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VISUALIZATION of the larynx at the time of direct laryngoscopy is dependent upon adequate illumination of the airway tissues by the laryngoscope. Illumination of the airway is determined, in part, by the intensity and the colour of the light cast and the area (light field) over which the light is cast. The intensity and colour of the light and the nature and dimensions of the laryngoscopic light field are influenced by the nature of the bulb (finish, composition, power rating), the potential of the power source applied to the bulb and, in fibreoptic systems, the characteristics of the fibre-bundle.

In the study of light measurement (photometry), there are a number of ways in which to express light intensity. The amount of light emitted by a point source (or the rate of flow of light from the source) is defined as the *luminous flux*. The SI unit of luminous flux is the lumen. *Luminous intensity* is the density or concentration of luminous flux per unit solid angle of a source (lumen per steradian) in a given direction; the SI unit is the candela (cd) and one candela equals one lumen·steradian^{-1}. A surface receiving light is said to be illuminated. The amount of light received on a unit area of the surface is the *illuminance*; the SI unit is the lux (lx) and one lux is equal to one lumen·m^{-2}. Finally, the amount of light emitted or re-emitted per unit area of a surface in a given direction is the *luminance*. Luminance is expressed in terms of luminous intensity per unit area and is measured in candela per square metre (cd·m^{-2}).

During laryngoscopy, luminance (the amount of light emitted back from the surface of the larynx toward the viewer) determines our perception of the brightness of the viewed field. The minimum required luminance for laryngoscopy is reported to be 100 cd·m^{-2}.[1] This was determined by Skilton *et al.*, who used a laryngoscope modified with a variable resistor in the handle to allow the light output to be varied by means of a dial control. Ten consultant anesthesiologists were asked to adjust the light setting to minimum acceptable level during direct laryngoscopy in elective surgical patients. The luminance resulting from this adjustment was then measured and the minimum lighting for laryngoscopy was found to be equivalent to a luminance of 100 cd·m^{-2} at the centre of the light field. The optimum dimensions of the light field were not reported.

Visible light occupies a small portion of the electromagnetic spectrum. A particular light is often described by its colour, which is quantitatively expressed as a frequency, inversely as a wavelength or as having a temperature. With the exception of light emitted from a laser, all other light sources emit light comprised of varying amounts of colour. For example, a tungsten bulb emits greater amounts of red, orange, and yellow light while a fluorescent bulb has higher quantities of green and blue light. When describing the colour of a light source, it is not usually practical to measure wavelengths or frequencies that comprise the light, but the temperature of the source, expressed in degrees Kelvin (°K), can be determined easily.

The colour of light cast onto an object may influence both its illumination and the perceived crispness of the image. In direct laryngoscopy, a hotter (higher temperature, shorter wavelength, less red) light is probably desirable as less of the light will be absorbed by the viewed tissue structures, leading to a greater appreciation of laryngeal anatomy. However, the optimal colour for laryngoscopy has not been defined.

Our institution purchased Rusch Lyncs™ (Rusch, Germany) fibre-light bladed (FLB) direct laryngoscopes in 1991: they have been in constant use since. Penlon bulb-light bladed (BLB) laryngoscopes removed from service at that time were either stored or used as backup instruments. The Macintosh laryngoscope blade is used nearly exclusively in our institution, the #3 more commonly than the #4. It was the opinion of most of the anesthesiology staff that the FLB laryngoscope performance had seriously deteriorated over time, to a level below that of the backup BLB laryngoscopes. We assessed performance and compared our supply of each type of FLB and compared them with the BLB laryngoscopes with respect to luminance and light field characteristics. We also determined the effect of residual battery potential and surface luminance on light colour temperature in our population of #3 and #4 Macintosh fibre-light laryngoscopes.

Methods

We determined the residual battery potential in the laryngoscope handles in daily use in our operating room (OR) with a digital voltmeter (Model #87, Fluke Corporation, Everett, Wash). When we assessed the luminance and light field characteristics of the laryngoscope blades, we used a power supply (Model #HPD300, Xantrex Technologies, North Van, BC) to eliminate the effect of variable battery potentials. It was set to provide a voltage source equal to that: 1) most commonly measured in our OR and; 2) measured with new batteries under load conditions. The power supply output was confirmed with the digital voltmeter. A new bulb was installed in the head assembly of a FLB handle prior to testing. The bulbs in the BLB were not replaced with new bulbs before testing and they were assessed and compared with the FLB at 2.8 v only. Measurements were made in a dark room with the light cast onto the matt grey base of a test fixture, employed to support the laryngoscope's head assembly and blade in a constant and reproducible fashion. Measurements were recorded 30 cm above the light field, using a Pentax digital spotmeter, with a 1° visual target. Light field width measurements were made using a mm increment ruler mounted on the base of the test fixture. The diameter of the area of maximum luminance was measured (mm) and this constituted our light field. Statistical analysis was with the Student's t test. Significance was assumed for $P < 0.05$.

To determine the influence of luminance and battery potential on light colour, we used a power supply to provide a voltage source equal to that measured with new batteries under load conditions (2.8 v). Our population of used Macintosh (#3 and #4) FLB was then attached to the head assembly and luminance ($cd{\cdot}m^{-2}$) and colour temperature (°K) measurements were made. Measurements were made 30 cm above the light field, using a Pentax digital spotmeter and a Minolta Color III color light meter. These measurements were then repeated, increasing the power source potential from two to three volts in increments of 0.1 volts, to reflect the impact of variable residual battery potentials only on light colour. For this assessment, five new Rusch Lyncs™ #3 Macintosh blades were employed to assess the impact of variable battery potential on light colour. New blades were used to eliminate the potential that damaged fibre bundles in the used blades might impact on the findings. Mean colour temperatures were calculated for each luminance and potential value and lines of correlation were constructed between the variables. Significance was assumed for $P < 0.05$.

Results

The most commonly measured residual potentials in the battery handles (n = 20) were 2.5 and 2.8 v (Figure 1). The measured potential with new batteries under load conditions was 2.8 v. The table reports the findings [mean ± SD, (range)] on peak luminance ($cd{\cdot}m^{-2}$) and light field width (mm) for the two populations (#3 and #4) of Macintosh FLB laryngoscope blades at 2.5 and 2.8 v. Increasing the supplied potential increased the luminance generated within each group ($P < 0.001$). There were greater luminance values generated with the #4 blades at each level of supplied potential ($P < 0.001$). There was no difference in mean light field dimensions between the groups. The table reports the findings on peak luminance ($cd{\cdot}m^{-2}$) and light field width (mm) for the two populations (BLB and FLB) of blades. Greater luminance values were generated with the #3 and #4 BLB ($P < 0.001$).

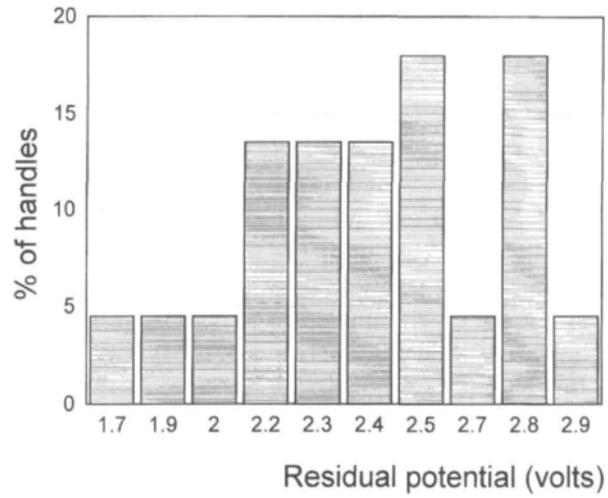

FIGURE 1 The distribution of the measured residual potentials (under load conditions) of the fibre-light battery handles.

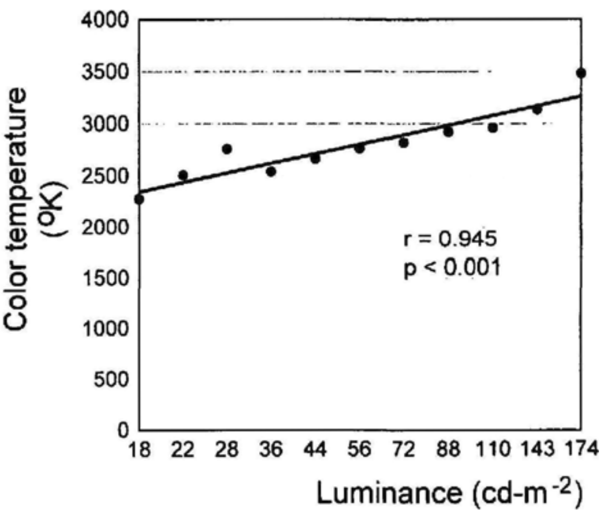

FIGURE 2 The relationship between luminance and light temperature. As luminance decreases, there is a reduction in colour temperature ($P < 0.001$).

Fifteen percent of the BLB did not meet the minimum luminance for laryngoscopy of 100 $cd{\cdot}m^{-2}$ but 92% of the FLB did not meet that same standard. Again, there was no difference in mean light field dimensions between the groups.

As luminance values decreased, there was a reduction in the colour temperature of the light (the light became more red), r = 0.945, $P < 0.001$ (Figure 2).

TABLE Luminance and light field width (mean ± SD, [range]) for #3 and #4 fibre-light blades and bulb-light blades at 2.5 (FLB only) and 2.8 volts (FLB and BLB) supplied potential.

	2.5 volt source	*2.8 volt source*
Luminance (cd·m^{-2})		
#3 fibre-light blades (n = 17)	23.9 ± 11.4, [9 - 44]	41.7 ± 17.2, [14 - 72]
#4 fibre-light blades (n = 20)	58.6 ± 21.4, [22 - 110]	90.9 ± 32.2, [56 - 174]
#3 bulb-light blades (n = 12)		176.9 ± 83.6, [44 - 350]
#4 bulb-light blades (n = 14)		248 ± 141.7, [56 - 573]
Field width (mm)		
#3 fibre-light blades (n = 17)	8.8 ± 4.4, [2 - 15]	8.7 ± 4.2, [3 - 16]
#4 fibre-light blades (n = 20)	9.8 ± 4.2, [4 - 16]	10.1 ± 4.4, [3 - 18]
#3 bulb-light blades (n = 12)		8.6 ± 2.6, [5 - 14]
#4 bulb-light blades (n = 14)		9.2 ± 3.7, [6 - 16]

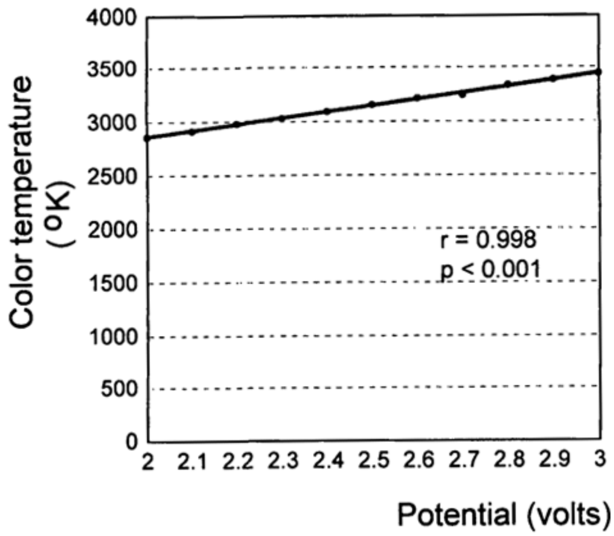

FIGURE 3 The relationship between power source potential and light temperature. As potential decreases, there is a reduction in colour temperature ($P < 0.001$).

Similarly, as the power source potential was decreased, there was a reduction in the colour temperature of the light, r = 0.9988, $P < 0.001$ (Figure 3). The peak luminance produced by the new blades used to assess the impact of the power source potential on light colour was 156 ± 25 candela·m^{-2} at 2.8 v.

Discussion

The majority of our laryngoscopes in daily use did not produce 100 cd·m^{-2} even under battery conditions which would be obtained with continuously new batteries in the handles. This compares to Skilton's report that 27% of their instruments did not meet their defined standard.[1] Our poorest performing laryngoscope blades (Macintosh #3 FLB) were those most commonly relied upon by the majority of our staff. None of our #3 blades met Skilton's standard at any stage in the assessment; only 5% of the #4 Macintosh FLB did so under usual battery conditions (2.5 v), 30% did so under the condition of new batteries (2.8 v).

It is our opinion that the poorer performance of the #3 blades was due to greater use resulting in more advanced fibre bundle deterioration. On visual inspection, the fibre bundles of the #3 blades had many more surface imperfections, a result of higher use and handling. There was no difference in the cross sectional area of the fibre bundles when the #3 blades were compared with the #4 nor have we measured differences in peak luminance when comparing new #3 blades with new #4 blades from a number of providers. Thus, we assume that there was little or no difference between the blades at the outset and that the difference, now measured, was acquired.

Fibreoptic bundles deteriorate with time and use. Obviously, rough or inappropriate handling of instruments containing fibreoptic bundles will hasten this process. Specifically, manufacturers caution against routine and repeated steam autoclaving of fibreoptic laryngoscopes. In our institution, following use, the laryngoscope blades are washed by hand with a surgical scrub brush, rinsed in water, soaked in activated (alkaline) glutaraldehyde 2.4% for a minimum of 20 min, rinsed thoroughly, air-dried, and then returned to service.

By controlling the supplied potentials using the power source, we were able to eliminate variable battery potentials as a cause of poor luminance. In this way, we were able to isolate blade performance. Increasing the voltage improved luminance values, but had no effect on light field dimensions. However, the improved luminance values were still most often inadequate. Thus the majority of our fibre-light blades would not provide adequate illumination for laryngoscopy even if batteries were refreshed continuously. Our used bulb-light blades generated higher luminance values than did our fibre-light blades and would provide adequate light for laryngoscopy under routine conditions of use.

By using new blades while assessing the impact of residual battery potential on light colour, we were able to eliminate blade condition as a variable and to isolate handle performance. As luminance values decreased, either because of deterioration in the battery potential (decreased voltage) or the condition of the laryngoscope blades, there was a reduction in the colour temperature of the light. Thus, in older laryngoscopes, with lower residual potentials, the negative effect of these two variables on the intensity and quality of light would presumably be, at least, additive.

Skilton's work has not been corroborated. However, it is our opinion that we would not generate a minimally acceptable luminance value that was different from his if we were to repeat his experiment. That is because the laryngoscopes producing luminance levels below 100 $cd \cdot m^{-2}$ were generally deemed to be poor performers under clinical conditions by our clinical staff. The colour of light which would be optimal for laryngoscopy has not previously been determined. Our findings suggest that the colour of light produced by laryngoscopes moves away from the optimal spectral range as battery potential or blade condition deteriorates. However, whether these changes, although statistically significant, are clinically important, remains to be proved.

There are a number of implications to our findings. It was clear that our laryngoscopes are no longer adequate for their intended purpose and they were replaced. It is both surprising and concerning that they performed as poorly as they did. We cannot ignore the possibility that poor lighting conditions have contributed to difficulties in airway management in our operating room. We have had no ongoing and objective assessment of laryngoscope performance as part of our routine equipment maintenance program and this deficiency has been corrected. Obvious attributes to a new system, based on our assessment, would be a high and sustainable potential (voltage) source. This would reduce the impact of deteriorating fibrebundle condition on the quality (luminance and colour) of the light produced. A larger fibrebundle may also decrease the impact of bundle deterioration on light quality. Finally, in assessing the cost of a new system, it should be acknowledged that the system is likely to serve for not less than five years, and, if our past experience is predictable, longer.

We do not wish to suggest with this report that our Rusch Lyncs™ system was defective. The laryngoscopes had been used for eight years in an operating room providing care to 15,000 patients a year. There had been limited efforts over the years to assess, repair or replace system components. The system has served us well and we used it for far longer than we should reasonably have expected it to last under the conditions of use.

We have described a technique to measure the performance of direct laryngoscopes, and, using that technique, have determined that the majority of our laryngoscopes do not meet a reasonable standard of performance. We recommend that ongoing performance assessments of direct laryngoscopes should be part of all routine equipment maintenance programs in all operating rooms.

Reference

1 *Skilton RWH, Parry D, Arthurs GJ, Hiles P.* A study of the brightness of laryngoscope light. Anaesthesia 1996; 51: 667–72.