Am J Cancer Res 2022;12(6):2433-2446
www.ajcr.us /ISSN:2156-6976/ajcr0143874

Review Article

Development of endotracheal intubation devices for patients with tumors

Yang Liu[1,2*], Yang Zhang[3*], Bin Zhu[4], Wenyun Xu[2], Yi Yang[4], Zui Zou[1,2]

[1]*School of Anesthesiology, Naval Medical University, Shanghai 200433, China;* [2]*Department of Anesthesiology, Second Affiliated Hospital of Naval Medical University, Shanghai 200003, China;* [3]*Department of Anesthesiology, Tianjin Fourth Central Hospital, No. 1 Zhongshan Road, Tianjin 300140, China;* [4]*Department of Anesthesiology, The People's Hospital of Suzhou New District, No. 95 Huashan Road, Suzhou 215129, Jiangsu, China.* [*]*Equal contributors.*

Received May 3, 2022; Accepted May 13, 2022; Epub June 15, 2022; Published June 30, 2022

Abstract: The incidence and mortality of malignant tumors are rapidly increasing in the world. Patients with malignant tumors often need surgery for treatment. Endotracheal intubation is a necessary technique for surgical patients undergoing general anesthesia. It is also an important procedure for critically ill patients in the emergency room or ICU. Most patients with head and neck tumors and some specific patients have difficult airways, so the operator may need to use a variety of intubation devices. The commonly used devices for endotracheal intubation include endotracheal tube, direct laryngoscope, video laryngoscope, introducer, optical stylet, fiberoptic bronchoscope. With the advancement in science and technology, the endotracheal intubation devices have been improved, and new devices have been developed. These devices are safer and more feasible in clinical practice. In this review, we summarized the features and applications of some of the currently used devices. Each device has its own uniqueness and meets different needs. The devices and their respective properties are strongly suggested to be mastered by the anesthesiologists as well as related staffs, so as to select the appropriate device for intubation.

Keywords: Tumor, endotracheal intubation, device, development

Introduction

Malignant tumor is one of the main causes of morbidity and mortality. There are many types of malignant tumors, including lung cancer, liver cancer, stomach cancer, colon cancer, and head and neck cancer. Head and neck malignant tumors have high morbidity and mortality, with more than 380,000 new cases occurring worldwide per year, accounting for about 3% of all malignant tumors [1]. About 196,000 of these cases are fatal, making it one of the leading causes of cancer deaths. Most patients with tumors need to undergo surgery under general anesthesia. Head and neck malignant tumors usually involve the airway and cervical spine, resulting endotracheal intubation much more difficult and risk in these patients than that of conventional airway. Therefore, it is necessary to pay close attention to the safety of airway management in these patients.

Endotracheal intubation is also a necessary technique for general anesthesia, and an essential measure for treatment of critically ill patients in the emergency department or ICU. It has been reported that the annual number of surgeries in the world is over 320 million and is increasing every year [2]. In the United States, approximately 1.6 million critically ill patients in ICU require endotracheal intubation to establish artificial airway per year [3]. The latest data from the Fourth National Audit Project (NAP4) of the Royal College of Anesthetists and the Difficult Airway Society show that 38.4% of patients undergoing general anesthesia use tracheal intubation for airway management, with approximately 1.1 million cases requiring endotracheal intubation each year [4]. Therefore, there is a tremendous need for successful endotracheal intubation.

During intubation, the operator may encounter anticipated or unexpected difficult airways. Difficult airway intubation or failed intubation is closely related to hypoxemia, cardiovascular and cerebrovascular accidents, and other complications, resulting in an increased risk of death [3]. According to an incomplete statistical analysis, the proportion of difficult intubation accounts for 1% to 6% of the total intubation, and the incidence of failed intubation accounted for 0.1% to 0.3% of the total intubation [5, 6]. Most patients in ICU and emergency department are hospitalized for critical conditions; hence, medical staff need to complete endotracheal intubation quickly and, more importantly, to provide airway management in those situations where no adequate emergency preparation and facilities are available [7]. To accomplish endotracheal intubation more quickly and accurately, the technology and equipment are constantly developed.

The commonly used devices for endotracheal intubation are endotracheal tube, direct laryngoscope, video laryngoscope, introducer, fiberoptic laryngoscope, fiberoptic bronchoscope, etc. [8-11]. To provide more useful information for the endotracheal intubation of patients with tumors, especially those with potentially difficult airways, such as patients with head and neck tumors, in this review, we compared and discussed the application, the advantage, and the limitation of these commonly used devices.

Endotracheal tube (ETT)

Traditional ETT

The origin of the ETT dates back to the 18th century, when Cullen suggested endotracheal intubation and ventilation with bellows to save the life of dying patients, which was the early form of mechanical ventilation [12]. Charles Kite was the first to use endotracheal intubation for resuscitation in drowning patients and to describe the use of oral and nasal intubation [13]. Guedel and Ralph Waters made tracheal tubes with inflatable cuff to prevent leakage and aspiration [12]. Sir Ivan Whiteside Magill further applied the innovation of curved ETT to general anesthesia surgery, and many of his inventions are still in use today [14].

An ETT with a cuff is the most reliable device for maintaining the airway, ensuring an effective oxygenation and ventilation, and preventing aspiration during general anesthesia. Currently, the design, shape, and material of the cuff have been optimized to reduce airway complications. For example, the cuff can automatically inflate and deflate to adjust pressure. However, the automatic control management has not shown an advantage in reducing airway injury [15]. There are two types of single-lumen tracheal tube: curved tube and straight tube, both of which have a oblique opening on the tip. The average radius of the curved type is 14 ± 2 cm [16]. There is a Murphy eye opposite to the beveled opening on the tip of the tube, which is mainly used to prevent airway obstruction caused by the tube tip sticking to the airway wall. The common single-lumen tubes include spiral steel wire reinforced tube, flexible tracheal tube, LITA tube, and subglottic suction tube [17-19]. These ETTs have a hard tip and a soft body and need to be preshaped with a stylet before intubation.

Ralph Waters developed the technique of lung isolation to perform thoracic surgery with a double-cuff, single-lumen tube [20], while E. Carlens and G. White developed a double-lumen tube for single-lung intubation [21, 22]. The Carlens tube is a left double-lumen tube with the tip of the tube inserted into the left main bronchus [23]. The structure of the White tube is similar to that of the Carlens tube; however, the tip of the White tube is inserted into the right main bronchus, with a side hole aligned to the opening of the right upper bronchus. Another one is Robertshaw double-lumen tube, which is divided into left and right [24]. Its left tube, although similar to the Carlens tube, has an optimized structural design, which makes the intubation easier. In addition, the distal opening of its right tube is not closed, and there is a lateral opening between the front and the back cuffs on the opening of the right upper lobe bronchus.

The major risks associated with endotracheal intubation are tissue injury, bleeding, laryngeal edema, ventilator-associated pneumonia, etc. To successfully complete endotracheal intubation, manage difficult airway, and reduce complications, the traditional ETT has been improved in aspects such as fabrication materials, structural design, and additional functions. A variety of products, such as mucus shaving tube, temperature-measuring tube, laryngeal nerve injury prevention tube, cardiac pacing tube and biofilm coating tube, have been designed and gradually integrated to achieve the multi-functions of endotracheal tube. However, these novel tubes need to be evaluated in large, multicenter studies.

ETView tracheoscopic ventilation tube (ETView TVT)

ETView TVT is a single-use endotracheal tube integrated with video camera technology, which assists the operator in intubation by displaying the anatomy of the larynx, vocal cords, and the proximal part of the trachea, and enables continuous observation of the airway during surgery. There are currently two types of ETView TVT: VivaSight-DLT and VivaSight-SLT [25, 26]. Based on the conventional single-lumen tube and double-lumen tube, the visual ETT is embedded with a high-resolution camera, data transmission system, and a flushing system. The high-resolution camera with PIXELS CIF of 320 × 240 (76,800 Pixels) provide a field depth of 12-60 mm and a field of view of 100° [27]. The camera has two white light sources that do not burn the airway, and the image sensor is made of Complementary Metal Oxide Semiconductor (CMOS). The camera is cylindrical with 2 mm in diameter and 16 mm in length, located at the oval opening on the tip of the tube (the camera of the double-lumen tube is located at the opening between the two cuffs). Micro-cables embedded in the wall of the tube transmit images to a high-definition monitor or other portable video device and power the camera and the light source, so that the operator can view real-time images for precise positioning and operation. When the secretions or blood obscure the field of vision, the camera lens can be rinsed by an additional injection interface; however, the efficiency is limited due to the tube structure and the viscosity of the secretions.

ETView TVT has advantages in situations with difficult airway intubation and one-lung ventilation [28, 29]. The continuous visualization and the real-time positioning of the airway enables a faster and more accurate intubation and ensures the timely detection and correction of tube displacement, which increases the quality and safety of airway management. VivaSight-SLT can also be used to accurately place the bronchial blocker and to correct blocker displacement during surgery [26]. Patients with ETView TVT intubation may not need fiberoptic bronchoscopy during intubation or surgery, which avoid some of the limitations of fiberoptic bronchoscope [30]. Indeed, randomized controlled trials have demonstrated that these features help improve the intubation fluency and safety, and effectively reduce the incidence of complications from endotracheal intubation, which is ultimately beneficial to patients [31]. Therefore, ETView TVT has the value of long-term application.

Laryngoscope for endotracheal intubation

Direct laryngoscope

The singer Manuel Garcia invented the direct laryngoscope and performed the first direct laryngoscopy in 1854 [12]. Direct laryngoscope is a great innovation in the history of endotracheal intubation and a key device to ensure the establishment of an artificial airway for patients undergoing general anesthesia. It has been the standard technique for endotracheal intubation for nearly a century. Later, Robert A Miller and Robert Reynolds Macintosh refined the direct laryngoscope. Miller invented the straight laryngoscope, the Miller laryngoscope, in 1941 [32]. In 1943, Macintosh introduced the classic and most widely used curved direct laryngoscope, the Macintosh laryngoscope [33]. In addition, Polio laryngoscope, Alberts laryngoscope and Mccoy laryngoscope have also been developed to meet the special intubation needs of patients.

A direct laryngoscope usually consists of a battery-equipped handle and a detachable metal blade. During intubation, the blade slides into the throat through mouth along the tongue, moves the soft tissues of mouth and throat, lifts the epiglottis, and exposes the glottis for intubation. Curved laryingosope indirectly raises the epiglottis by pressing the hyoid epiglottis ligament, while straight laryingosope directly raises the epiglottis. Although direct laryngoscopy can effectively avoid interference with peripheral soft tissues, intubation still requires the patient to be in a “sniffing position” to ensure the mouth, pharynx, and larynx are aligned to provide a good visual field.

Miller laryngoscope blade is straight; the tip of the blade is curved, while the proximal root of the blade and the handle connector are relatively thin [34]. The blade has a narrow tongue depressor and a low baffle. Miller laryngoscope has advantages in pediatric patients and patients with prominent mandible, long epiglottis, and limited mouth opening since it can easily lift the jaw to observe epiglottis [35]. However, this device provides a smaller field of vision, which is difficult to expose the glottis to implement intubation and may even cause epiglottis injury [36]. Patients with limited cervical mobility such as cervical spine injury or instability may further aggravate the injury. Therefore, it can be used as a supplementary means to curved laryngoscope.

Notably, the curved blade of the Macintosh laryngoscope is wider and thicker than that of the Miller laryngoscope. Furthermore, a higher baffle in the curved blade helps patients open their mouth and expose their epiglottis more easily and expands the field of view of the throat, which facilitates the intubation. The Macintosh laryngoscope allows the operator's axis of vision to rotate with the line of sight according to the height of the baffle, the arc of the blade, and the patient's physiological characteristics. Thus, a curved laryngoscope is more suitable for intubation than a straight laryngoscope. Alter et al. found that the effectiveness of the first intubation attempt was 86% for Macintosh blades and 73% for Miller blades [37]. Despite the obvious advantages and applications of Macintosh laryngoscope, there are some limitations. It is easy to cause tooth damage, and the difficulty of intubation increases in patients with limited mouth opening, difficult epiglottis exposure, and obesity [38].

At present, direct laryngoscope is still the main intubation device in undeveloped regions/countries or outside the operating room [37]. With the development of video laryngoscope, direct laryngoscope will be gradually replaced. Compared with direct laryngoscope, video laryngoscope has more advantages: (1) It exposes the structure of the throat more clearly, which facilitates the operator to operate more smoothly and improves the success rate of intubation [39]; (2) The chance of damage to airway, teeth and oral soft tissue is reduced [40]; (3) The airway grade of patients is lowered, and video laryngoscopy can provide laryngeal vision for patients whose exposure is not ideal with direct laryngoscopy [41]; (4) The operator can observe the real-time image, which can be used as a teaching tool.

Video laryngoscope

Video laryngoscopy was applied in clinic in the early 21st century [42-44]. Video laryngoscope can move the soft tissue of oral cavity and throat and transmit laryngeal image to eye lens or monitor by optical technology, camera technology or digital imaging technology, so that the operator can observe the real-time operation of intubation. The invention of the video laryngoscope overcomes the limitation on field of vision and lowers the airway grade. Moreover, it can alleviate the agitation of intubation and reduce the incidence of intubation failure and airway trauma. Therefore, it becomes a new method for partially difficult airway intubation. Indeed, studies have shown that the video laryngoscopy can significantly optimize Cormack-Lehane grade, with the vast majority of airway grades I-II [45]. Overall, video laryngoscopy can greatly improve the success rate of intubation. The operator does not need to look directly into the glottis when using the video laryngoscope, which simplifies the operation of direct laryngoscopy-assisted intubation and makes the operator more relaxed and comfortable. Additionally, the long distance between the operator and the patient can reduce the contact with the patient's exhaled aerosol. Moreover, the blades of the video laryngoscope are mostly disposable, which can effectively reduce the risk of cross infection. Therefore, video laryngoscope, as an intubation device that benefits both doctors and patients at the same time, has been favored and developed rapidly in recent 20 years.

There are a variety of video laryngoscopes, which have been invented according to different intubation needs. The popular video laryngoscopes include GlideScope, McGrath video laryngoscope, Storz C-MAC/V-Mac video laryngoscope, Pentax Airway scope and AirTraq laryngoscope [44, 46-48].

The Glidescope family has three video laryngoscopes: the Glidescope, the Glidescope Cobalt, and the Glidescope Ranger. The distal end of a typical Glidescope blade is bent at an angle of 60°, and a camera is embedded in the blade [44]. A video monitor is installed on the handle of the laryngoscope. The Glidescope Cobalt is modified to use disposable plastic blades for intubation to reduce cross infection [49], while the Glidescope Ranger is a portable video laryngoscope designed to be fog proof for tracheal intubation outside the operating room [50].

The most popular laryngoscopes in the McGrath family are the McGrath series5 and McGrath MAC [51]. The blade length of McGrath Series5 can be adjusted according to the airway, and the tip of the blade is angled at 60° to facilitate intubation [52]. The McGrath MAC has some improvements over the McGrath Series5, adding the regular Macintosh type blade and expanding the LCD screen [51]. The McGrath video laryngoscope is also portable and can be used for intubation under various airway conditions. Moreover, the blade is for single use to prevent cross infection.

Karl Storz developed the V-MAC, C-MAC, and C-MAC-D-Blade video laryngoscopes, which are similar in structure to Macintosh blade [53, 54]. These laryngoscopes optimize the angle of the blades but can also be used as a direct laryngoscope.

Pentax Airway scope (Pentax-AWS) is a new rigid video laryngoscope whose fixed structure is more like a short video stylet [48]. The single-use blade has two guide channels parallel to the video system. The main channel is used to insert the tracheal tube, while the subchannel can accept tube ≤ 4.0 mm in diameter for suction or local anesthesia.

AirTraq laryngoscope is an optical laryngoscope consisting of a lens, a prism, and an eyepiece [47]. The eye lens can be equipped with an optical accessory to transmit real-time images to an external monitor. The Airtraq has an adapter installed in its viewfinder to connect to smartphones, iPad, and computer.

Compared with the direct laryngoscope, the vision of the video laryngoscope is determined by the direction of the camera, and the scope and the quality of the vision are significantly improved, which improves the effectiveness of the intubation greatly, usually, the success rate is 98-99% [55]. The application of video laryngoscope and direct laryngoscope has been reviewed in a Cochrane Systematic Review [39]. It showed that the number of failed intubations was significantly reduced when using video laryngoscopy, and fewer intubations failed in the anticipated difficult airway. In summary, video laryngoscope can provide a wider field of view and allow the operator to directly observe the movement of the glottis and the position of the tracheal tube, in some cases replacing fiberoptic bronchoscopy for difficult airways [56]. Video laryngoscopy simplifies the traditional endotracheal intubation methods and is an ideal choice for both inexperienced medical staff and experienced senior physicians.

Optical stylet

In 1979, the concept of "optical stylet" was first proposed by American endoscopists G. Katz and R. Berci [57]. When they performed endotracheal intubation with a straight rigid metal endoscope, they had to position the patient and used a direct laryngoscope to lift the base of the tongue and epiglottis, which was complicated and had many limitations [58]. Hence, as a feasible, new intubation method, optical stylet has been used in clinical practice for nearly half a century. The optical stylet consists of a stylet carrying optical fibers, light source, and a handle, which can be divided into straight or curved, and rigid or semi-rigid devices. The tip of the most stylets is usually bent at an angle to facilitate intubation. The distal end of the semi-rigid stylet is malleable and can be preshaped according to the anatomical structure before endotracheal intubation.

There are several types of optical stylet. In 1983, Bonfils designed the rigid fiberoptic laryngoscope (Bonfils Retromolar Intubation Fiberscope), and the distal end of the stylet was bent by 40° [59]. This improvement was more in line with the anatomical curvature of the larynx to facilitate intubation and resulted in a new technique for retromolar endotracheal intubation [60].

The Shikani optical stylet consists of a "J" shaped fiberoptic stylet, a detachable eyepiece, a handle, and a light source, and its first clinical application was reported in 1999 [61]. The stylet is made of malleable rust-proof metal, and the distal end of the stylet can be shaped according to the anatomical structure of the airway. An adapter can be mounted on the eyepiece to transmit a real-time image of the airway to the monitor.

Levitan FPS stylet is similar to the Shikani optical stylet, but it is 10 cm shorter and is used in direct laryngoscopy or endotracheal intubation [62]. In contrast, SensaScope is an "S" shaped rigid fiber optic laryngoscope with an overall length of 43 cm [63]. The 3 cm distal end of the stylet allows for a flexible manipulation to facilitate endotracheal intubation.

These optical stylets have the advantages of high intubation success rate (all around 99-100%), less complications and a steep learning curve and can be used as a tool for difficult airway management [59, 62, 64]. It is suitable for patients with small opening and reduced cervical hyperextension movement, which is beneficial to patients with suspected or existing cervical injury [64-66]. The success rate of awake intubation is comparable to that of fiberoptic bronchoscopy, but with faster operation time [9, 67]. For conventional airway intubation, this device is more feasible than direct laryngoscope and is as good as video laryngoscope [64]. Nevertheless, its downsides include blurred field of vision due to contamination of secretions and blood and inability to observe tracheal tube movement during intubation.

In recent ten years, several new malleable optical stylets have been developed, which are more convenient and reliable than traditional optical stylets. Their video systems use complementary metal oxide semiconductor (CMOS) video sensors with monitors mounted on handles or directly connected to smartphones and other mobile devices. Clarus Video System (Trachway intubating stylet) was approved for clinical intubation in 2009 [68]. This device is composed of a detachable stylet, a rechargeable handle, and an adjustable color monitor. The camera and light source are located on the atraumatic tip of stylet. The monitor can be rotated to different angles using the monitor rotary control knob. Oxygen is supplied through an attached ventilation connector during intubation. Trachway Intubating Stylet has been used for oral intubation, nasal intubation, double-lumen intubation, and emergency intubation with satisfactory results [69-72]. Lee et al. found that awake nasal endotracheal intubation using Trachway intubating stylet was easier to perform and faster than fiber bronchoscope [70]. In addition, Trachway Intubating Stylet is also a less invasive and highly successful intubation method in patients with difficult airways such as head, neck and facial malformations, and large upper respiratory tumors [73]. The main drawback of this device is the failure of intubation due to blurred vision and improper tube delivery, resulting in trauma and bleeding of throat tissue.

The C-MAC Video Stylet is a straight rigid intubation stylet [74]. The video stylet is 41 cm long and has a flexible tip (length: approx. 4 cm), which allows the tip to deflect up to 60° when intubating. StyletViu Inc is another video intubation stylet with free rotation angle and detachable display, which can be used for intubation and exchanging the ETT [75]. Moreover, the stylet is basically not restricted by the application object, and can be used in newborns, children, and adults. In recent years, more optical stylets such as the Intular Scope and the UE scope have also been introduced [75, 76]. However, their application needs to be validated by a large number of clinical studies and supported by evidence-based medicine.

Introducer

Bougie and stylet are two effective introducers to assist tracheal intubation. Bougie-guided intubation and stylet-preshaped tracheal tube can significantly increase the success rate of endotracheal intubation. With further improvement, some introducers can provide oxygen, suck sputum and exchange tracheal tubes, reducing the risk of hypoxemia, laryngeal spasm, and cardiovascular and cerebrovascular accidents [77]. Since the invention of video laryngoscope, its combination with the introducers has greatly optimized the endotracheal intubation technology.

The bougie-guided intubation was first developed by Macintosh through modifying a urethral dilatation catheter in 1949, and it was called "Gum Elastic Bougie" [78]. In the 1970s, a specialized introducer, the Eschmann Tracheal Introducer was invented [79]. Since then, Bougie-guided intubation has been widely used in clinical practice. Common devices are the Eschmann Tracheal Introducer, the Frova Intubating Introducer, the Flexible Tip Bougie, the Airway Exchange Catheter (AEC), the VBM Tube Catheter, the Aintree Intubating Catheter, etc. [80-82]. Studies have proved that the Bougie has a good auxiliary role in tracheal intubation, which can improve the success rate of first attempt and reduce complications, in both pre-hospital or hospital care [83-85]. The main advantage of the bougie is its slender and flexible, enabling successful intubation in the case of insufficient mouth opening and poor glottis exposure by laryngoscope, and many guidelines recommend it for the management of difficult airways [86-88]. The Eschmann Tracheal Introducer, the Frova Intubating Introducer, AEC, and other introducers are expensive; some of them are reusable and require repeated disinfection, so the usage rate is low in less developed regions/countries.

Stylets are mainly divided into rigid stylets and plastic stylets. Rigid stylets are made of malleable rust-resistant metal with a smooth surface and are commonly used for rapid sequence intubation and pre-hospital emergency intubation [89]. Plastic stylet is a single-use stylet made of plastic, and the representative product is Parker-Flex-It Directional Stylet, which is not required to preshape before intubation [90]. During intubation, the operator's thumb pushes the lever to change the curvature of the stylet, leading to the alteration in the direction of the tube top, which is useful for oral and nasal intubation. However, some stylets are not firm enough; the tube may deform easily during intubation. On the other hand, some stylets are hard and sharp, which tends to cause airway damage. The endotracheal intubation with stylet can usually be performed rapidly by a single person, unlike bougie-guided intubation, resulting in faster intubation.

Complications associated with introducer include cardiovascular reactions due to intubation agitation, soft tissue damage, bleeding, perforation of the trachea, bronchial rupture, and pneumothorax [89]. There are also reports that the device fractured resulting in an intratracheal foreign body and pulmonary migration of a sheared fragment [91]. In addition, using an introducer to provide oxygenation and ventilation for the patient can cause the barotrauma [92]. And there is a risk of cross infection when the reusable introducer is applied [93].

SEEK^{flex} (Safe Easy Endotracheal Kit-Flexible) is a new single-use endotracheal intubation kit that was developed by our team in the early days of COVID-19 [94]. It is an inexpensive introducer with characteristics of malleable, stretchable, detachable, lockable, and diverse functions. The main structure of the device includes a stainless metal guide, a flexible catheter, a handle, a fixed lock connector and a detachable transition connector (**Figure 1**). The lock connector, transition connector and catheter are designed to tight easily and separate freely according to the operation demands. Because the metal guide can be stretched in the catheter, the length can be adjusted (the stretchable length ranges from 43 to 81 cm), which can guide tracheal intubation and exchange tracheal tubes. The tip of the catheter has three vents and three rows of small side holes, and the proximal end of the catheter can be fitted with a matching adapter (with standard 15 mm connector and Luer lock connector functions) after removing the connector. It can be connected to respiratory loop connector and nasal catheter through adapter and can also be used for drug and oxygen delivery through catheter.

Despite the similarities to both AEC and Frova Intubating Introducer in construction and functionality, SEEK^{flex} has its unique advantages (**Table 1**). Its flexible design allows for a wide range of functions and a much lower cost than the other two devices, making it a potential alternative to the AEC and the Frova Intubating Introducer. After training, the operator can quickly master the operation essentials of SEEK^{flex} and can easily complete tracheal intubation. A preshaped SEEK^{flex} can also be used as a stylet for intubation without changing the operating routines of some anesthesiologist, which is another advantage over the bougie.

In clinical application, we found that the device has a high success rate of guiding tracheal intubation, minimal agitation to the airway, and low incidence of adverse reactions. However, our device needs to be further tested in a large sample size and in hospitals of different levels by doctors of different proficiency.

Fiberoptic bronchoscope

Fiberoptic bronchoscopy is the gold standard for assessing difficult airways and one of the most used auxiliary tools for anesthesiologists, emergency physicians, and critical care physicians to manage difficult airways. Traditional rigid bronchoscope has limited visual field and is painful for many patients during operation. In

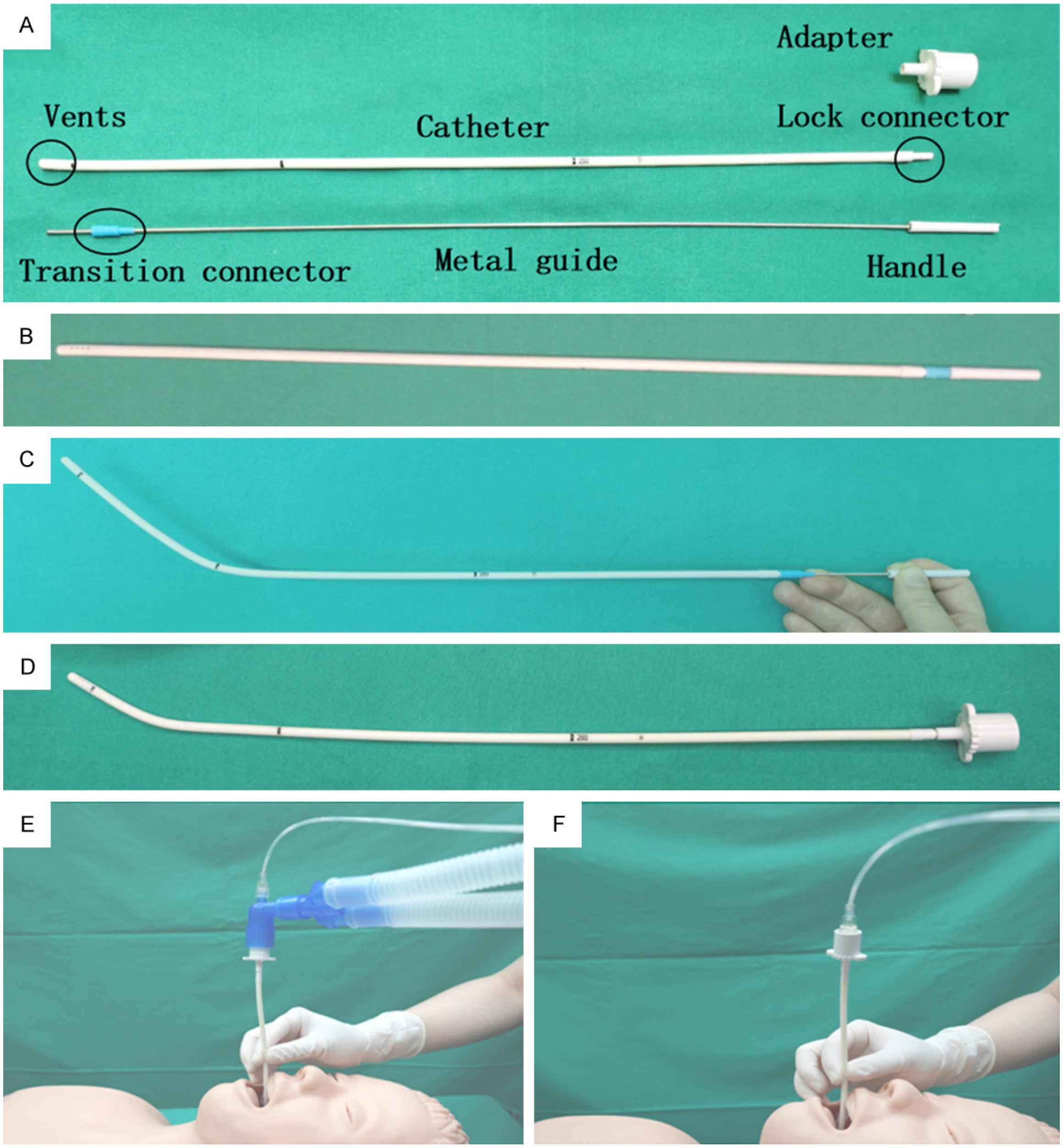

Figure 1. Structure and function diagram of SEEK^{flex}. A. Structure of SEEK^{flex} after disassembly; B. The initial state of SEEK^{flex}; C. SEEK^{flex} after shaping. It was extended by stretching the metal guide in the catheter; D. Connection of the catheter to the adapter; E. The catheter is connected to the ventilator circuit through the adapter; F. The catheter is connected to the nasal catheter through the adapter.

1967, P. Murphy first described the use of fiberoptic choledochoscope for nasal intubation, an innovation that led to the development of fiberoptic bronchoscope and a breakthrough in the management of difficult airways [95]. The fiberoptic bronchoscopes have been refined to provide an increased visibility, allowing physicians to operate even when the bronchial tubes are twisted, displaced, or narrowed. The HD monitor and the internal storage of the device enable easy observation as well as the storage of a large amount of valuable video data. In addition to airway assessment and endotracheal intubation, the fiberoptic bronchoscope is also commonly used for airway examination, alveolar lavage, retention of specimens and airway therapy.

Conventional reusable flexible fiberoptic bronchoscopes use fiber-optic technology to trans-

Table 1. The characteristics of AEC, Frova Intubating Introducer, and SEEK^{flex}

	AEC	Frova Intubating Introducer	SEEK^{flex}
Function	Exchange tracheal tube	Endotracheal intubation	Endotracheal intubation, Exchange tracheal tube
Structure	Single catheter with no metal guide	Single catheter with metal guide	Single catheter with stretchable metal guide (detachable and reconnected)
Length	45 cm/83 cm	35 cm/70 cm	43 cm-81 cm
Malleability	unmalleable	Malleable	Malleable
Vent	single hole at the tip, small vents on the side	Small vents on the side of the catheter tip	3 small vents at the tip of the catheter and multiple side holes at the end
Connector	15 mm connector and Luer lock connector	15 mm connector and Luer lock connector	An adapter has the function of both 15 mm connector and Luer lock connector
Usage	Single use	Single use	Single use

mit the view to an eyepiece, which can be connected to a video system to display the image on a monitor [96]. The recently developed, more popular video flexible bronchoscopes are equipped with charge-coupled video-chip sensors instead of fiber-optic imaging and are illuminated steadily by LED [97]. In anesthesiology, single-use flexible bronchoscopes, the aScope and C-Mac Five S series gradually become mainstream devices because they maintain flexible capabilities, unlike reusable fiber-optic bronchoscopes, and don't require disinfection and maintenance costs, such as to avoid possible cross-contamination risks [75, 98]. Although Karl Storz is a leader in the endoscopic industry, the C-Mac Five S is still inferior to the aScope in terms of performance and cost control management in the field of disposable flexible bronchoscopes.

Earlier studies suggested that there was a gap between endotracheal intubation using the old aScope and conventional fiberoptic bronchoscope [98, 99]. However, the researchers compared the new disposable bronchoscope, the aScope 4, with conventional fiberoptic bronchoscope and found that the aScope 4 had greater flexibility, maneuverability, and clearer field of vision, suggesting that the device should be the first choice for awake intubation, diagnostic and therapeutic procedures [96]. In addition, some studies have proved that it also has an ideal effect in alveolar lavage [100]. Cost analysis shows that disposable flexible bronchoscope consumes more than reusable flexible bronchoscope, but it has economic and social benefits in hospitals with few patients [101]. However, considering the infection risk and mobility, disposable bronchoscope is still highly practical.

The use of fiberoptic bronchoscope has certain limitations: (1) Sputum, blood and secretions can easily blur the field of vision and affect the operation [96]; (2) The learning curve is long, requiring skilled doctors to operate; (3) During awake intubation, the tracheal tube is likely to be obstructed at the vocal cords, resulting in a strong stimulus response, an unpleasant patient experience, and the risk of cardiovascular and cerebrovascular accidents. Moreover, reflux may occur during operation, and hypoxemia may result from interruption of ventilation during intubation; (4) The placement of the ETT may require repeated operation, which can cause damage to the glottis and airway, even bleeding and pneumothorax; (5) Fiberoptic bronchoscopes are expensive and easily damaged by improper handling, and traditional devices require costly disinfection and maintenance; Besides, the disinfection is not always effective [98]; (6) Due to the long operation time, patients cough and exhale large amounts of aerosols, increasing the risk of cross infection. In addition, reusable fiberoptic bronchoscope is also a risk factor for increasing the probability of infection.

Recently, some guidelines recommended that patients with suspected and confirmed COVID-19 should be intubated with disposable bronchoscope whenever possible, with adequate protection and airway preparation [102, 103]. Furthermore, video laryngoscope is recommended for intubation when possible, mainly because of the reduced aerosol exposure and faster intubation [103]. Although the introduction of video laryngoscope, introducer and other auxiliary tools has partially replaced its role in difficult airway management, fiberoptic bronchoscope is still the first choice for most of the difficult airway. In the context of the COVID-19 pandemic, we need to increase the use of disposable devices, which is essential to reduce the spread of infectious diseases.

Future perspectives

With the development in technology, new approaches have been used in the clinical practice of endotracheal intubation. For example, for the concern of how to accurately evaluate the airway and implement intubation, chest X-rays and chest CT have been used to select the size of tracheal tube by measuring the diameter of the trachea. However, their general use in the clinic remains limited due to the radiation exposure [104]. Ultrasound examination has advantages in choosing appropriate tube size in pediatric patients, but there are still limitations [105]. Artificial intelligence (AI) has attracted much attention in health care in recent years because of its power over traditional statistical methods [106]. AI has been applied to many aspects of airway management research, including diagnosis, assessment, management, and risk prediction. With the progress in AI research, AI may help achieve rapid diagnosis and recommend treatment options in emergency situations, which is very important in prehospital setting and for difficult airway assessment and management. Furthermore, robots can be developed to assist people to complete endotracheal intubation in urgent circumstances and further relieve the pressure of medical treatment. Therefore, the development of AI endotracheal intubation technology is of great significance to patients and society.

Summary

Endotracheal intubation is an important rescue technique for both surgical and critically ill tumor patients. Different intubation methods are suitable for different patients. For example, head and neck tumors are one of the most common causes of difficult airways, often associated with forced position, airway compression, and ventilation dysfunction. The operator may need to use several devices, such as video laryngoscope, Fiberoptic bronchoscope and introducer, to improve the success rate and to reduce the risk of difficult intubation. We also hope to develop more devices like SEEK^{flex} that can be used to perform conventional intubations and difficult airway management. In clinical practice, an appropriate device should be selected after comprehensive evaluation based on the actual situation and personal experience. Otherwise, it may cause a certain degree of injury to the patient, or even failed intubation, resulting in irreparable loss and social impact.

Acknowledgements

This study was funded by the Shanghai Municipal Committee of Science and Technology (18411951300, 20XD1434400), the Talent Development Fund of Shanghai (2020075), Health commission of Tianjin (TJWJ2021MS0-25) and Exceptional Young Talents Fostering Foundation 2021 of the Tianjin Fourth Central Hospital (Grant No. tjdszxyy20210010).

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Yi Yang, Department of Anesthesiology, The People's Hospital of Suzhou New District, No. 95 Huashan Road, Suzhou 215129, Jiangsu, China. E-mail: 2764707892@qq.com; Dr. Zui Zou, School of Anesthesiology, Naval Medical University, Shanghai 200433, China; Department of Anesthesiology, Second Affiliated Hospital of Naval Medical University, Shanghai 200003, China. E-mail: zouzui@smmu.edu.cn

References

[1] Torre LA, Bray F, Siegel RL, Ferlay J, Lortet-Tieulent J and Jemal A. Global cancer statistics, 2012. CA Cancer J Clin 2015; 65: 87-108.

[2] Weiser TG, Haynes AB, Molina G, Lipsitz SR, Esquivel MM, Uribe-Leitz T, Fu R, Azad T, Chao TE, Berry WR and Gawande AA. Estimate of the global volume of surgery in 2012: an assessment supporting improved health outcomes. Lancet 2015; 385 Suppl 2: S11.

[3] Heidegger T. Management of the difficult airway. N Engl J Med 2021; 384: 1836-1847.

[4] Woodall NM and Cook TM. National census of airway management techniques used for anaesthesia in the UK: first phase of the Fourth National Audit Project at the Royal College of Anaesthetists. Br J Anaesth 2011; 106: 266-271.

[5] Crosby ET, Cooper RM, Douglas MJ, Doyle DJ, Hung OR, Labrecque P, Muir H, Murphy MF, Preston RP, Rose DK and Roy L. The unanticipated difficult airway with recommendations for management. Can J Anaesth 1998; 45: 757-776.

[6] Shiga T, Wajima Z, Inoue T and Sakamoto A. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. Anesthesiology 2005; 103: 429-437.

[7] Carlson JN and Wang HE. Updates in emergency airway management. Curr Opin Crit Care 2018; 24: 525-530.
[8] Luo F, Darwiche K, Singh S, Torrego A, Steinfort DP, Gasparini S, Liu D, Zhang W, Fernandez-Bussy S, Herth FJF and Shah PL. Performing bronchoscopy in times of the COVID-19 pandemic: practice statement from an international expert panel. Respiration 2020; 99: 417-422.
[9] Cheng T, Wang LK, Wu HY, Yang XD, Zhang X and Jiao L. Shikani optical stylet for awake nasal intubation in patients undergoing head and neck surgery. Laryngoscope 2021; 131: 319-325.
[10] Sanguanwit P, Yuksen C and Laowattana N. Direct versus video laryngoscopy in emergency intubation: a randomized control trial study. Bull Emerg Trauma 2021; 9: 118-124.
[11] Jaber S, Rolle A, Godet T, Terzi N, Riu B, Asfar P, Bourenne J, Ramin S, Lemiale V, Quenot JP, Guitton C, Prudhomme E, Quemeneur C, Blondonnet R, Biais M, Muller L, Ouattara A, Ferrandiere M, Saint-Leger P, Rimmele T, Pottecher J, Chanques G, Belafia F, Chauveton C, Huguet H, Asehnoune K, Futier E, Azoulay E, Molinari N and De Jong A; STYLETO trial group. Effect of the use of an endotracheal tube and stylet versus an endotracheal tube alone on first-attempt intubation success: a multicentre, randomised clinical trial in 999 patients. Intensive Care Med 2021; 47: 653-664.
[12] Szmuk P, Ezri T, Evron S, Roth Y and Katz J. A brief history of tracheostomy and tracheal intubation, from the Bronze Age to the Space Age. Intensive Care Med 2008; 34: 222-228.
[13] Ohry A. A short history of anaesthesia. Korot 1983; 8: 281-283.
[14] Ellis H. Magill's endotracheal tube. J Perioper Pract 2006; 16: 562-563.
[15] Nseir S, Duguet A, Copin MC, De Jonckheere J, Zhang M, Similowski T and Marquette CH. Continuous control of endotracheal cuff pressure and tracheal wall damage: a randomized controlled animal study. Crit Care 2007; 11: R109.
[16] Chandler M. Tracheal intubation and sore throat: a mechanical explanation. Anaesthesia 2002; 57: 155-161.
[17] Yamasaki H, Takahashi K, Yamamoto S, Yamamoto Y, Miyata Y and Terai T. Efficacy of endotracheal lidocaine administration with continuous infusion of remifentanil for attenuating tube-induced coughing during emergence from total intravenous anesthesia. J Anesth 2013; 27: 822-826.
[18] Yamauchi H, Nakayama M, Yamamoto S, Sata M, Mato N, Bando M and Hagiwara K. A comparative study of the Parker Flex-Tip tube versus standard portex tube for oral fiberoptic intubation in bronchoscopy performed by pulmonologists with limited experience. Respir Investig 2021; 59: 223-227.
[19] Rajkumar A and Bajekal R. Intraoperative airway obstruction due to dissection of a reinforced endotracheal tube in a prone patient. J Neurosurg Anesthesiol 2011; 23: 377.
[20] Frost EA. Tracing the tracheostomy. Ann Otol Rhinol Laryngol 1976; 85: 618-624.
[21] Inada K, Kishimoto S, Sato A and Watanabe T. Bronchospirometry with the carlens double lumen catheter; evaluation and exercise test. J Thorac Surg 1954; 27: 173-186.
[22] White GM. A new double lumen tube. Br J Anaesth 1960; 32: 232-234.
[23] Carlens E. A new flexible double-lumen catheter for bronchospirometry. J Thorac Surg 1949; 18: 742-746.
[24] Wyatt R and Garner S. A defect in Robertshaw double lumen endotracheal tubes corrected. Anaesthesia 1981; 36: 830-831.
[25] Massot J, Dumand-Nizard V, Fischler M and Le Guen M. Evaluation of the Double-Lumen Tube Vivasight-DL (DLT-ETView): a prospective single-center study. J Cardiothorac Vasc Anesth 2015; 29: 1544-1549.
[26] Barak M, Putilov V, Meretyk S and Halachmi S. ETView tracheoscopic ventilation tube for surveillance after tube position in patients undergoing percutaneous nephrolithotomy. Br J Anaesth 2010; 104: 501-504.
[27] Umutoglu T, Bakan M, Topuz U, Alver S and Ozturk E. Use of ETView Tracheoscopic Ventilation Tube® in airway management of a patient with tracheal injury. Minerva Anestesiol 2014; 80: 398-399.
[28] Yu H and Zuo MZ. Use of the ETView Tracheoscopic ventilation tube in airway management of a patient with unanticipated difficult bag-mask ventilation. J Anesth 2016; 30: 699-701.
[29] Maciejewski A, Nowicki MM, Dabrowski M, Dabrowska A and Klosiewicz T. ETView® VivaSight SL as a novel method of endotracheal intubation. Am J Emerg Med 2017; 35: 1766.
[30] Levy-Faber D, Malyanker Y, Nir RR, Best LA and Barak M. Comparison of VivaSight double-lumen tube with a conventional double-lumen tube in adult patients undergoing video-assisted thoracoscopic surgery. Anaesthesia 2015; 70: 1259-1263.
[31] Oh SK, Lim BG, Kim YS, Lee JH and Won YJ. ETView VivaSight single lumen vs. conventional intubation in simulated studies: a systematic review and meta-analysis. J Int Med Res 2020; 48: 300060520925653.
[32] Intress RH. A modified Miller laryngoscope. Anesthesiology 1955; 16: 812.
[33] Jephcott A. The macintosh laryngoscope. A historical note on its clinical and commercial development. Anaesthesia 1984; 39: 474-479.

[34] Jones RD. Lamp placement and the Miller I laryngoscope blade. Anesthesiology 1985; 62: 207.
[35] Raw D and Skinner A. Miller laryngoscope blades. Anaesthesia 1999; 54: 500.
[36] Landry WB 3rd and Nossaman BD. Airway risk factors for the Miller laryngoscope blade. J Clin Anesth 2016; 33: 62-67.
[37] Alter S, Haim E, Sullivan A and Clayton L. Intubation of prehospital patients with curved laryngoscope blade is more successful than with straight blade. Am J Emerg Med 2018; 36: 1807-1809.
[38] Callander CC and Thomas J. Modification of Macintosh laryngoscope for difficult intubation. Anaesthesia 1987; 42: 671-672.
[39] Lewis SR, Butler AR, Parker J, Cook TM, Schofield-Robinson OJ and Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation: a cochrane systematic review. Br J Anaesth 2017; 119: 369-383.
[40] Lewis SR, Butler AR, Parker J, Cook TM and Smith AF. Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation. Cochrane Database Syst Rev 2016; 11: CD011136.
[41] Zaouter C, Calderon J and Hemmerling TM. Videolaryngoscopy as a new standard of care. Br J Anaesth 2015; 114: 181-183.
[42] Weiss M, Schwarz U, Dillier CM and Gerber AC. Video-intuboscopic monitoring of tracheal intubation in pediatric patients. Can J Anaesth 2000; 47: 1202-1206.
[43] Kaplan M, Ward D and Berci G. A new video laryngoscope-an aid to intubation and teaching. J Clin Anesth 2002; 14: 620-626.
[44] Cooper RM. Use of a new videolaryngoscope (GlideScope) in the management of a difficult airway. Can J Anaesth 2003; 50: 611-613.
[45] Hamal PK, Yadav RK and Malla P. Performance of custom made videolaryngoscope for endotracheal intubation: a systematic review. PLoS One 2022; 17: e0261863.
[46] Tosh P, Rajan S and Kumar L. Ease of intubation with C-MAC videolaryngoscope: use of 60 degrees angled styletted endotracheal tube versus intubation over bougie. Anesth Essays Res 2018; 12: 194-198.
[47] Hirabayashi Y and Seo N. Airtraq laryngoscope has an advantage over Macintosh laryngoscope for nasotracheal intubation by novice laryngoscopists. J Anesth 2009; 23: 172-173.
[48] Hirabayashi Y and Seo N. Airway scope: early clinical experience in 405 patients. J Anesth 2008; 22: 81-85.
[49] Fiadjoe J, Isserman R, Gurnaney H and Kovatsis P. GlideScope cobalt videolaryngoscope: mirrors and illusions. Anesthesiology 2015; 122: 436.
[50] Xue F, Yang G and Sun C. Performance of glidescope ranger video laryngoscope for prehospital emergency intubation. Crit Care Med 2016; 44: e1141.
[51] Kim W, Choi HJ, Lim T and Kang BS. Can the new McGrath laryngoscope rival the GlideScope Ranger portable video laryngoscope? A randomized manikin study. Am J Emerg Med 2014; 32: 1225-1229.
[52] Noppens R, Möbus S, Heid F, Schmidtmann I, Werner C and Piepho T. Evaluation of the McGrath series 5 videolaryngoscope after failed direct laryngoscopy. Anaesthesia 2010; 65: 716-720.
[53] van Zundert A, Maassen R, Lee R, Willems R, Timmerman M, Siemonsma M, Buise M and Wiepking M. A Macintosh laryngoscope blade for videolaryngoscopy reduces stylet use in patients with normal airways. Anesth Analg 2009; 109: 825-831.
[54] de Carvalho C, da Silva D, Lemos V, Dos Santos T, Agra I, Pinto G, Ramos I, Costa Y and Santos Neto J. Videolaryngoscopy vs. direct Macintosh laryngoscopy in tracheal intubation in adults: a ranking systematic review and network meta-analysis. Anaesthesia 2022; 77: 326-338.
[55] McNarry AF and Patel A. The evolution of airway management - new concepts and conflicts with traditional practice. Br J Anaesth 2017; 119: i154-i166.
[56] Jiang J, Ma D, Li B, Wu A and Xue F. Videolaryngoscopy versus fiberoptic bronchoscope for awake intubation - a systematic review and meta-analysis of randomized controlled trials. Ther Clin Risk Manag 2018; 14: 1955-1963.
[57] Berci G and Katz R. Optical stylet: an aid to intubation and teaching. Ann Otol Rhinol Laryngol 1979; 88: 828-831.
[58] Katz RL and Berci G. The optical stylet-a new intubation technique for adults and children with specific reference to teaching. Anesthesiology 1979; 51: 251-254.
[59] Nowakowski M, Williams S, Gallant J, Ruel M and Robitaille A. Predictors of difficult intubation with the bonfils rigid fiberscope. Anesth Analg 2016; 122: 1901-1906.
[60] Thong SY and Wong TG. Clinical uses of the bonfils retromolar intubation fiberscope: a review. Anesth Analg 2012; 115: 855-866.
[61] Shikani AH. New “seeing” stylet-scope and method for the management of the difficult airway. Otolaryngol Head Neck Surg 1999; 120: 113-116.
[62] Aziz M and Metz S. Clinical evaluation of the levitan optical stylet. Anaesthesia 2011; 66: 579-581.
[63] Greif R, Kleine-Brueggeney M and Theiler L. Awake tracheal intubation using the sensascope in 13 patients with an anticipated difficult airway. Anaesthesia 2010; 65: 525-528.

[64] Xu M, Li XX, Guo XY and Wang J. Shikani optical stylet versus macintosh laryngoscope for intubation in patients undergoing surgery for cervical spondylosis: a randomized controlled trial. Chin Med J (Engl) 2017; 130: 297-302.
[65] Rudolph C, Schneider JP, Wallenborn J and Schaffranietz L. Movement of the upper cervical spine during laryngoscopy: a comparison of the Bonfils intubation fibrescope and the Macintosh laryngoscope. Anaesthesia 2005; 60: 668-672.
[66] Mahrous RSS and Ahmed AMM. The shikani optical stylet as an alternative to awake fiberoptic intubation in patients at risk of secondary cervical spine injury: a randomized controlled trial. J Neurosurg Anesth 2018; 30: 354-358.
[67] Kaufmann J, Laschat M, Engelhardt T, Hellmich M and Wappler F. Tracheal intubation with the Bonfils fiberscope in the difficult pediatric airway: a comparison with fiberoptic intubation. Paediatr Anaesth 2015; 25: 372-378.
[68] Ong J, Lee CL, Lai HY, Lee Y, Chen TY and Shyr MH. A new video intubating device: trachway intubating stylet. Anaesthesia 2009; 64: 1145.
[69] Kim JK, Kim JA, Kim CS, Ahn HJ, Yang MK and Choi SJ. Comparison of tracheal intubation with the airway scope or clarus video system in patients with cervical collars. Anaesthesia 2011; 66: 694-698.
[70] Lee MC, Tseng KY, Shen YC, Lin CH, Hsu CW, Hsu HJ, Lu IC and Cheng KI. Nasotracheal intubation in patients with limited mouth opening: a comparison between fibreoptic intubation and the Trachway®. Anaesthesia 2016; 71: 31-38.
[71] Hsu HT, Chou SH, Chen CL, Tseng KY, Kuo YW, Chen MK and Cheng KI. Left endobronchial intubation with a double-lumen tube using direct laryngoscopy or the Trachway(R) video stylet. Anaesthesia 2013; 68: 851-855.
[72] Cooney DR, Beaudette C, Clemency BM, Tanski C and Wojcik S. Endotracheal intubation with a video-assisted semi-rigid fiberoptic stylet by prehospital providers. Int J Emerg Med 2014; 7: 45.
[73] Seo H, Lee G, Ha SI and Song JG. An awake double lumen endotracheal tube intubation using the clarus video system in a patient with an epiglottic cyst: a case report. Korean J Anesthesiol 2014; 66: 157-159.
[74] Pius J and Noppens R. Learning curve and performance in simulated difficult airway for the novel C-MAC® video-stylet and C-MAC® Macintosh video laryngoscope: a prospective randomized manikin trial. PLoS One 2020; 15: e0242154.
[75] Matek J, Kolek F, Klementova O, Michalek P and Vymazal T. Optical devices in tracheal intubation-state of the art in 2020. Diagnostics (Basel) 2021; 11: 575.
[76] Xue F, Yang B, Liu Y, Li H and Yang G. Current evidences for the use of UEscope in airway management. Chin Med J (Engl) 2017; 130: 1867-1875.
[77] Price L, Carter P, Hodzovic I, Alderman M, Hughes G, Phillips P, Varadarajan V and Wilkes A. An assessment of introducers used for airway management. Anaesthesia 2022; 77: 293-300.
[78] Henderson J. Development of the 'gum-elastic bougie'. Anaesthesia 2003; 58: 103-104.
[79] Venn PH. The gum elastic bougie. Anaesthesia 1993; 48: 274-275.
[80] Cormack J, Langley B, Bhanabhai LR and Kluger R. A randomised crossover comparison of two endotracheal tube introducers: the FROVA and the flexible tip bougie for GlideScope intubation of a difficult airway manikin by infrequent intubators. Int J Emerg Med 2020; 13: 38.
[81] Bogdanov A and Kapila A. Aintree intubating bougie. Anesth Analg 2004; 98: 1502.
[82] Detave M, Shiniara M and Leborgne JM. Use of Eschmann's gum elastic bougie in difficult orotracheal intubation, an audit over eight years of clinical practice. Ann Fr Anesth Reanim 2008; 27: 154-157.
[83] Tollman J and Ahmed Z. Efficacy of tracheal tube introducers and stylets for endotracheal intubation in the prehospital setting: a systematic review and meta-analysis. Eur J Trauma Emerg Surg 2021; [Epub ahead of print].
[84] Driver B, Semler MW, Self WH, Ginde AA, Gandotra S, Trent SA, Smith LM, Gaillard JP, Page DB, Whitson MR, Vonderhaar DJ, Joffe AM, West JR, Hughes C, Landsperger JS, Howell MP, Russell DW, Gulati S, Bentov I, Mitchell S, Latimer A, Doerschug K, Koppurapu V, Gibbs KW, Wang L, Lindsell CJ, Janz D, Rice TW, Prekker ME and Casey JD; BOUGIE Investigators and the Pragmatic Critical Care Research Group. BOugie or stylet in patients UnderGoing Intubation Emergently (BOUGIE): protocol and statistical analysis plan for a randomised clinical trial. BMJ Open 2021; 11: e047790.
[85] Masuda T, Nosaka N, Uchimido R and Nagashima M. Use of stylet and airway management procedure in critically ill patients. Intens Care Med 2021; 47: 1497-1498.
[86] Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM and Ahmad I; Difficult Airway Society intubation guidelines working group. Difficult airway society 2015 guidelines for management of unanticipated difficult intubation in adults. Br J Anaesth 2015; 115: 827-848.

[87] Apfelbaum JL, Hagberg CA, Caplan RA, Blitt CD, Connis RT, Nickinovich DG, Hagberg CA, Caplan RA, Benumof JL, Berry FA, Blitt CD, Bode RH, Cheney FW, Connis RT, Guidry OF, Nickinovich DG and Ovassapian A; American Society of Anesthesiologists Task Force on Management of the Difficult Airway. Practice guidelines for management of the difficult airway: an updated report by the american society of anesthesiologists task force on management of the difficult airway. Anesthesiology 2013; 118: 251-270.
[88] Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R and Cook TM; Difficult Airway Society; Intensive Care Society; Faculty of Intensive Care Medicine; Royal College of Anaesthetists. Guidelines for the management of tracheal intubation in critically ill adults. Br J Anaesth 2018; 120: 323-352.
[89] Grape S and Schoettker P. The role of tracheal tube introducers and stylets in current airway management. J Clin Monit Comput 2017; 31: 531-537.
[90] McElwain J, Malik M, Harte B, Flynn N and Laffey J. Determination of the optimal stylet strategy for the C-MAC videolaryngoscope. Anaesthesia 2010; 65: 369-378.
[91] Chalhoub V, Richa F, El-Rassi I, Dagher C and Yazbeck P. Pulmonary migration of a fragment of plastic coating sheared from a stylet. J Emerg Med 2013; 44: 1097-1100.
[92] Law JA, Duggan LV, Asselin M, Baker P, Crosby E, Downey A, Hung OR, Kovacs G, Lemay F, Noppens R, Parotto M, Preston R, Sowers N, Sparrow K, Turkstra TP, Wong DT and Jones PM; Canadian Airway Focus Group. Canadian airway focus group updated consensus-based recommendations for management of the difficult airway: part 2. Planning and implementing safe management of the patient with an anticipated difficult airway. Can J Anaesth 2021; 68: 1405-1436.
[93] Miller DM, Youkhana I, Karunaratne WU and Pearce A. Presence of protein deposits on ‘cleaned’ re-usable anaesthetic equipment. Anaesthesia 2001; 56: 1069-1072.
[94] Song L, Tan L, Ma N, Li Q, Zhou M, Hu Y, Liu Y, Chen H, Xu W and Zou Z. Reintubation during COVID-19 pandemic: a simple self-made guiding device facilitates reintubation and minimizes transmission. Am J Transl Res 2021; 13: 13811-13814.
[95] Murphy P. A fibre-optic endoscope used for nasal intubation. Anaesthesia 1967; 22: 489-491.
[96] Kriege M, Dalberg J, McGrath BA, Shimabukuro-Vornhagen A, Billgren B, Lund TK, Thornberg K, Christophersen AV and Dunn MJG. Evaluation of intubation and intensive care use of the new Ambu® aScope™ 4 broncho and Ambu® aView™ compared to a customary flexible endoscope a multicentre prospective, non-interventional study. Trends in Anaesthesia and Critical Care 2020; 31: 35-41.
[97] Vijayakumar M, Clarke A, Wilkes A, Goodwin N and Hodzovic I. Comparison of the manoeuvrability and ease of use of the Ambu aScope and Olympus re-usable fibrescope in a manikin. Anaesthesia 2011; 66: 689-693.
[98] Kristensen M and Fredensborg B. The disposable Ambu aScope vs. a conventional flexible videoscope for awake intubation - a randomised study. Acta Anaesth Scand 2013; 57: 888-895.
[99] Krugel V, Bathory I, Frascarolo P and Schoettker P. Comparison of the single-use Ambu(®) aScope™ 2 vs. the conventional fibrescope for tracheal intubation in patients with cervical spine immobilisation by a semirigid collar*. Anaesthesia 2013; 68: 21-26.
[100] Zaidi S, Collins A, Mitsi E, Reiné J, Davies K, Wright A, Owugha J, Fitzgerald R, Ganguli A, Gordon S, Ferreira D and Rylance J. Single use and conventional bronchoscopes for broncho alveolar lavage (BAL) in research: a comparative study (NCT 02515591). BMC Pulm Med 2017; 17: 83.
[101] Tvede M, Kristensen M and Nyhus-Andreasen M. A cost analysis of reusable and disposable flexible optical scopes for intubation. Acta Anaesth Scand 2012; 56: 577-584.
[102] Xia H, Huang S, Xiao W, Lin Y, Hu X, Nie B, Lin K, Lu D, Chen X, Song L, Wang L, Zhang Y, Yao S and Chen X. Practical workflow recommendations for emergency endotracheal intubation in critically ill patients with COVID-19 based on the experience of Wuhan Union Hospital. J Clin Anesth 2020; 66: 109940.
[103] Orser BA. Recommendations for endotracheal intubation of COVID-19 patients. Anesth Analg 2020; 130: 1109-1110.
[104] Park HP, Hwang JW, Lee JH, Nahm FS, Park SH, Oh AY, Jeon YT and Lim YJ. Predicting the appropriate uncuffed endotracheal tube size for children: a radiograph-based formula versus two age-based formulas. J Clin Anesth 2013; 25: 384-387.
[105] Naina P, Syed KA, Irodi A, John M and Varghese AM. Pediatric tracheal dimensions on computed tomography and its correlation with tracheostomy tube sizes. Laryngoscope 2020; 130: 1316-1321.
[106] Wang F, Casalino LP and Khullar D. Deep learning in medicine-promise, progress, and challenges. JAMA Intern Med 2019; 179: 293-294.