Innovation of a Three-Dimensional (3D) Printed Video Laryngoscope for Difficult Airway Management in a Rural Setting

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ABSTRACT

Background: Managing difficult airways remains a critical challenge in anesthetic practice, particularly in resource-limited settings. While modern video laryngoscopes are effective, their high cost and limited availability hinder their use in peripheral areas.

Case Presentation: We report a 41-year-old woman with an abscess colli sinistra, classified as ASA III, who presented with a difficult airway requiring general anesthesia for surgical debridement. Due to anticipated intubation difficulty and limited access to advanced equipment, we employed an innovative 3D-printed video laryngoscope made of polyethylene terephthalate glycol (PETG), equipped with a endoscopic camera. The device facilitated successful endotracheal intubation without complications.

Conclusion: This case highlights the potential of affordable, customizable 3D-printed video laryngoscopes as an alternative airway management tool in low-resource settings.

Keywords: airway innovation; difficult airway; rural healthcare; three-dimensional printing; video laryngoscope

Inovasi Penggunaan Video Laringoskop Berbasis Teknologi Cetak Tiga Dimensi pada Pasien Sulit Jalan Napas

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ABSTRAK

Latar belakang: Penanganan jalan napas sulit tetap menjadi tantangan utama dalam praktik anestesi, terutama di fasilitas dengan keterbatasan sumber daya. Meskipun video laringoskop modern efektif, harganya yang mahal dan ketersediaannya yang terbatas menyulitkan penggunaannya di daerah perifer.

Ilustrasi kasus: Kami melaporkan kasus seorang perempuan usia 41 tahun dengan abses colli sinistra dan status ASA III, yang memerlukan anestesi umum untuk debridemen bedah. Karena diperkirakan akan terjadi kesulitan intubasi dan keterbatasan alat canggih, kami menggunakan video laringoskop hasil cetak 3D berbahan polyethylene terephthalate glycol (PETG) yang dilengkapi dengan kamera endoskopi. Alat ini memungkinkan intubasi endotrakeal berhasil dilakukan tanpa komplikasi.

Simpulan: Kasus ini menunjukkan potensi video laringoskop cetak 3D yang terjangkau dan dapat disesuaikan sebagai alternatif alat bantu jalan napas di fasilitas dengan sumber daya terbatas

Kata kunci: cetak tiga dimensi, inovasi, jalan napas sulit, pelayanan kesehatan terpencil, video laringoskop

INTRODUCTION

A difficult airway refers to a clinical scenario where trained personnel experience difficulty with one or more established airway management methods. The American Society of Anesthesiologists (ASA) reported that inadequate airway management accounted for 30% of morbidities linked to anesthesia-related complications.1 A study revealed that difficult airway scenarios often led to severe outcomes, with death or permanent brain damage occurring in two-thirds of cases. Notably, over half of the adverse airway incidents occured during elective surgeries, with the majority taking place in hospital settings.[2]

Masses in the cervico maxillofacial region pose significant challenges for anesthesiologists due to the dense concentration of structures in a relatively confined space, resulting in the highest incidence of potentially difficult intubation. Given these risks, a thorough preoperative assessment using clinical and imaging tools is crucial to formulate an effective airway management strategy. Patients with head and neck masses present additional challenges due to anatomical and physiological alterations, which may complicate airway management throughout the perioperative period.[3]

Although numerous international organizations have developed several algorithms in handling difficult airways, their successful implementation depends on the availability of advanced equipment and clinician proficiency.[4,5] Unfortunately, in rural or resource-limited settings, access to such sophisticated devices is often lacking, forcing practitioners to rely solely on their clinical skills. This condition poses significant risks for patients with difficult airways. In response, we developed an innovative approach using a three-dimensional (3D) printed video laryngoscope as an accessible, low-cost alternative for managing difficult airways.

CASE ILLUSTRATION

A 41-year-old woman presented with a two-week history of painful swelling on the left side of her neck. Initially, she had noticed a painless lump for two days, which subsequently became painful. She also reported a continuous fever during this period, odynophagia, reduced appetite, and epigastric pain over the preceding three days. She denied dyspnea or respiratory distress.

Further history revealed a long-standing painless dental cavity in the right first molar. There were no complaints of chronic cough, hemoptysis, or night sweats. The patient also denied palpitations and episodes of cold sweating. She reported a 2-kg unintentional weight loss over the past three days. There were no complaints of polyuria, polydipsia, or polyphagia. Bowel and urinary functions were within normal limits.

The patient had no prior history of similar symptoms. Her medical history was unremarkable for hypertension, type 2 diabetes mellitus, cardiovascular disease, renal disease, thyroid disorders, tuberculosis, asthma, or malignancy. She had no known allergies and no family history of chronic illness or cancer. She had never undergone surgery or taken routine medications. The patient was a housewife, a non-smoker, and did not consume alcohol. Her dietary history included occasional consumption of cured fish, fewer than 10 times per month.

On examination, the patient was alert and oriented. Vital signs were; blood pressure 130/90 mmHg, pulse rate 130 beats per minute, respiratory rate 18 breaths per minute, temperature 39.5°C, and oxygen saturation 99% on room air. Pain was rated 4 out of 10 on the numerical rating scale. Her body weight was 61 kg and height 145 cm, resulting in a BMI of 29.01 kg/m². General physical examination was unremarkable. Neck examination revealed a 10 × 12 cm left-sided mass with associated edema and erythema. The mass was hard, tender, non-fluctuant, and limited neck flexion and extension due to pain. The patient experienced pain upon swallowing. Airway assessment revealed a Mallampati score of III. Needle aspiration of the mass yielded purulent fluid. Laboratory results are presented in Table 1. Electrocardiography demonstrated normal sinus rhythm.

The patient was diagnosed with a left cervical abscess with differential consideration of malignancy. Additional diagnoses included mild anemia (Hb 10.3 g/dL) and uncontrolled type 2 diabetes mellitus (random blood glucose: 308 mg/dL). She was scheduled for surgical debridement under general anesthesia with

endotracheal intubation. Due to the mass and anticipated airway distortion, the patient was classified as ASA Physical Status III with a predicted difficult airway (difficult intubation and possible tracheostomy).

Table 1. Laboratory results

Examination	Result		Normal Value
	HEMATOLOGY		
WBC	**19.1**	$10^3/\mu L$	4.0-12.0
LYM#	1.7	$10^3/\mu L$	1.0-5.0
MON#	0.5	$10^3/\mu L$	0.1-1.0
GRAN#	**16.9**	$10^3/\mu L$	2.0-8.0
LYM%	**8.8**	%	25.0-50.0
MON%	2.8	%	2.0-10.0
GRAN%	**88.4**	%	50.0-80.0
RBC	4.17	$10^6/\mu L$	4.00-6.20
HGB	**10.3**	g/dL	11.0-17.0
HCT	**34.1**	%	35.0-55.0
MCV	81.8	μm^3	80.0-100.0
MCH	**24.7**	pg	26.0-34.0
MCHC	**30.2**	g/dL	31.0-35.5
RDW-CV	13.4	%	10.0-16.0
RDWS	44.4	μm^3	37.0-46.0
PLT	**438**	$10^3/\mu L$	150-400
MPV	**6.3**	μm^3	7.0-11.0
PCT	0.276	%	0.200-0.500
PDW	13.7	%	10.0-18.0
P_LCR	**5.1**	%	12.0-42.0
	Clinical Chemistry		
Random Glucose	**308**	mg/dL	<160
	Coagulation Examination		
Bleeding time	1.30	minute	1-3
Clotting time	9.30	minute	6-15

Given the anticipated airway challenges, a video laryngoscope was selected to facilitate visual guidance during intubation. Preparations included obtaining informed consent, fasting for 8 hours, STATICS protocol setup (Figure 1), anesthesia machine and drug preparation, availability of multiple endotracheal tube sizes (6.5, 7.0, 7.5), oropharyngeal and supraglottic airway devices, and the 3D-printed video laryngoscope (Figure 2). The target preoperative blood glucose was <200 mg/dL.

General anesthesia was induced with intravenous fentanyl (100 mcg), slow titration of propofol (50 mg), and sevoflurane inhalation. Neuromuscular blockade was achieved with intravenous atracurium (20 mg). Intubation was successfully performed using the 3D-printed video laryngoscope, with clear visualization of the glottis and passage of a size 7.0 ETT. Correct ETT placement was confirmed at 21 cm depth with symmetrical bilateral breath sounds (Figure 3). Maintenance anesthesia included fentanyl at 0.5–1.5 mcg/kg body weight.

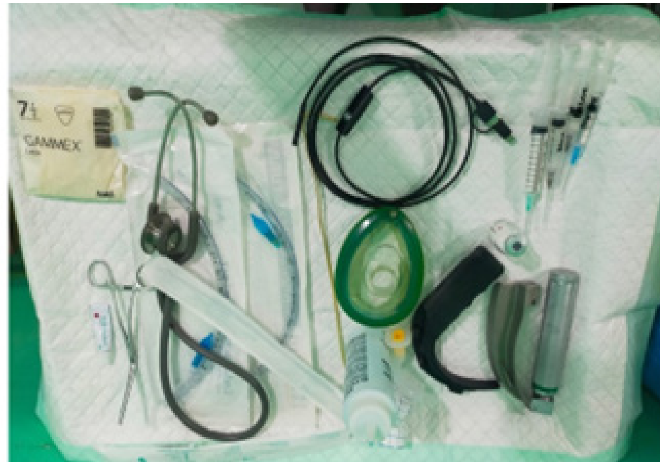

Figure 1. Equipment and material preparation.

Figure 2. 3D-printed video laryngoscope assembled with an endoscopy camera.

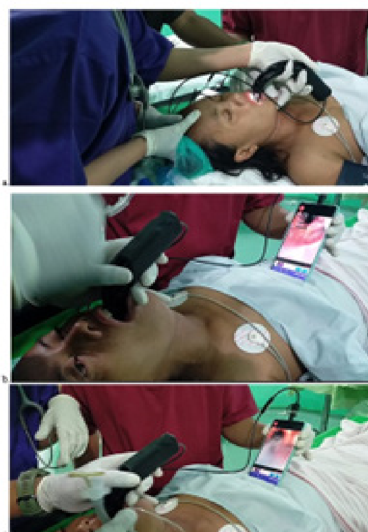

Figure 3. Intubation procedure: (a) patient positioning prior to intubation, (b) visualization of vocal cords, and (c) successful placement of the endotracheal tube under video guidance. All images presented in this article were published with prior informed consent and appropriate permission was obtained

The surgery lasted approximately 1.5 hours with an estimated blood loss of 20 mL. Intraoperative hemodynamic parameters remained stable: blood pressure ranged between 100–135/70–90 mmHg, heart rate 90–100 beats per minute, and oxygen saturation between 96–98%. Postoperatively, the patient received intravenous ketorolac 20 mg every 8 hours for analgesia.

The 3D-printed laryngoscope design was sourced from https://cults3d.com/en/3d-model/tool/video-laryngoscope-blades-number-1-2-3-and-4, an open-access platform offering royalty-free models. The laryngoscope was printed using an Ender® 3 S1 printer, utilizing Polyethylene Terephthalate Glycol (PETG) filament from SUNLU®, weighed approximately 104.78 grams. An endoscopy camera with built-in LED lighting and waterproof capability was inserted through a designated port at the top side of the laryngoscope. The camera provided a resolution of 480 pixels and was connected to an Android smartphone for real-time visualization via a mobile application.

DISCUSSION

In this case, we reported our innovation in using 3D-printing based laryngoscope as an approach to help a 41-year-old woman with abscess colli sinistra. Physical examination findings for pre-operative assessment using LEMON, MOANS, RODS, SHORT predict that the patient may encounter difficulties with intubation, placement of supraglottic airway, and tracheostomy.[5] In this case, the patient was found to have a mass in the neck. This mass restricts the patient's ability to flex or extend the neck. Additionally, the patient complains of difficulty swallowing which is indicating a suspicion of distorted airway anatomy. However, considering the current good oxygen saturation, absence of breathing difficulties, and no additional breath sounds, it is concluded that supraglottic airway placement is still feasible. Thus, the patient is predicted to experience difficulty in airway management, specifically with intubation and tracheostomy. The LEMON score has a sensitivity of 60% and specificity of 96.15% for predicting difficult airways. The positive predictive value is 83.33%.[6] Pre-operative assessment is crucial for anticipating the possibility of difficult airways.[7]

Guided by the difficult airway management guidelines provided by the American Society of Anesthesiologists in 2022,[8] we found that the patient might experience difficult intubation. However, for difficult ventilation, risk of aspiration, rapid desaturation, and difficulty in establishing an emergency route for invasive airway were not observed. Therefore, the patient can be attempted for intubation after general anesthesia. As a precautionary measure and to facilitate the intubation process, we decided to use a video laryngoscope. As far as we read, this will be the first case report of using 3D-printing based laryngoscope in Indonesia especially in rural place.

Currently, video laryngoscope is increasingly used for patients with difficult airways. This device can facilitate tracheal intubation by providing high-quality images of the larynx without the need for alignment of the three-axis airway (oral-pharyngeal-laryngeal). Additionally, it reduces problems associated with intubation by allowing remote observation of the glottis opening. A study on the use of video laryngoscope in patients with difficult intubation showed a success rate of 66% ($p = 0.074$) with a faster duration of 44.62 seconds.8 However, as we are aware, the cost of purchasing a video laryngoscope is relatively high. Therefore, in such circumstances, we innovated by using a more affordable video laryngoscope with some personal modifications.

Our video laryngoscope was a result of innovation using three-dimensional printing technology. The three-dimensional design of the laryngoscope is available on the website: https://cults3d.com/en/3d-model/tool/video-laryngoscope-blades-number-1-2-3-and-4 and then printed with a three-dimensional printing machine. Video footage is captured using a flexible endoscopic camera connected to a device for real-time video viewing.

The 3D-printed video laryngoscope served as a low-cost alternative to commercial video laryngoscopes such as the McGrath™ and GlideScope™. The total cost for making our video laryngoscope is Rp 195,000.00 compared to the market price of video laryngoscope starting from Rp 28,000,000.00 (January 2024). Certainly, this innovation can assist anesthesiologists

working in rural areas. Our 3D-printed video laryngoscope was fabricated using materials like PLA or ABS filament and integrated with consumer-grade endoscopy cameras, aiming to provide an affordable and accessible solution, particularly in low-resource settings. In contrast, McGrath™ and GlideScope™ were professionally engineered, FDA-approved devices that had been widely used in clinical environments with established safety and efficacy profiles. The McGrath™ featured an integrated screen and disposable blades, while the GlideScope™ offered high-definition imaging, anti-fog technology, and external monitor compatibility. The image quality of the 3D-printed model was modest and limited by resolution or video latency. Furthermore, the visual representation in the device layer and laryngoscope depth slightly differs, hence requiring adjustments in its application. Sterilization also presented a major challenge due to the thermal sensitivity of 3D-printed materials which were generally incompatible with standard autoclaving or high-level disinfection procedures. This video laryngoscope was sterilized using alcohol and could not be heated because it is made of plastic. In comparison, McGrath™ and GlideScope™ incorporated components that were either disposable or validated for safe reprocessing. Furthermore, the commercial devices were supported by robust clinical data and regulatory approvals, whereas the 3D-printed model lacked formal validation and remained experimental.[13] Despite these limitations, the 3D-printed laryngoscope addressed a critical gap in training, simulation, and potential emergency use in under-resourced environments, highlighting the need for accessible, cost-effective innovations in airway management. Although, it should have been noted that this case would have been strengthened by the inclusion of serial cases to improve its generalizability and clinical relevance. Relying on a single-case design limited the ability to draw broader conclusions or identify variability in outcomes across different clinical scenarios. Furthermore, the report did not include comparative performance metrics that are critical in evaluating airway management tools, such as intubation time, scoring of difficult intubation, difficulty in ventilation, challenges with supraglottic airway devices, and the complexity of tracheostomy procedures. The absence of these standardized measurements restricted objective assessment and prevented meaningful comparison with established devices. In addition, the study lacked long-term safety and usability evaluations, which were essential to determine the device's viability for repeated clinical use. Without such data, concerns related to complications, durability, and user adaptation over time remained unaddressed.

CONCLUSION

Considering both clinical efficacy and cost-effectiveness, this 3D printing-based video laryngoscope represents a viable alternative for managing difficult airways in resource-limited environments. It offers a promising solution where conventional video laryngoscopes are unavailable or unaffordable, particularly in rural and remote healthcare settings.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this case report.

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