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## An affordable videolaryngoscope for use during the COVID-19 pandemic

COVID-19 has infected millions of patients worldwide, with a substantial proportion of critically ill patients requiring endotracheal intubation and mechanical ventilation.<sup>1</sup> Tracheal intubation is a potentially aerosol-generating procedure and therefore imposes a large risk to the health-care workers who use it. Use of a videolaryngoscope can enable the operator to stay further away from the patient's airway compared with conventional laryngoscopy and might help to mitigate the risk associated with close patient contact.<sup>2</sup> In addition, compared with conventional laryngoscopy, videolaryngoscopy can facilitate better glottic view, can reduce attempts at intubation in patients with an unpredicted difficult airway, and can reduce laryngeal trauma, thus making this technique safer for patients.<sup>3</sup> By using videolaryngoscopy, airway management conditions and, subsequently, safety, can be improved, with additional safety benefits from use of personal protective equipment and barrier enclosure devices.<sup>4</sup>

Videolaryngoscopes have gradually become a standard of care for airway management in many places with adequate resources.<sup>5</sup> However, this technology is largely inaccessible in low-income and middle-income nations and in places with few resources. Even in adequately resourced places that have been deeply affected by the pandemic, the health-care facilities are unduly stretched, creating scarcity of basic drugs and equipment. We aimed to design a low-cost videolaryngoscope and to test its feasibility and effectiveness using a mannequin.

Local modifications to videolaryngoscopes have been proposed as a teaching and learning aid and for use in places where it is not easily available.<sup>6,7</sup> We converted a conventional rigid Macintosh adult laryngoscope (at size 3 or 4) into an improvised videolaryngoscope (appendix p 1). We used a borescope, which was originally designed for visualising the interior of engines, and works with similar principles to that of the endoscope. Borescopes have a diameter of 5 mm or 7 mm and length of 2 m. The tip of the borescope has multiple light emitting diodes around the camera and can be connected to version 6 or higher Android mobile phones with a free downloadable camera application (eg, inskam,

USB Camera, or as per manufacturer guidelines) with USB On-The-Go (a standardised specification that allows a device to read data from a USB device without requiring a PC).<sup>8</sup> At an average cost of US\$150, the device is affordable and easily available.

We removed the light source of the laryngoscope and fixed the tip of the camera of the borescope 4 cm proximally to the tip of laryngoscope blade, with a cable glued to the inner side of the flange. To disinfect the surface, the laryngoscope, borescope, and the connector wire were wiped with a cotton roll soaked with 70% alcohol and then allowed to dry.<sup>9</sup> A dedicated Android mobile phone with a plastic cover was used with the laryngoscope. The plastic cover of the phone was discarded after each procedure. The modification was hypothesised to increase airway distance between the operator and the patient (airway to airway [A-A] distance) and improve glottic view compared with the conventional laryngoscope. We included a transparent plastic cube as a barrier enclosure device (appendix p 2), with adapted dimensions, as suggested in a previous publication.<sup>4</sup>

To assess feasibility, we compared the glottic view (assessed by percentage of glottic opening [POGO] score)<sup>10</sup> and the distance between

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	Conventional laryngoscopy			Improvised video laryngoscopy			Conventional laryngoscopy with barrier			Improvised video laryngoscopy with barrier		
	POGO* score (%)	Intubation time† (s)	A-A distance‡ (cm)	POGO score (%)	Intubation time (s)	A-A distance (cm)	POGO score (%)	Intubation time (s)	A-A distance (cm)	POGO score (%)	Intubation time (s)	A-A distance (cm)
Anaesthesiologist 1	50%	17.4	48	100%	18.8	58	50%	17.9	53	100%	19.1	56
Anaesthesiologist 2	30%	13.1	28	100%	17.7	44	30%	17.9	38	80%	24.0	48
Anaesthesiologist 3	80%	12.4	33	100%	17.1	53	50%	18.2	55	80%	23.0	60
Anaesthesiologist 4	50%	13.9	38	75%	15.7	46	30%	16.3	40	75%	18.2	45
Anaesthesiologist 5	40%	10.8	38	60%	12.9	42	40%	13.5	48	80%	16.4	52
Mean (SD)	50.0 (18.7)	13.5 (2.5)	37.0 (7.4)	87.0 (18.6)	16.4 (2.3)	48.6 (6.7)	40.0 (10.0)	16.8 (2.0)	46.8 (7.6)	83.0 (9.8)	20.1 (3.2)	52.2 (6.0)

Outcomes of the one-way ANOVA were: POGO score ( $p=0.0001$ ), intubation time ( $p=0.007$ ), A-A distance ( $p=0.01$ ). Outcomes of the independent t-test were: CL vs IVL: POGO score ( $p=0.01$ ), intubation time ( $p=0.08$ ), A-A distance ( $p=0.03$ ); CLB vs IVLB: POGO score ( $p=0.001$ ), intubation time ( $p=0.08$ ), A-A distance ( $p=0.24$ ). A-A=airway to airway. CL=conventional laryngoscopy. CLB=conventional laryngoscopy with barrier. IVL=improvised video laryngoscopy. IVLB=improvised video laryngoscopy with barrier. POGO=percentage of glottic opening. \*POGO scores range from 0% (no part of the glottis seen) to 100% (the entire glottis, including anterior commissure, is seen). †Intubation time, recorded as the time between insertion of laryngoscope in the airway until positioning of the endotracheal tube in the trachea. ‡A-A distance, recorded as a linear minimum distance between the angle of the mouth of the operator to the angle of the mouth of the mannequin. With use of the barrier device, A-A distance was the linear parallel distance measured using a caliper between the angle of the mouth of the operator and the angle of the mouth of the mannequin (marked outside the barrier device).

**Table:** Comparison of glottic view, intubation time, and airway to airway distance using conventional laryngoscopy or improvised video laryngoscopy with or without barrier device

See Online for video

the angle of mouth of the operator and the mannequin (ie, the A-A distance), as tested by five certified anaesthesiologists (video). With conventional laryngoscopy (with or without barrier), still images were obtained along the airway axis. For video laryngoscope (with or without barrier), recorded videos of the glottis during laryngoscopy were obtained. All scoring was done by an independent observer, after viewing the recorded videos and still images. A one-way ANOVA was done to analyse the overall differences in the groups and an independent t-test was done for subgroup analysis.

We found that, with the improvised videolaryngoscope, the operator could intubate a patient an average of 11.6 cm further away than when using conventional laryngoscopy (table). We also noticed an improvement in intubation time and glottic view when the improvised videolaryngoscope was used (table). We repeated the comparison after using the barrier device. Although the intubation time and airway-to-airway distance were similar when the conventional laryngoscope was compared with the videolaryngoscope using a barrier device, the videolaryngoscope had an improved glottic view. All the intubations, using both the videolaryngoscope and the conventional laryngoscope, were done on the first attempt and without any assisted external laryngeal manipulation.

Our preliminary observations suggest that the improvised videolaryngoscope could be a viable option to conventional videolaryngoscopy, and at a cheaper cost (the average cost of conventional videolaryngoscope being around \$1500). The larger permitted distance between the airways of the operator and the mannequin when intubation was done without an enclosure device could confer enhanced safety when the application of an enclosure device is not possible. Moreover, as the borescope we used

had a 2 m long cord, the screen of the mobile can be placed outside the enclosure device, permitting better visibility, and would potentially overcome the compromised visibility due to possible fogging of the enclosure device.<sup>11</sup> Moreover, the device can be beneficial for fast tracking the training of non-anaesthesiologists in techniques of intubation.

These preliminary observations are encouraging. However, further studies on mannequins and in real patients is warranted to validate these findings. Nevertheless, there exists a challenge to find equipoise between the focus on patient management and doing well designed studies while facing a global pandemic.<sup>12</sup> In places where use of videolaryngoscopes are not usual practice, simulation-based learning before application in real-world scenarios can help to adapt this improvised technology with confidence, thus conferring benefit and safety for both the operator and the patient.<sup>2</sup>

We declare no competing interests.

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