Original Article

Videolaryngoscopes differ substantially in illumination of the oral cavity: A manikin study

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ABSTRACT

Background and Aims: Insufficient illumination of the oral cavity during endotracheal intubation may result in suboptimal conditions. Consequently, suboptimal illumination and laryngoscopy may lead to potential unwanted trauma to soft tissues of the pharyngeal mucosa. We investigated illumination of the oral cavity by different videolaryngoscopes (VLS) in a manikin model. **Methods:** We measured light intensity from the mouth opening of a Laerdal intubation trainer comparing different direct and indirect VLS at three occasions, resembling optimal to less-than-optimal intubation conditions; at the photographer's dark room, in an operating theatre and outdoors in bright sunlight. **Results:** Substantial differences in luminance were detected between VLS. The use of LED light significantly improved light production. All VLS produced substantial higher luminance values in a well-luminated environment compared to the dark photographer's room. The experiments outside-in bright sunlight-were interfered with by direct sunlight penetration through the synthetic material of the manikin, making correct measurement of luminance in the oropharynx invalid. **Conclusion:** Illumination of the oral cavity differs widely among direct and indirect VLS. The clinician should be aware of the possibility of suboptimal illumination of the oral cavity and the potential risk this poses for the patient.

Key words: Airway, anaesthetic techniques-laryngoscopy, equipment-laryngoscopes, intubation

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INTRODUCTION

Indirect videolaryngoscopes (VLS) make endotracheal intubation possible without extensive experience.[1-3] Since their introduction,[4] the singular goal is optimal visibility of the pharyngolarynx.

An underestimated aspect of the design is lighting. When illumination is poor, positioning the endotracheal tube is difficult, potentially traumatizing soft tissue, especially when using a rigid stylet.[5]

The aim of this study was to compare the intensity of illumination from the light source between different VLS. Devices were compared in a photographer's dark room, an operating theatre and outside-in bright sunlight. The intensity of light was measured at the oral cavity opening of a Laerdal intubation trainer.

METHODS

We informed and consulted the Institutional Review Board concerning this study. The Board decided that formal review was not necessary as this study did not involve any patients nor participants other than the investigators.

In this *in vitro* study, using a manikin (Airway Trainer™,

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Laerdal Stavanger, Norway), fourteen different VLS were compared, readily available in the institution where both authors were employed at the time of the study (respectively as resident and professor in anaesthesiology):Coopdech VLP-100® (Daiken Medical, Tokyo, Japan), C-MAC® (8402 ZX Monitor) and C-MAC PM® (Karl Storz, Tuttlingen, Germany), GlideScope Ranger® (Ranger Single Use System) and GlideScope Cobalt® (GVL System) (Verathon Medical, Bothell, WA, USA), King Vision® channelled and MAC (King systems, Noblesville, IN, USA), McGrath Series 5® and MAC EDL® (Aircraft Medical, Edinburgh, UK), Venner AP Advance channelled® and MAC® (Venner Medical, Kiel, Germany), Airtraq A-011® (Prodol Meditec, Guecho, Spain), Pentax AWS-S100® (Hoya Corporation, Tokyo, Japan) and a classic direct laryngoscope (Brite Blade® LED) (Karl Storz, Tuttlingen, Germany).

Measurements were performed at three different locations; the photographers' dark room, the operating theatre and outside, in bright sunlight (copying endotracheal intubation in a prehospital setting).

The investigator placed the VLS in the manikin's mouth, achieving the best possible view of the glottis. Once achieved, width and depth of vision were analyzed by scoring the Cormack and Lehane grade. The Cormack and Lehane grade was scored to make the quality of laryngoscopy as uniform as possible; it was not used as a way to score oral illumination.

Hereafter, a professional photographer, knowledgeable in measuring light intensity, measured light intensity from the opening of the oral cavity, using a Sekonic L-758Cine Digital Master® light meter (Sekonic Corporation Japan, Tokyo, Japan), set to cd/m². The light meter was placed inside the oral cavity. Due to the size of the light meter, this was within 2 cm of the mandibular dental margin. All VLS had fully loaded new batteries inserted, or were used while directly connected to mains electricity. Light intensity was measured three times per VLS and defined as luminance (cd/m²), the amount of light emitted or re-emitted per unit area of a surface in a given direction.[6,7]

At the operating theatre, all ceiling lamps were lit along with one satellite lamp. This satellite lamp (KLS Martin, Tuttlingen, Germany; VAC 50/60 Hz, 24 VDC, 300 VA) was directed towards the thorax of the same Laerdal manikin, resembling normal endotracheal intubation conditions.

After the experiment, we analysed the illumination by the different VLS by comparing the values of luminance (cd/m²).

RESULTS

A Cormack and Lehane grade 1 was achieved with every laryngoscopy. As depicted in Tables 1 and 2, the measurements of luminance differed substantially among devices. In the photographer's dark room, luminance ranged from 1.2 cd/m² (Pentax AWS) to 73.2 cd/m² (C-MAC).

In the operating theatre, large differences in luminance were measured among the VLS, ranging from 2.7 cd/m² (McGrath series 5) to 110.0 cd/m² (C-MAC). All VLS, except McGrath series 5 and McGrath MAC, produced substantial higher luminance values in a well-illuminated environment compared to the dark photographer's room [Figures 1 and 2].

Our experiments outside-in bright sunlight-were interfered by direct sunlight penetrating through the synthetic material of the manikin. This caused the light meter to measure the intensity of sunlight instead

Table 1: Light intensity (luminance cd/m²) per non-channelled (video) laryngoscope (Macintosh design blade)

Device (video) laryngoscope	Power supply	Luminance cd/m²	
		Photographer's dark room	Operation theatre
Direct Macintosh	2.5 VNiMH battery	15.0	50.0
McGrath Series 5	Single AA (Mignon/ IEC-LR6 battery) 1.5 V battery	3.7	2.7
McGrath MAC	Proprietary 3.6 V Lithium Battery Pack	4.3	4.3
GlideScope Cobalt	7.2 V 2200 mAh Li-ion battery	2.6	5.7
King Vision MAC	Three AA (Mignon/ IEC-LR6 battery) 1.5 V batteries	3.4	15.0
Coopdech	3.7 V DC 1500 mAh Li-ion battery - rechargeable	2.3	17.3
Venner MAC	Handle: AA (Mignon/ IEC-LR6 battery) 1.5 V Battery Monitor: rechargeable batteries	24.6	25.3
GlideScope Ranger	12 V DC battery - rechargeable	1.6	30.0
C-MAC PM	12 V DC battery - rechargeable	30.0	64.0
C-MAC	12 V DC battery - rechargeable	73.2	110.0

Data are presented as mean

of light intensity of the laryngoscopes. This was the case for both the VLS and the direct laryngoscope.

DISCUSSION

The existing VLS mainly differ whether they use: (1) Channelled or non-channelled blades; (2) classic Macintosh curved, or more acutely angled blades; and (3) whether the illumination results from halogen, xenon bulbs or from LED light origin.

All of the above have major implications for the anaesthesiologist. A clear visibility of the oropharynx and laryngeal entrance and the availability of substantial space in the mouth for manoeuvring an endotracheal tube and other adjuncts (e.g., gum elastic bougie, stylets, oro/nasogastric tube, Magill forceps) are keys to success. VLS has proven to result in successful endotracheal intubation more easily.[8,9] So although less than optimal illumination does not have to result in unsuccessful endotracheal intubation, the risk of trauma remains. Indeed, it is important that we clearly see what we do during any manipulation in the mouth to avoid traumatising tissue. The existence of so-called 'blind spots' is known to cause palatal, palatopharyngeal and tonsillar trauma.[5,10,11] For direct laryngoscopy, the minimum required luminance is reported to be 100 cd/m^2 at the centre of the light field. The optimum dimensions of the light field hereby were however not reported.[7] To the best of our knowledge, such information is not available for VLS. The minimum required luminance for VLS is not yet known. Although we cannot determine the minimum required amount of illumination to prevent oral trauma, when the amount of illumination is 40 times less than the minimum required for direct laryngoscopy, the caregiver should be well-aware of this.

Table 2: Light intensity (luminance cd/m^2) per channelled video laryngoscope

Device channelled (video) laryngoscope	Power supply	Luminance cd/m^2	
		Photographer's dark room	Operation theatre
Pentax Airway Scope	Two AA (Mignon/ IEC-LR6 battery) 3 V batteries	1.2	8.0
Airtraq	Single use (60 min battery life expectancy)	3.3	10.0
King Vision	Three AA (Mignon/ IEC-LR6 battery) 1.5 V batteries	5.0	12.0
Venner	Handle: AA (Mignon/ IEC-LR6 battery) 1.5 V battery Monitor: Rechargeable batteries	50.6	80.0

Data are presented as mean

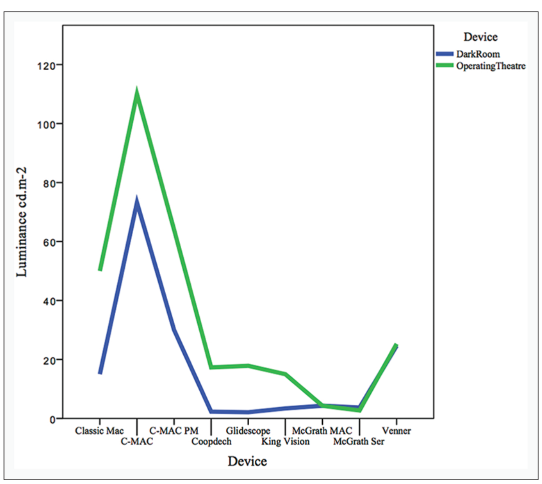

Figure 1: Light intensity measured in non-channelled (video) laryngoscopes

Over the years, illumination of the oral cavity during direct laryngoscopy was improved significantly by changing the filament bulbs, and later by changing the halogen or xenon bulbs into the more solid-state LED lights. Compared to conventional bulb-on-blade laryngoscope lighting systems (using halogen light), LED bulbs use very little energy, operate with less heat, produce a brilliant light and have a much longer lifespan than the earlier bulbs (15,000–30,000 h compared to approximately 1000 h), thereby eliminating the need for bulb replacement.

Improvement in quality and longevity of batteries

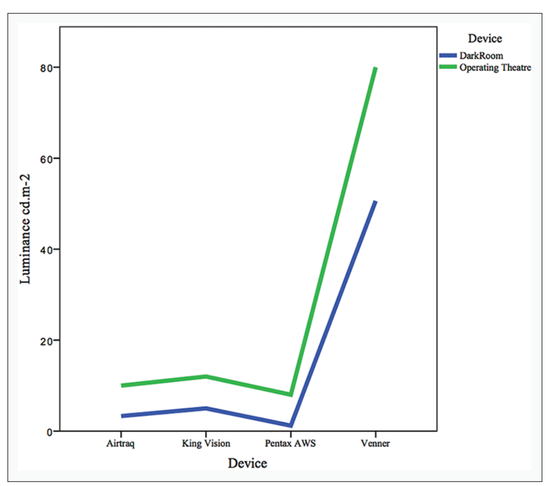

Figure 2: Light intensity measured in channelled (video) laryngoscopes

and using the mains, further improved illumination options and visibility for both direct and VLS.

One can argue if the reported minimum required luminance of 100 cd/m^2 for direct laryngoscopy also holds true for VLS. Indeed, the techniques are not simply interchangeable. On the other hand, the importance of seeing what one is doing while passing an endotracheal tube (especially one with a rigid stylet *in situ*!) is applicable to both techniques. When applying this limit of 100 cd/m^2 to this study, illumination in all tested VLS (except the C-MAC) is poor when used in the operating theatre.

Our finding, that due to extensive glare on the monitor screen of different VLS endotracheal intubation in bright sunlight while looking at the screen is severely hampered, needs further investigation. The material of the manikin is penetrated by direct sunlight, in contrast to human skin. As a consequence, we cannot draw conclusions from this part of our study, but we can conclude that studies in bright sunlight involving manikins have severe limitations.

Prehospital endotracheal intubation has highly variable success rates and can be challenging due to patient immobilisation, entrapment, air medical evacuation, constrained access to the patient, poor patient positioning and variable ambient lighting. VLS have been used in the field where sunlight is very intense.[12,13] Our finding (hampered endotracheal intubation due to extensive glare) could, however, have major implications for the caregiver in the prehospital setting (e.g., ambulance, air-ambulance services and war zone circumstances) and should be taken into account when choosing a device.

VLS, using channelled VLS, may impair direct visibility of the oral cavity by the significant additional volume of the blade itself or the acute angle of the blade, whereby the light produced at the top illuminates more the anterior part of the laryngeal entrance, and not necessarily the whole mouth. This is in contrast with VLS that uses a Macintosh design blade whereby a larger part of the oral cavity is illuminated. We believe that the triad: (1) Less room to manoeuvre in the mouth; (2) distraction by 'looking at the monitor screen' outside the mouth: And (3) the use of a sharp, rigid styletted endotracheal tube combined with less optimal illumination possibly resulting in 'blind spots', may pose a greater risk to harm the patient (oesophageal intubation and trauma).[5,10,11]

There are limitations to this study. First, it is a manikin-based study. The goal of the study was to compare the intensity of illumination between different VLS. To compare different devices in exactly the same circumstances, it would have been necessary to place all the different VLS in the same persons' mouth. Ethically this is not correct, and for a first comparison not even necessary. Light intensity in humans may be different due to absorption and/or reflection by the manikin. Comparing maybe one or two different devices could perhaps be done in a group of patients/ volunteers. Another solution may be a cadavre study.

Second, background light (in the operating theatre) could possibly have influenced the measurements more than the light emission *per se*. However, we performed a baseline recording when we compared illumination by the different devices in a photographer's dark room. This way, we got a primary idea on the amount of light emitted by the VLS, and when using a VLS, virtually there always is background light.

When comparing illumination, we chose to place the light meter at the opening of the oral cavity. This is the same position the eye of the caregiver (thus the 'light meter' of the caregiver) normally has. The eye of the operator registers the amount of light from the opening of the oral cavity when manoeuvring the endotracheal tube before looking at the video screen. As stated by Vincent and colleagues 'it is important to advance the endotracheal tube beyond the uvula before directing one's attention to the video monitor'.[14] Precisely, the fact that the amount of light emitted and the amount of light reaching the eye of the caregiver may significantly differ could pose an extra risk to the patient. When the image on the screen is well-lit, but there is little light reaching the eye when one is looking into the oral cavity and not looking at the video screen, one is still poking in the dark, which poses a subsequent risk to the patient! Even when the amount of light emitted is enough to (easily) intubate a patient (although maybe not the preferred 100 cd/m^2), suboptimal illumination poses a risk to the patient, especially that of palatopharyngeal trauma.

We wanted to investigate the relationship between light emission by VLS and oral cavity illumination. Measuring light emission at the laryngeal entrance would provide a different parameter. The relationship between light emission at the oral cavity and light emission at the laryngeal entrance is not well-described in current literature. Furthermore, a search for suitable equipment small enough to measure light emission from the laryngeal entrance learned that it is not available.

Third, the synthetic material of the manikin may not only be penetrated by direct sunlight but possibly also by the light of the lamps in the operating theatre. When this is true, the amount of penetration would have been the same for all devices for all measurements and thus does not influence the comparison between devices. The fact that in the operating theatre for the McGrath series 5 and McGrath MAC the amount of light measured is less (McGrath series 5) and the same (Mc Grath MAC) as in the photographer's dark room, contradicts penetration of the synthetic material of the manikin. It is also possible that the material of the manikin reflected the light of the devices. When this is true, this may result in a different level of illumination when the VLS are used in humans, but again this is valid for all devices, which makes comparison still possible.

Fourth, we did not investigate if there are differences when a device is connected to mains instead of working on a (fully charged) battery. Possibly, the light output is better when a VLS is connected to mains.

Finally, we used a LED lit direct laryngoscope (Karl Storz, Tuttlingen, Germany), as which was the standard in hospital use for endotracheal intubation. It would have been interesting to know how a direct laryngoscope using a conventional light bulb would perform, compared to different VLS.

CONCLUSION

Illumination of the oral cavity differs substantially among VLS in a manikin model. Illumination is best when using the C-MAC VLS. Comparing these results with the recommendations made previously for direct laryngoscopy, illumination is poor with all VLS tested, except for the C-MAC when used in the operating theatre. Clinicians should be aware of these shortcomings and differences between devices.

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Conflicts of interest

There are no conflicts of interest.

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