Chapter

A Paradigm Shift of Airway Management: The Role of Video-Assisted Intubating Stylet Technique

Hsiang-Ning Luk, Hsuan-Nu Luk, Jason Zhensheng Qu and Alan Shikani

Abstract

Difficult or failed intubation is a major contributor to morbidity for patients and to liability for the provider. Research to improve understanding, prevention, and management of such complications remains an anesthetic priority, and a driving force behind continuous improvements in intubation techniques and intubation equipment. The purpose of this review article is to focus on the video-assisted intubating stylet technique (VS; also known as the Shikani optical stylet technique for intubation) and video-assisted optical stylet devices, both for routine use and alternative rescue application for tracheal intubation, and stress their advantages as compared to conventional direct laryngoscopy and videolaryngoscopy. The VS technique was introduced by Dr. Alan Shikani in 1996 and popularized with the advent of the Shikani optical stylet and subsequent similar stylets variations. We focus on the clinical details of the technique itself, and on the various advantages and troubleshooting under different clinical scenarios and practice settings. In our experience, video-assisted intubating stylet technique often constitutes the most appropriate approach both for daily routine and emergency airway management. Furthermore, we also emphasize the importance of video-assisted intubating stylets in enhancing the practitioner systems response when difficult or failed tracheal intubation is encountered.

Keywords: airway management, endotracheal intubation, difficult airway, resuscitation, laryngoscopy, video-assisted intubating stylet, Shikani stylet, anesthesia, COVID-19, critical care

1. Introduction

Airway management has often presented challenges for clinicians since the early times when direct laryngoscope (DL) was invented [1, 2]. The complications related to difficult airway or failed tracheal intubation can be devastating to both the patients and the anesthesiologists. Clinicians have continually strived to improve tracheal intubation techniques and devices to avoid complications. In this article, we review the role of video-assisted intubating stylet (VS; also known as the Shikani optical stylet technique for intubation), and we focus on its technical aspects and its potential advantages over conventional DL and videolaryngoscope (VL).

The term "optical stylet" was coined by George Berci and Ronald Katz in 1979 [3, 4]. The main part of this device included a straight rigid endoscope functioning as an endotracheal tube stylet to facilitate endotracheal intubation. The straight design of the stylet was however not workable for cases of difficult laryngoscopy and the device had to be introduced with the aid of a Macintosh laryngoscope. The technique of tracheal intubation with the rigid stylets was later improved in 1983 by Pierre Bonfils with a device that was similar. Instead of a straight design, it employed a fixed curved distal tip at the angle of 40 degrees [5]. This allowed better access to the anteriorly located larynx. In 1996, Alan Shikani introduced the Shikani optical stylet (Clarus Medical, Minneapolis, MN, USA) and the first series were published in 1999 [6], with numerous large studies to follow. The Shikani stylet is semi-malleable and its tip may be bent to better fit to the patient's upper airway anatomy. With this newly designed stylet, Shikani also introduced a technique for tracheal intubation (the Shikani technique). Briefly, the operator grasps patient's mandible with one hand and lifts the jaw anteriorly and then introduces the optical stylet, preloaded with the endotracheal tube with the other hand and advances the combination into the larynx. Because the stylet "sees" where the endotracheal tube is going, successful entry into the trachea is confirmed by direct visualization, and importantly this is done without any need for using a Macintosh blade or putting any pressure on the teeth or extending the cervical spine. The Shikani technique for intubation is described in **Figures 1** and **2**.

Figure 3 shows clinical endoscopic views confirming by endoscopy (**Figure 3A**), whereby VS provides clear glottic view before sliding the endotracheal tube (ET tube) into the trachea (**Figure 3B**). VS is superior to DL and VL in obtaining an easy look at the glottic area and ensuring smooth railroading of the ET tube into trachea. Although VL with different angles/shapes of the blades frequently provides a decent laryngeal and glottis view, the operator may sometimes encounter difficulty in sliding the ET tube into the glottis, with occasional laryngeal trauma or misguided esophageal intubation. This could be due to the inherent design of VL device, inadequate mouth opening and/or oropharyngeal space, three axes alignment, etc. [7–11]. These issues are easily circumvented with VS.

Our experience and that of many others has shown optical stylets to be simple, durable, portable and lightweight, easy to learn and handle, affordable, and convenient to clean and disinfect [12–15]. The Clarus Video System (Clarus Medical LLC, Minneapolis, MN, USA) is a modification of the Shikani optical stylet which was originally introduced in the mid 1990s and since then multiple similar video-assisted intubating stylets have also been brought to market (**Table 1**). At our institution, we are currently equipped with 22 sets of four different brands of VS for routine use on daily basis since 2009 (**Figure 4**). Ours is an 1110-bed tertiary medical center with 1788 personnel, 20 operation rooms, 18 attending anesthesiologists, and 54 nurse anesthetists. Out of all surgeries that needed general anesthesia and tracheal intubation, more than 90% of the intubations were performed using VS (**Table 2**). The rest of tracheal intubations were conducted using flexible fiberoptic endoscope (FOB) mostly in some selected predictable difficult airway scenarios. In contrast, VL was

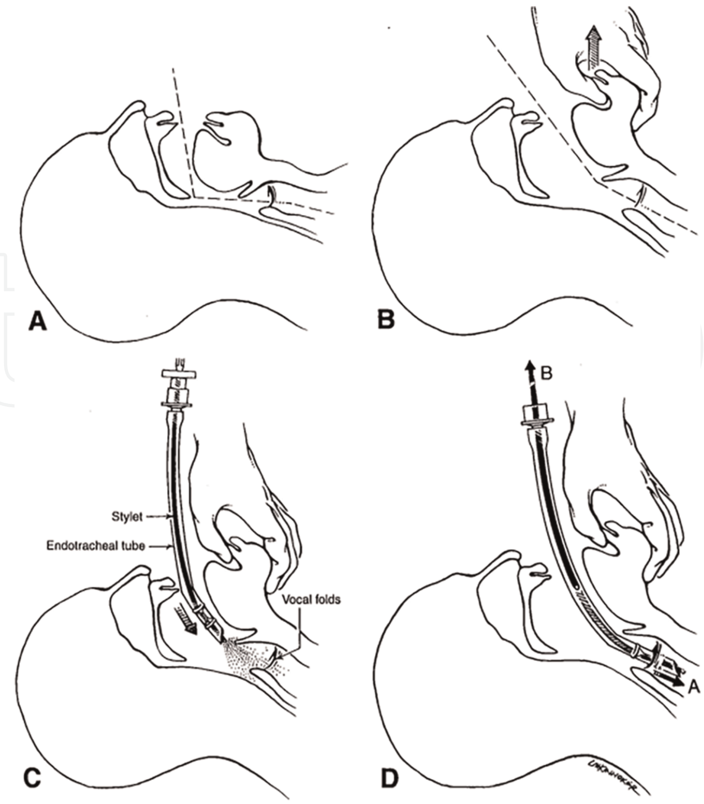

Figure 1.
The Shikani technique for intubation using the Shikani optical stylet. (A) Head is initially in the resting position. (B) Head is placed in the sniffing position, and the mandible is lifted with the left hand. (C) Stylet, preloaded with the endotracheal tube, is inserted into the mouth with the right hand, and the larynx is visualized. (D) Stylet–endotracheal tube unit is advanced through the vocal cords (arrow A) under direct visualization, and the stylet is removed (arrow B). (Courtesy of the SAGE Publishing. Permission to reproduce the images from [6] was granted).

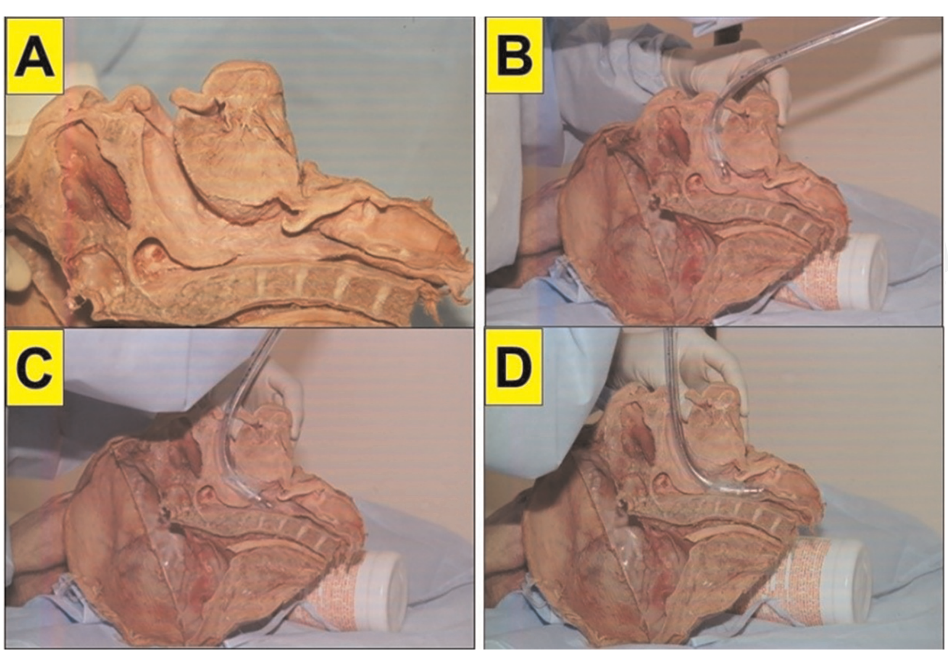

Figure 2.
Demonstration of the Shikani technique for intubation using the Shikani optical stylet in cadavers. (A) Before insertion of VS. The oral space is occupied by the tongue. (B and C) Jaw-thrust by operator's left hand allows the insertion of VS into oropharyngeal space. The hockey stick design of the VS makes insertion easy to access the epiglottis and approach glottic area. (D) Entry of the VS into trachea.

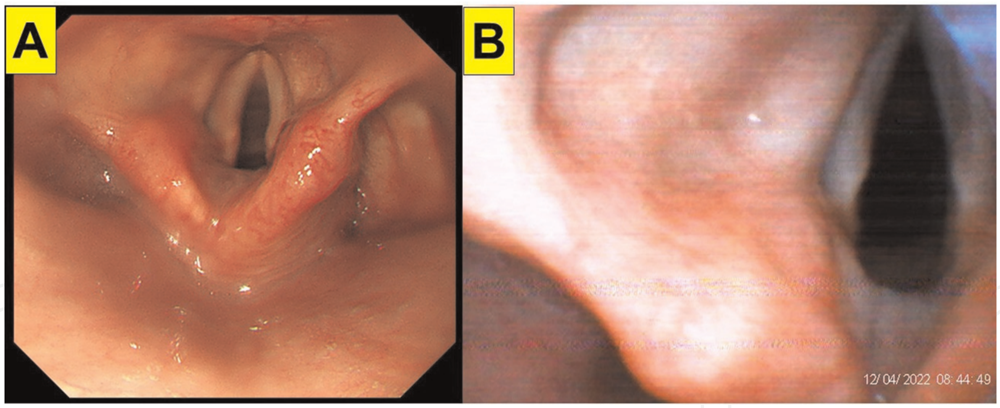

Figure 3.
Laryngeal and glottic views. (A) A perfect full-range glottic view from a flexible esophagogastroduodenoscopy examination in a 66-year-old man when the patient was under procedural analgesia. (B) A view from the video-assisted intubating stylet (VS) in an 89-year-old woman during tracheal intubation and general anesthesia. Laryngoscopic definition: POGO scale 100%; Cormack-Lehane class: I.

	AincA video stylet	**BESDATA reusable video stylet (BD-VSL)**	**IntuVu video stylet**	**Sensorendo® video stylet S-RVL**	**UE VL400-S3 video stylet**
Price	620 USD	700 USD	NA	NA	1800–5000 USD
Weight	NA	225 g	300 g	NA	180 g
Camera	NA	≥150 LUX, 1280 × 720 pixel	NA	1080 × 720 pixel resolution	NA
Display	2.4” full color video monitor	3” LCD, 640X480 (RGB)	3.5” IPS HD screen	3.5” video scree	2.5” LCD
Stylet	Malleable, waterproof	NA	NA	Waterproof	NA
Reusable	+	+	+	+	+
Clean and disinfection	Standard	NA	NA	Sterilizable	NA
ETT size	>6.0	NA	NA	4.5 mm diameter	3.0 mm, 5.2 mm

	ProVu™ Video Stylet	**Clarus Video System**	**Karl Storz C-MAC VS**	**TUORen Kingtaek Video Intubating System**	**HugeMed VL3H**
Price	600 USD	6000 USD	NA	5000 USD	800 USD
Weight	NA	NA	NA	NA	NA

Camera	NA	NA	NA	3840 × ≥150 LUX	640 × 480 (RGB), 2 M Piexel high resolution
Display	ProVu 3.5″ screen	4" LCD screen	NA	3.5″ screen	3.5″ screen
Stylet	NA	Waterproof	Completely watertight	Waterproof	NA
Reusable	+	+	+	+	+
Clean & Disinfection	NA	Soakable	Standard disinfection	Standard disinfection	NA
ETT size	6.5–8.0 mm	5.5–9.0 mm	Tube size 6.0 mm	NA	3.0–5.0 mm
					

Table 1.
Examples of commercially available video-assisted intubating stylet.

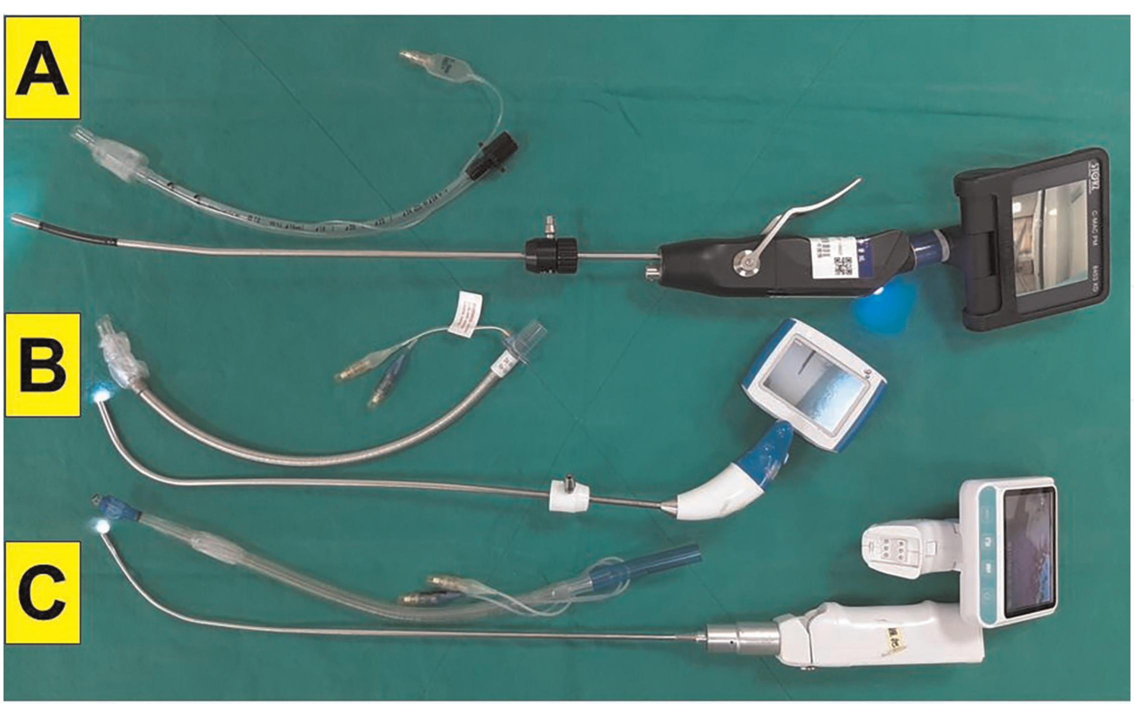

Figure 4.
Examples of commercial devices of VS. We apply the video-assisted intubating stylet technique at our institute on a daily routine basis. (A) C-MAC® VS, Karl Storz GmbH & Co. KG, Tuttlingen, Germany). (B) UE video stylet (UE, Xianju, Zhejiang, China). (C) Trachway video intubation system (Markstein Sichtec Medical Corp., Taichung, Taiwan). It is noted that these VS can accommodate various ET tubes, including regular ET tube (A), laser-resistant stainless steel ET tube (B), and double-lumen endobronchial tube (C).

	2016	2017	2018	2019	2020	2021
Total anesthesia number	16,077	17,831	17,998	19,307	19,721	19,244
GA number	15,339	16,893	17,497	18,481	19,009	18,574
LMA-GA number	5544	5134	5816	5902	5863	5714
ET-GA number	5953	6504	6920	6966	7418	6982
VL number	0	0	20	100	635	336
VS number	5953	6504	6900	6866	6783	6646

GA: general anesthesia. LMA: laryngeal mask anesthesia. ET: endotracheal intubation. VL: videolaryngoscope. VS: video-assisted intubating stylet.

Table 2.
Use coverage of video-assisted intubating stylet technique for tracheal intubation in the Department of Anesthesia, Hualien Tzuchi Medical Center, Hualien, Taiwan from 2016 to 2021.

used mostly for teaching purposes or personal preferences. With such a high volume of clinical practices using VS, we have acquired a significant experience with this technique and present it in the following sections.

2. Clinical experiences of optical intubating stylet

2.1 Airway grading

It is sometimes challenging to get a proper view of the glottis during routine tracheal intubation using DL. A simple prediction scale is therefore necessary and quite helpful in assessing and predicting risk during tracheal intubation [16–18]. We use the modified Cormack–Lehane (C–L) grading system of glottis view [19] to predict difficulty of tracheal intubation [20]. Modified scoring methods have also been used in our practice (e.g., percentage of glottis opening scale) [21, 22]. In addition to the competency in intubation technique, the quality of the airway assessment (e.g., difficult airway predictability) made by airway operators is also crucial for a successful intubation.

2.2 Preparation for placement of endotracheal tube

VS technique provides a superior view of the vocal cords and continuous visualization of the glottis for an easy and precise placement of the ET tube, as compared to DL and VL (**Figure 3B**). There are, however, some potential issues to be aware of when using VS: (1) Possible fogging of the lens (**Figure 5A**), which by the way can also happen with VL [23–26]. This is easy to prevent by careful wiping out the tip-lens with an anti-fog before use (**Figure 5B** and **C**). (2) Mucus or saliva covering the lens, and a good preventive maneuver is to keep the stylet a few millimeters proximal from the tip of ET tube, hence protecting the lens of the stylet. **Figure 5C** shows the appearance of the Murphy eye of an ET tube (side vent near the distal end of an ET tube) on a LCD screen. It should be emphasized that good video screen visualization is important for successful tracheal intubation when an optical stylet is used [27].

DOI: http://dx.doi.org/10.5772/intechopen.108340

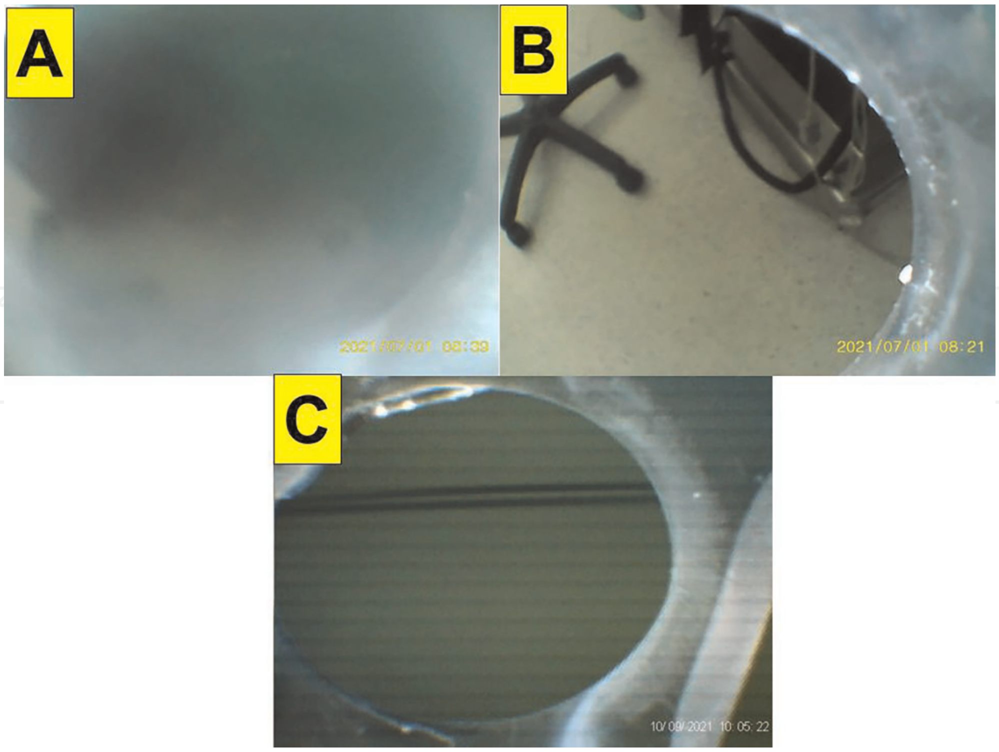

Figure 5.
The tip of VS should be kept clean and clear before use. (A) The optical lens was obscured and caused blurred vision. (B) Clear view after cleaning. (C) The relative position of the tips of the video stylet and endotracheal tube. The stylet tip was a little more backward than its position in (B).

2.3 Entrance to oral cavity

Since its original introduction in 1996 [6], numerous papers have been published on the application of the VS along with its advantages and benefits [13, 28–31]. An actual operating scenario for the Shikani technique of intubation is briefly described below. The operator first lifts up patient's mandible with the left hand and displaces it anteriorly until the lower teeth are anterior to the upper teeth (**Figure 6A**). The stylet-loaded ET tube set is then advanced forward by the right hand until the epiglottis is seen on the monitor. The operator can then maneuver the stylet beneath and pass around the epiglottis while continuously visualizing the airway. This allows a smooth and atraumatic railroading of the ET tube through the glottis and into the trachea. Occasionally, the tongue is large and in the way and the glottis cannot be seen clearly. In these situations, combining a Macintosh blade would further open the upper airway and bring the glottis into view. Alternatively, in contrast to the single-handed chin lift maneuver, a two-handed jaw thrust aided by an assistant can be used to facilitate the VS intubation (**Figure 6B**). With this strategy, the assistant stands either side by side or opposite the operator [32, 33]. It should be cautioned that the BURP (backward, upward, rightward external laryngeal pressure) is not helpful or recommended for VS technique. The combined use of VL or DL was also reported using the Bonfils rigid endoscope [34] or a lighted stylet [35]. **Figure 6C** shows the combination of DL and VS. Detailed description of such combination method will be presented in the latter part of this article.

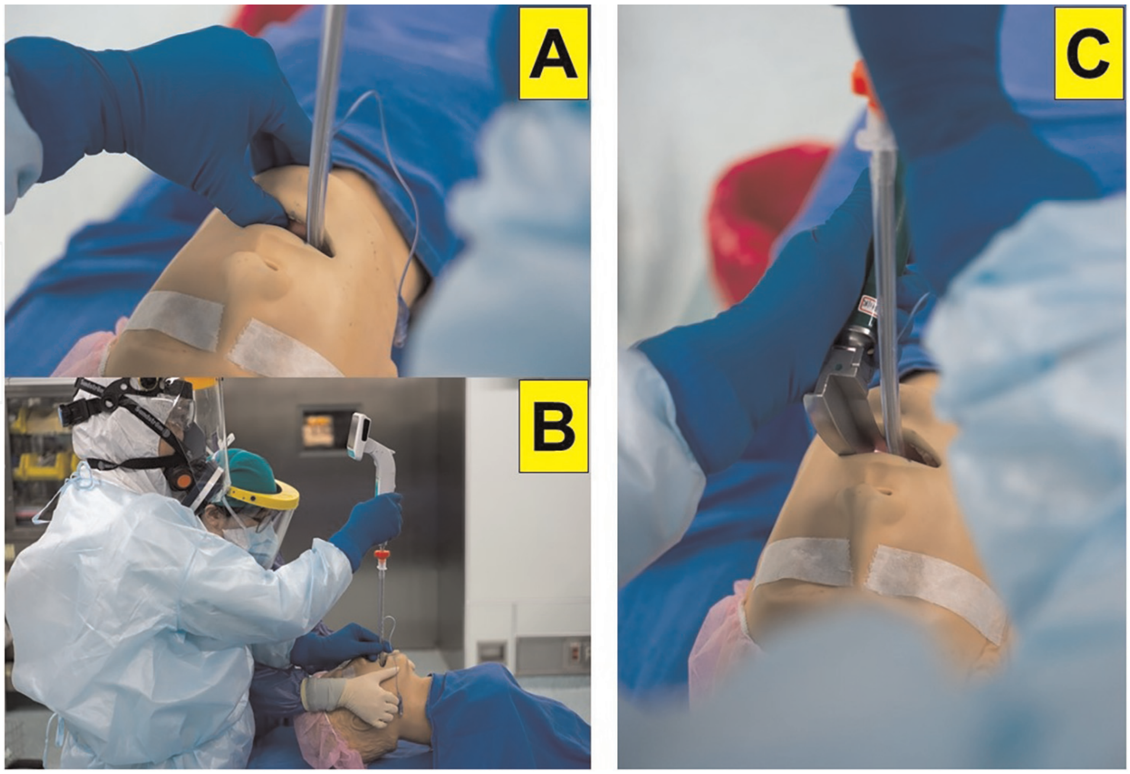

Figure 6.
Three methods to perform the VS technique. (A) Classical Shikani method. (B) Two-person performance. An assistant stood side by side with the operator (or opposite the operator) to provide jaw-thrust maneuver. (C) Combined use of laryngoscopy and VS technique. All three maneuvers can open patient's airway and enlarge retropharyngeal space for further advancement of the video stylet.

2.4 Glottic view

While the original and modified Cormack-Lehane grading system are useful [36], they are clinically meaningful and transferrable only if optimal intubating technique (e.g., optimal blade and its position, lifting force, head/neck position, external laryngeal manipulation, awake or anesthetized) is employed [37]. The main purpose of the C-L grading system is to describe the glottic view during direct laryngoscopy and might not necessarily translate to ease and speed of tracheal intubation. When VL was introduced [38], some reported that it had higher rates of successful intubation on the first attempt with improved glottic views, as compared to DL [7]. However, in different clinical settings (e.g., in emergency room or intensive care unit) and different patient populations (e.g., pediatric patients), VL did not show its superiority in first-pass success rate and time to intubation, as compared to DL [39].

In contrast to DL and VL, VS seems to provide the best glottic view as the tip of the stylet can access the laryngeal inlet and be positioned beneath the epiglottis. Because the vocal cords are directly visualized, the passage of the stylet-ET tube into trachea is almost assured. This allows minimal (if any) trauma while circumventing any laryngeal pathology such as cysts, tumors, etc.

We believe the glottis visualization grading systems for VS technique should be simply graded as "easy, restricted, and difficult". The crux of the matter in airway intubation is "to see is to accomplish". If the vocal cords can be seen, the placement of ET tube is then easy. We propose such a grading system (LQS system) specific for VS technique shown in **Figure 7**.

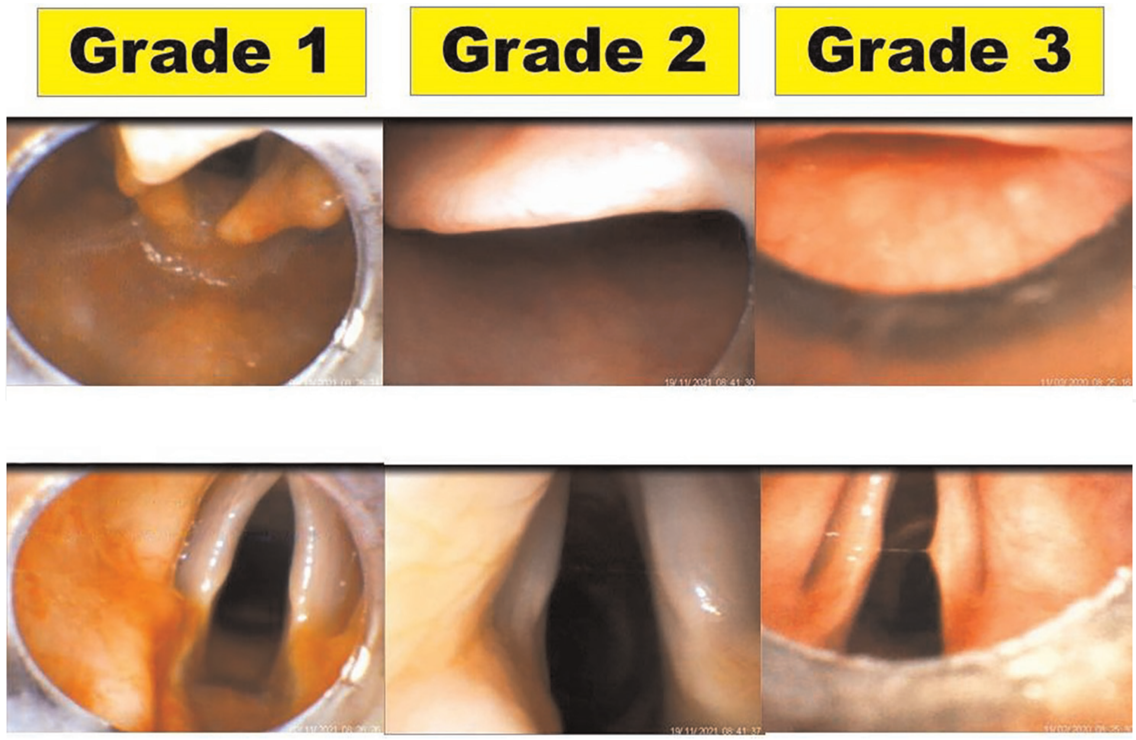

Figure 7.
*LQS grading score on glottis visualization by VS technique. Grade 1: Able to see any part of the vocal cords and arytenoid cartilages. Grade 2: None of glottis parts can be seen. Only epiglottis can be seen and there is enough space left between the epiglottis and posterior pharyngeal wall. Grade 3: The space under the epiglottis is very narrow and probably will create difficulty passing the stylet. It should be emphasized that once the stylet can be introduced beneath the epiglottis, full glottis view can be obtained (images shown in the lower row). This is a case for double-lumen endobronchial tube placement. Intubation time (for demonstration purposes): 28, 26, and 30 s, respectively. Please also compare with **Figure 8**. (Also see the Supplementary Materials Videos S1–S3. To watch the supplementary videos contact the email address: lukairforce@gmail.com).*

- **Grade 1**: Any part of the glottis (vocal cords and arytenoid cartilages) can easily be seen. The stylet-ET tube set can easily be passed into the trachea.
- **Grade 2**: The glottis cannot be visualized, but there is enough space between the floppy epiglottis and posterior pharyngeal wall. This allows the stylet-ET tube combination to be maneuvered to pass around the epiglottis and enter the trachea.
- **Grade 3**: The space between the epiglottis and glottis opening is extremely small, requiring a significant jaw-thrust or combining VS with a Macintosh blade to open the airway and allow visualization of the glottis.

The majority of the cases (74%) fell into grade 1 (**Figure** 7, left panel), 25% into grade 2 (**Figure** 7, middle panel), and very few (1%) classified into grade 3 (**Figure** 7, right panel) that required more laborious maneuverability to pass the stylet-ET tube set through the glottis. Our proposed grading method (LQS grading score), similar to other systems (e.g., C–L score, POGO score), does not require exact knowledge of grading minutiae (e.g., subdivided into 2a, 2b, 3a, 3b) [36, 40]. Our clinical experiences of the use of VS for routine and emergency intubation indicated that the LQS grading system was correlated with various intubating outcomes, such as intubating time, first-attempt success rate, easiness, complication rates, etc.

In our experience using the VS technique, we encountered some problems that caused the intubation to be more difficult, including: (1) copious mucus and saliva obscuring the lens and views; (2) stiff neck and restricted cervical mobility limiting the jaw-thrust; and (3) swollen soft tissues and floppy epiglottis hindering the pass of the stylet-ET tube either from midline or from the side of epiglottis (**Figure 8B**, left panel). In those difficult cases, the FOB technique may be helpful (**Figure 8B**, middle and right panels).

It should be emphasized that the LQS grading system is for VS technique combined with the simple jaw-thrust maneuver and may be affected by various patient conditions (e.g., restricted head/neck motility, pathological obstruction of airway, efficiency of jaw-thrust maneuver). Therefore, in patients with simulated difficult airway (e.g., using cervical collar or manual in-line stabilization) and a confirmed a high C–L grade by DL, the subsequent use of VS may take a longer time [41]. However, similar high intubation success rates with VS technique were obtained in both low C–L grade and high C–L grade patients in the simulated difficult airway scenario. During such intubation with VS, visualization of vocal cords and advancement into the glottis for the high-grade group was significantly more difficult than in the low-grade group [41].

In patients with a large and floppy epiglottis (i.e., LQS grade 3), the view can be improved by simply applying a jaw-thrust maneuver or by combining with a Macintosh blade [42, 43]. **Figure 9** shows such an example using a jaw-thrust maneuver to lift up the epiglottis for passage of the stylet-ET tube set. In this case, the oro-

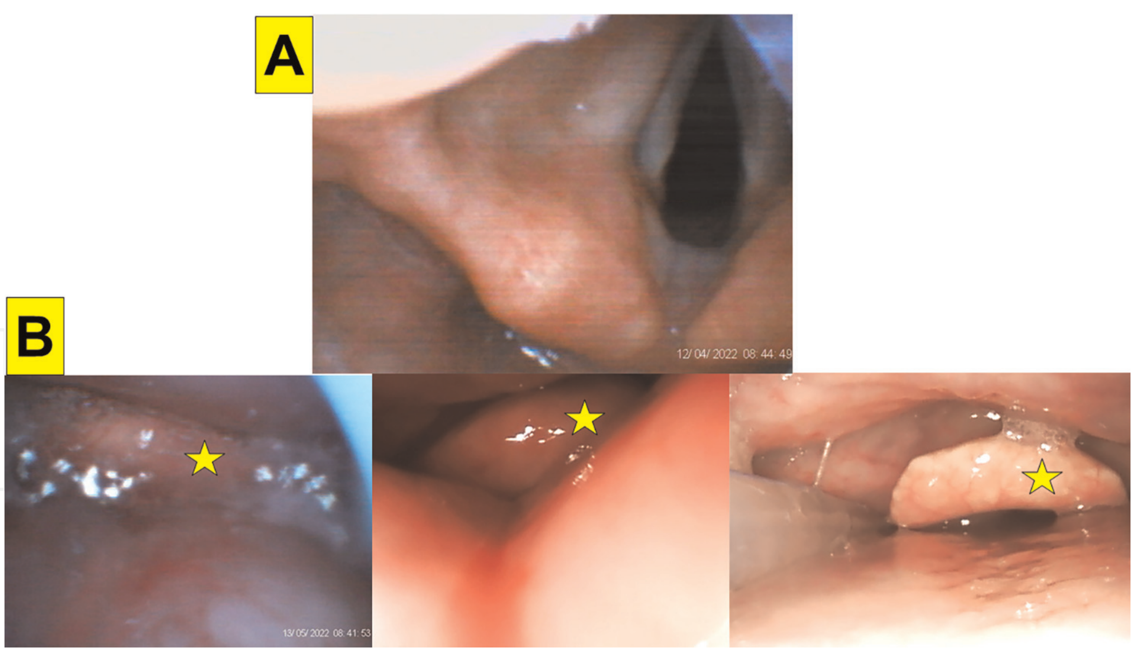

Figure 8.
*Two uncommon cases seen from VS camera. (A) Case 1: An 89-year-old woman. The glottis is perfectly visualized simply by jaw-thrust maneuver and the vocal cords fully open and visible (i.e., Cormack-Lehane class 1, POGO 100%). (B) Case 2: A 75-year-old man. The epiglottis could not be lifted up at all by jaw-thrust maneuver due to severe radiation fibrosis of the neck. The epiglottis is labeled by the yellow star. Left panel: The epiglottis was completely attached to the posterior pharyngeal wall when the patient was anesthetized and paralyzed. Intubation with VS technique failed after several attempts. Middle panel: The patient was quickly reversed from anesthetized status to asleep status with spontaneous respiration. Rescue intubation was eventually achieved by FOB. The epiglottis still remained drooped. Right panel: Three weeks later, the same patient received elective tracheostomy due to difficulty breathing. Awake nasal intubation was done with FOB. The patient in **Figure 8B** is the same as in **Figures 36–40**.*

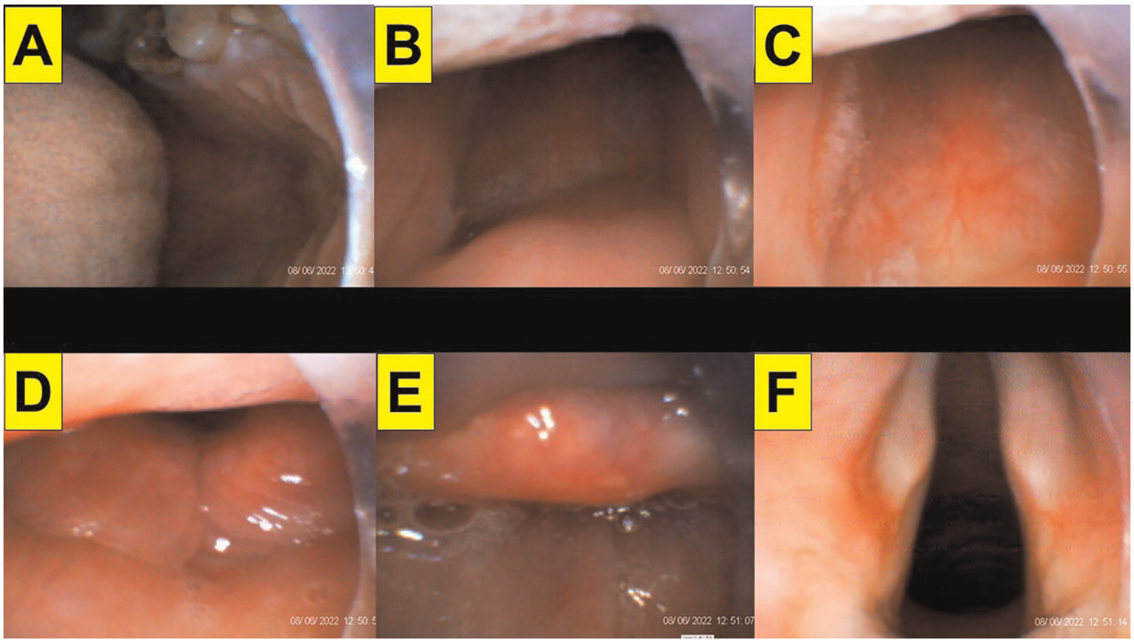

Figure 9.
Effect of jaw-thrust maneuver on improving glottis view seem from VS. this is a 66-year-old man with a BMI 25.0 kg/m² (167 cm, 70 kg). Mallampati score: Class 2. Neck circumference 44 cm. (A) View of oral cavity by opening mouth. (B) View of pharynx entry and uvula. (C) Laryngeal inlet. (D) Jaw-thrust created a LQS score grade 1 with partial view of glottic region. (E) Without jaw-thrust maneuver, epiglottis stayed back and attached to posterior pharyngeal wall. (F) Close-up panorama view of glottis. Intubation time (from lip to trachea, for demonstration): 30 s (Supplementary Materials Video S4).

pharyngeal-laryngeal space/inlet was open and accessible (**Figure 9A–C**). However, jaw-thrust could only lift up the epiglottis to expose the vocal cords less than 50% (**Figure 9D** and **E**) in this patient. Once the space underneath the epiglottis was wide enough to allow VS passage, the vocal cords could easily be viewed fully (**Figure 9F**). Further placement of the ET tube was easy by railroading the tube from VS.

2.5 Time to intubation

A mounting body of evidence indicates that VL reduces the rate of failed intubation and results in higher rates of successful intubation on the first attempt with an improved glottic view [7]. In patients with anticipated difficult airways (e.g., cervical collar limited mouth opening and neck movement), VL was safe and quicker in controlling the airway (time to view the vocal cords: 20–30 s (median); time to advance tube 30–40 s (median); intubation time of successful attempt: 50–60 s) [44]. The reported intubation time for emergency intubation by VL is 60 s ± 31 s (difficulty score with Visual Analogue Scale 0–100: 39 ± 27) [45]. In adult patients with a normal airway, the time for successful tracheal intubation with VL is short (17–38 s) [46]. Similar time ranges were found for emergency intubation with VL in these patients (12–15 s) [47].

Figure 10 shows four examples of the use of VS technique in patients with normal airways under routine tracheal intubation for elective surgeries. In two patients who needed rapid sequence intubation, the intubation time (from lip to trachea) using VS was 5–7 s, respectively (**Figure 10**, the left two panels). For teaching purposes or if there is a need to "look around the corner", the intubation time was slowed down to 20–30 s (**Figure 10**, the right two panels). If the intubation takes a longer time (e.g.,

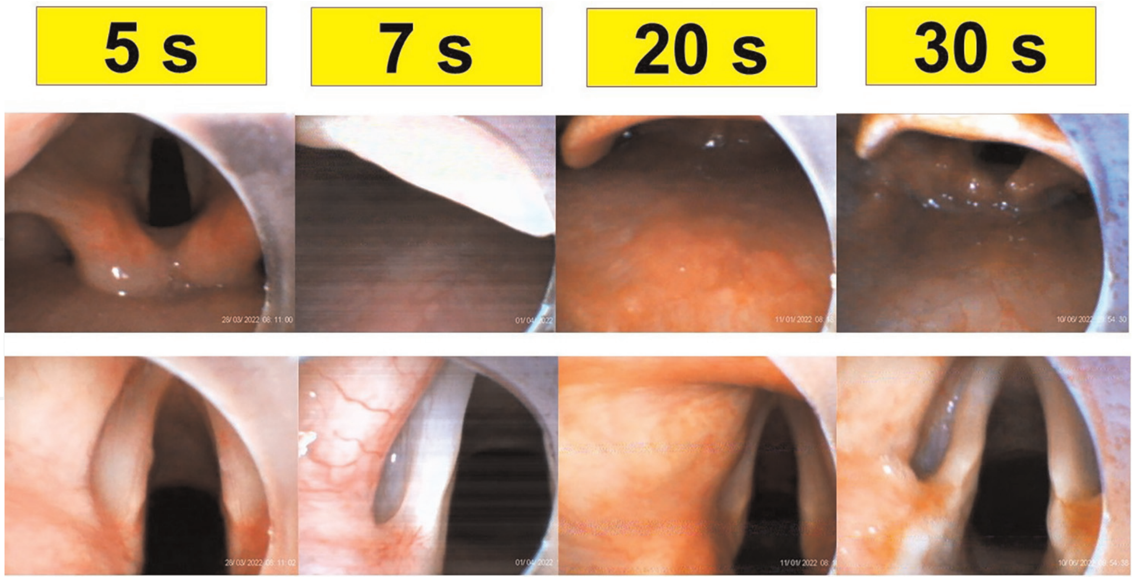

Figure 10.
Time to intubation (from lip to trachea) using VS technique in four examples. Upper row: View from epiglottis. Lower row: Close-up view of glottis. Left (5 s): A 36-year-old man with BMI 22.7 kg/m² (178 cm, 72 kg). Second from the left (7 s): A 52-year-old woman with BMI 24.0 kg/m² (162 cm, 63 kg). Third from the left (20 s): A 42-year-old man with BMI 29.3 kg/m² (174 cm, 89 kg). Right (30 s): A 55-year-old man with BMI 23.0 kg/m² (164 cm, 62 kg). It is noted that the speed of intubation was deliberately slowed down (20 and 30 s) for demonstration purpose. (Also see the Supplementary Materials Videos S5–S8).

between 30 and 60 s), the operator should anticipate a potentially difficult intubation (e.g., **Figure 8B**) and a plan B should always be prepared.

During airway management, the airway is not always as clear as seen in **Figure 10**. In the real world, the airway operator using VS technique might encounter copious thick mucus, saliva, or sometimes blood in the airway. Those secretions may obscure the lens of the optical intubating tool and make intubation more difficult. Frank emesis and massive vomitus or blood can occur in certain traumatic emergencies [48, 49]. Quick, effective, and continuous suctioning of pharyngeal secretions or blood is necessary to reduce the risk of losing visualization. A tracheal suction catheter or Yankauer suction tip would help clearing the oropharynx and larynx. **Figure 11** shows the saliva impeding the glottic view when VS technique was applied. Pre-medication with an anti-sialagogue and proper suctioning are helpful to reduce such problems before inserting the optical stylet into the patient's oropharynx.

3. Routine use of VS in elective and emergency surgeries

VL and DL have been used for decades in both elective and emergency intubations. The introduction of VL has shifted the paradigm of airway management [50]. VS was first introduced by Shikani in patients (both adults and children) undergoing routine otolaryngologic procedures [6] and has since been applied in various clinical scenarios, including difficult and emergency airway [12, 51]. The VS technique has been studied in adults in supine position [52–56], in lateral decubitus position [57], and in pediatric patients with difficult airway [30, 58]. It has also been used during awake intubation [53, 59] and for diagnostic bronchoscopy [60]. VS has also been used by emergency room physicians [61] and emergency medical technicians in the pre-hospital airway management [62].

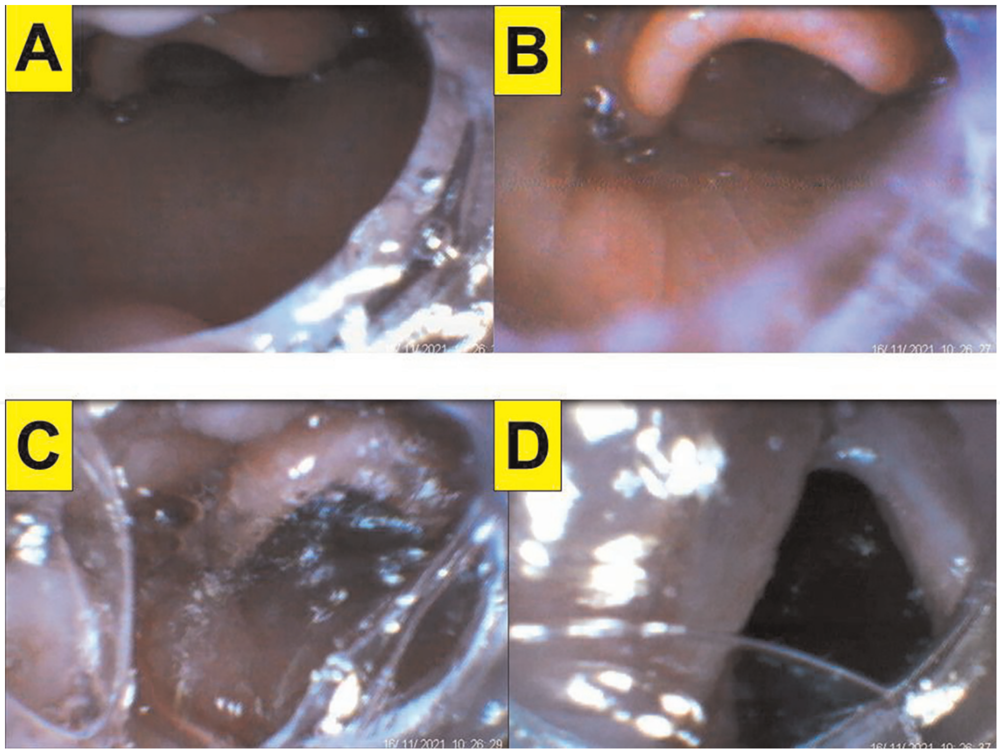

Figure 11.
Presence of mucus and saliva interfering with laryngeal views obtained by VS technique during tracheal intubation. A morbidly obese 42-year-old woman with BMI 46.6 kg/m² (165 cm, 127 kg) underwent fasciotomy and debridement. Past history included sleep apnea and snoring. LQS score grade 1. The intubation time (for demonstration) is 22 s. (Also see the Supplementary Materials Video S9).

In 2010, VS was introduced into our department. At that time, most of our staff still used DL and some tried VL (e.g., GlideScope®) [63, 64]. We established a formal airway training course in DL, VL, and VS use for the staff and novice operators using cadaver and mannequins. Currently, we have more than 22 sets of VS from four different brands in our 21 operating rooms. Although it is not mandated to use VS, VS prevails among all the available intubating tools we have. We regularly survey the novice users and trainees to evaluate their performance and obtain feedback. Notably, VS is used in more than 90% of tracheal intubations (**Table 2**).

Figure 12 demonstrates the routine use of VS for tracheal intubation in an elective surgery. We have previously reported on the application of VS in patients undergoing an emergency surgery during the COVID-19 pandemic [65–70] (see **Figures 13** and **14**). The coverall personal protective equipment (PPE) and plastic sheet barrier did not interfere with smooth tracheal intubation using VS in COVID-19 patients. In both clinical scenarios (**Figures 12–14**), VS technique provides a swift, and safe tracheal intubation, while protecting the intubating provider from secretions as he/she does not have to put his/her face close to the patient's mouth.

Table 3 summarizes the strengths and weakness of VL and VS. The clinical performance of VS is usually evaluated in many aspects, including (1) insertion in the oropharynx; (2) visualization of the epiglottis; (3) advancement in the glottic aperture; (4) maneuverability of the stylet; and (5) adverse events such as dental trauma, soft tissues damages, autonomic overstimulation, aspiration, hypoxia, etc. In both normal airway and difficult airway scenarios, VS shows its advantages with shorter intubating time [13, 71–74], less autonomic stimulation [55], and shorter learning curve [75].

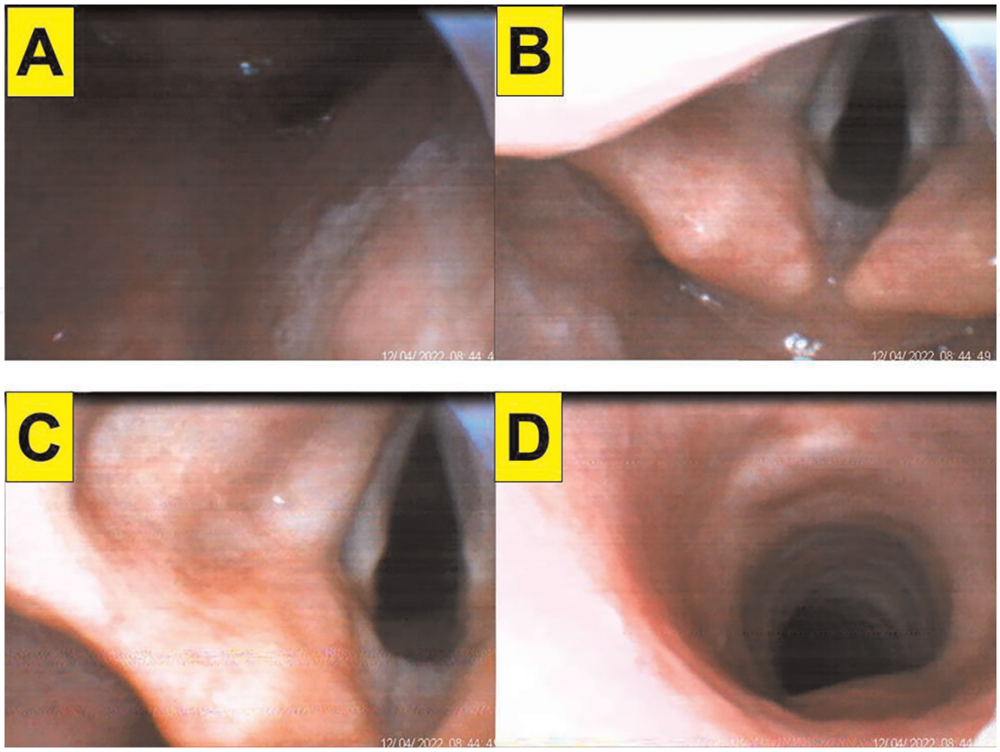

Figure 12.
A typical case of routinely applying VS technique for tracheal intubation in elective surgery. An 89-year-old woman with BMI 25.3 kg/m² (150 cm, 57 kg). The intubation time (from lip to trachea) is 7 s. (Also see the Supplementary Materials Video S10).

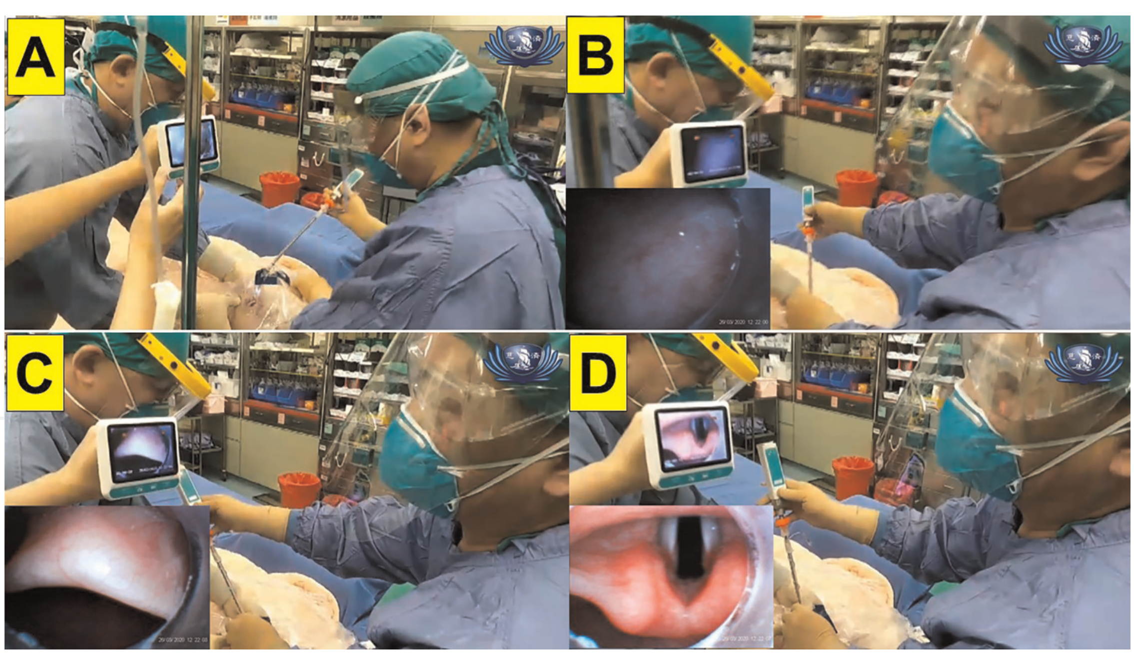

Figure 13.
A typical case of routinely applying VS for tracheal intubation during emergency surgery. A 26-year-old woman with BMI 21.3 kg/m² (150 cm, 48 kg) underwent an emergent orthopedic surgery due to multiple trauma during COVID-19 pandemic in 2020. Combined use of VS and a piece of plastic sheet as a protective barrier was noted. The two anesthesiologists wore PPE during tracheal intubation procedure. The anesthesia assistant was performing jaw-thrust maneuver. (Also see the Supplementary Materials Video S11).

DOI: http://dx.doi.org/10.5772/intechopen.108340

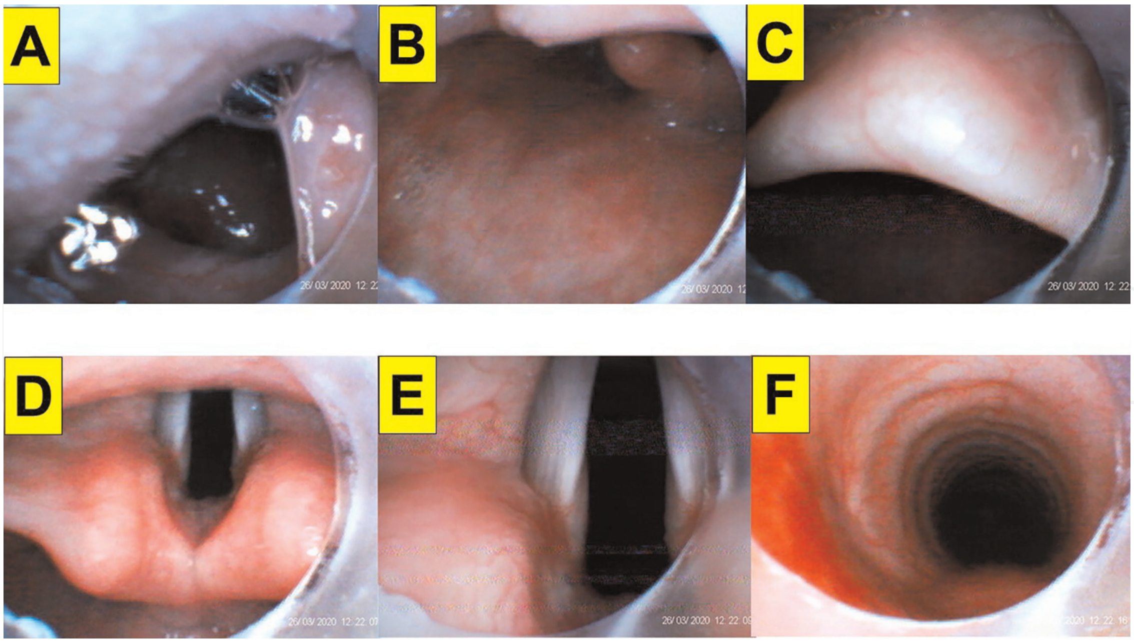

Figure 14.
Same patient as in ***Figure 13****. Close-up views from the VS video LCD screen. (A and B) Views of oropharynx and larynx. (C) Epiglottis. (D and E) Views of glottis and vocal cords. (F) Entry into trachea. The intubation time was 12 s. (Also see the Supplementary Materials Video S12).*

	VL	VS
Required use of a blade	+	–
Forces to laryngoscopy	++	–
Require mouth-opening	+++	+
Forces applied to the maxillary incisors	++	–
Use of a stylet	±	–
Maneuverability during navigation	+	+++
Ability to control the tip and displace soft tissues	+	+++
Require lift-up epiglottis	+++	+
Better Cormack-Lehane/LQS grading	+	+++
Difficult placement/insertion	+++	–
Ability to visualize the insertion of the tip of ET tube into trachea	+	+++
High first-attempt success rate	++	+++
More number of attempts	++	+
High overall success rate	++	+++
Short time to intubation	++	+++
Need of external laryngeal maneuver	++	–
Esophageal intubation	++	–
Autonomic stimulation	++	–
Airway trauma/injury	++	–

	VL	VS
Other complications	++	–
Affordable (cost)	+	++
Short setup time and portability	+++	+++
Availability, accessible, maintenance	++	++
Skill/technique learning curve	++	+++

VL: Videolaryngoscope. VS: Video-assisted intubating stylet. Complications: Hypoxemia, hypotension. "+" and "–" denote the degree of relative comparison between use of VL and VS.

Table 3.
Comparison between videolaryngoscopes (VL) and video-assisted intubating stylet (VS).

4. First-line choice of VS in difficult airway

Over the last decade, the VS technique has been widely used as an alternative to VL in simulated difficult airways (e.g., rigid cervical collars applied) [6, 31, 76–83], cervical spine surgeries [84, 85], upper airway obstruction [86–89], double-lumen endobronchial tube placement [90–92], and emergent awake intubation [93]. In the following sections, we present our clinical experiences of using the VS technique as the first-line intubating modality in several difficult airway scenarios.

4.1 Head neck lesions

Various video-assisted intubating stylets have been used in potential or anticipated difficult airway as the first-line tool for tracheal intubation. We previously reported use of VS in patients with anticipated difficult airway, such as facial-oral tumors, enlarged tonsils, radiation neck fibrosis, hypopharyngeal cancers, and laryngeal tumors and cysts [94]. Similarly, VS was also reported in patients with an epiglottic cyst [86, 87], retropharyngeal tumor [88], and in awake nasal intubation [89].

Although awake/asleep flexible fiberoptic bronchoscopy and elective/emergency tracheostomy still remain the gold standard of the airway management in extreme difficult airway (e.g., hypopharyngeal cancer, severe radiation-induced fibrosis over neck, giant neck tumors, restricted mouth opening), VS can play a role in anticipated difficult airway, similar to the proposed role of awake FOB and VL [95]. One advantage of the Shikani stylet over the fiberoptic scope is the ability to maneuver it around a floppy epiglottis, especially if the patient is asleep and in the supine position. It should be mentioned that rigid endoscopy is one of the difficult airway rescue modalities [96].

Figure 15 shows an example of a potential difficult airway in a patient with hypopharyngeal cancer undergoing laryngo-microsurgery (LMS) intubated with VS. The epiglottis was difficult to lift up but the space between the epiglottis and posterior pharyngeal wall was just wide enough to allow the stylet-ET tube set to go through. A good glottis view was obtained, and intubation was completed without delay. When VS is used in patients with head/neck lesions, the operator should expect that mucus and blood can blur the lens of VS and be prepared to handle that (**Figure 16**).

When a patient has been previously treated with radiotherapy or surgery, a stiff neck caused by radiation fibrosis, flap, or scar is expected. In **Figure 17**, the patient's mouth opening was wide enough, but the neck was stiff and the cervical spine

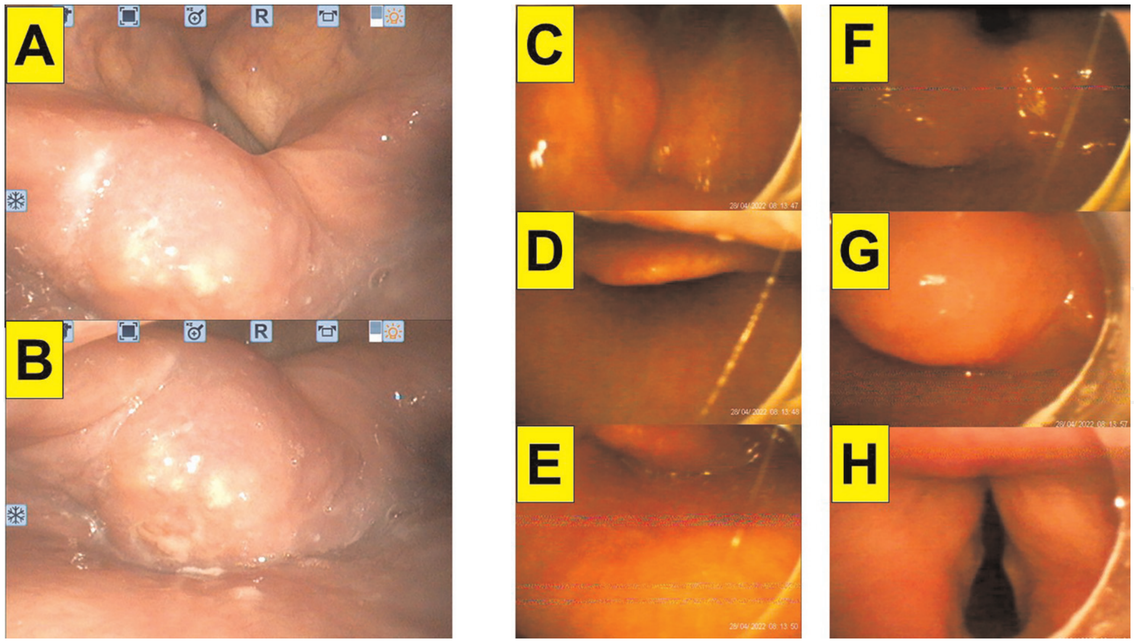

Figure 15.
Use of VS technique in a patient with anticipated difficult airway. A 66-year-old man (BMI 22.6 kg/m²; 164 cm, 61 kg) with hypopharyngeal cancer underwent LMS surgery. (A) and (B) Pre-operative endoscopic survey images. (C–H): Serial views during tracheal intubation using VS under general anesthesia. The epiglottis could not be fully lifted up by sole jaw-thrust maneuver (D). The intubation time: 20 s. (also see the Supplementary Materials Video S13).

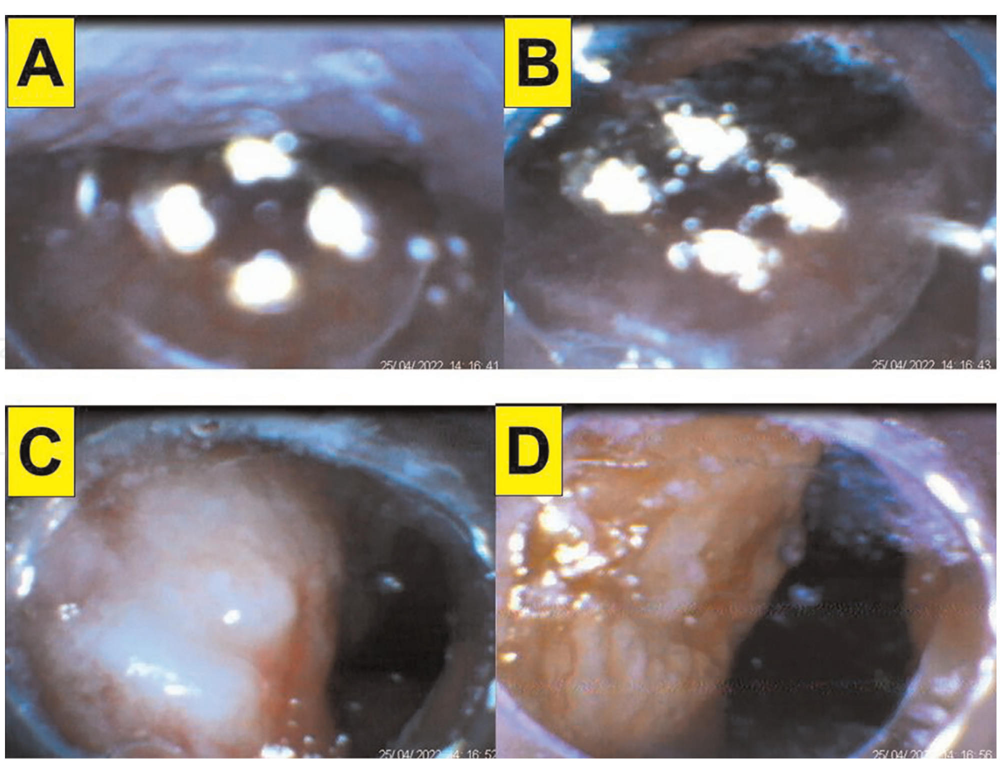

Figure 16.
Use of VS technique complicated by a saliva bubble in a patient with hypopharyngeal cancer. This is a 57-year-old man with BMI 26.0 kg/m² (172 cm, 77 kg). The intubation time: 20 s. (Also see the Supplementary Materials Video S14).

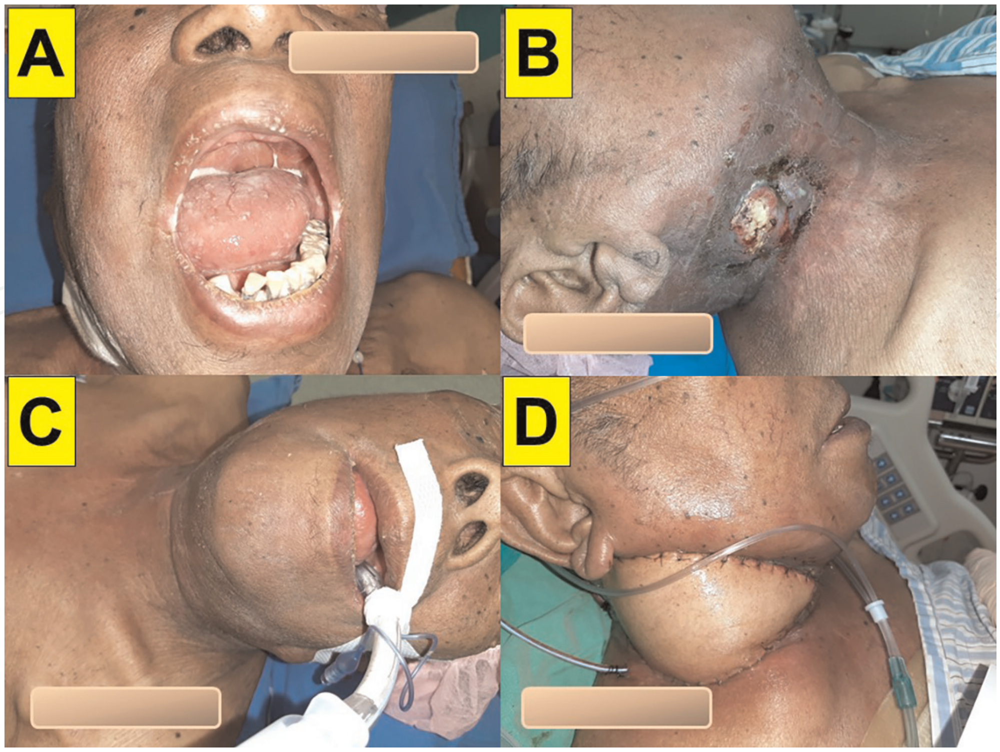

Figure 17.
Use of VS technique in a patient with stiff neck caused by radiation therapy. This is a 72-year-old man with BMI 20.4 kg/m² (174 cm, 62 kg). He had squamous cell carcinoma over the neck with metastasis and received definitive concurrent chemoradiotherapy. (A) Mouth opening is wide enough. (B) Stiff neck due to radiation fibrosis with ulceration. (C) Post-intubation. (D) Post-operation after extubation.

mobility was restricted. His glottic inlet was narrow due to edema of the pharyngeal tissues and epiglottis. The intubation was nevertheless smoothly executed using VS technique (**Figure 18**).

4.2 Morbid obesity

Obesity and morbid obesity can complicate airway management. Impaired glottis visualization [97–102] leads to greater lifting force and external laryngeal pressure. Several prediction algorithms have been proposed for the morbidly obese patient [103–105], including anthropometric parameters [106–109]. Body mass index and neck circumference are commonly used to predict difficult airways [110–113], although some studies showed no association with difficult intubation [114]. Still, it is a general consensus that morbid obesity makes tracheal intubation difficult [109]. There are various intubating modalities for obese patients [115–120] and VL is superior to conventional DL [121–130]. VS is useful in morbid patients due to its improved visualization of the larynx and the ease with tube advancement [131, 132].

Our clinical experiences support the role of VS in morbidly obese patients. **Figure 19** shows tracheal intubation with VS in a patient whose oropharynx was too narrow for laryngoscopy (**Figure 19F**). In the last six years, we have performed hundreds of intubations on morbidly obese patients (including more than 100 patients undergoing bariatric surgery), and there were only two cases that we were not able to intubate with VS. **Figure 20** shows three examples of the application of VS in morbidly obese patients (BMI 36.6, 49.9, and 58.4 kg/m^2, respectively). The

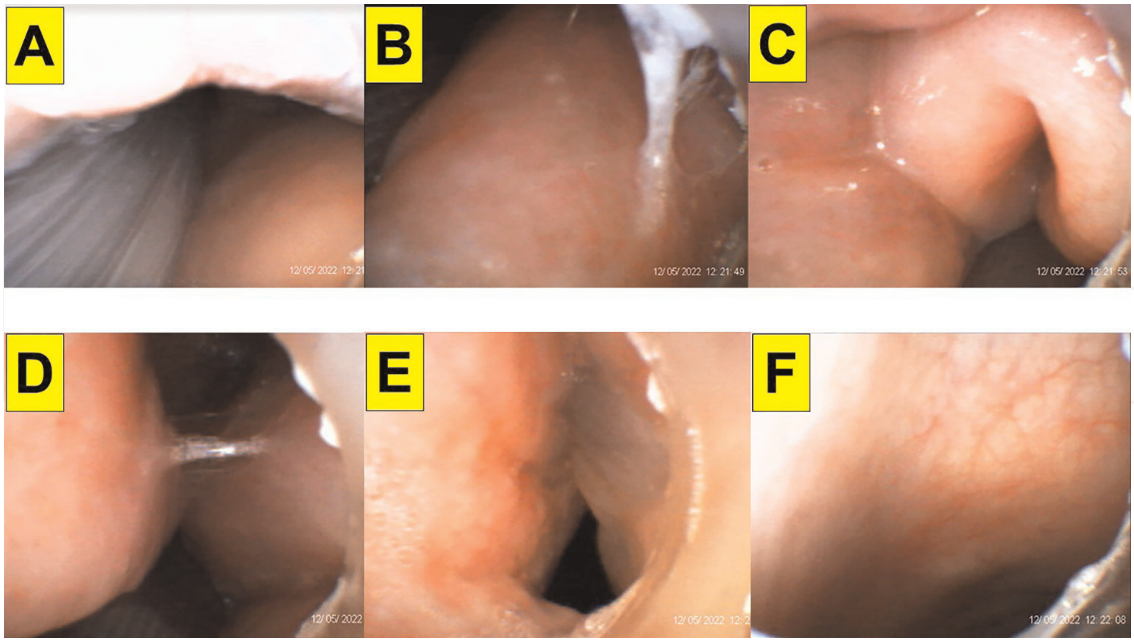

Figure 18.
Close-up views from VS in the same patient from ***Figure 17****. Due to limited effects of jaw-thrust maneuver in the presence of radiation fibrosis of the neck, the oro-pharynx (A and B), larynx (C and D) are crowded. The epiglottis curls inward and manifests omega-shaped folding (C). (E) The glottis opening is narrow. (F) ET tube is secured into trachea. The intubation time is 24 s. (Also see the Supplementary Materials Video S15).*

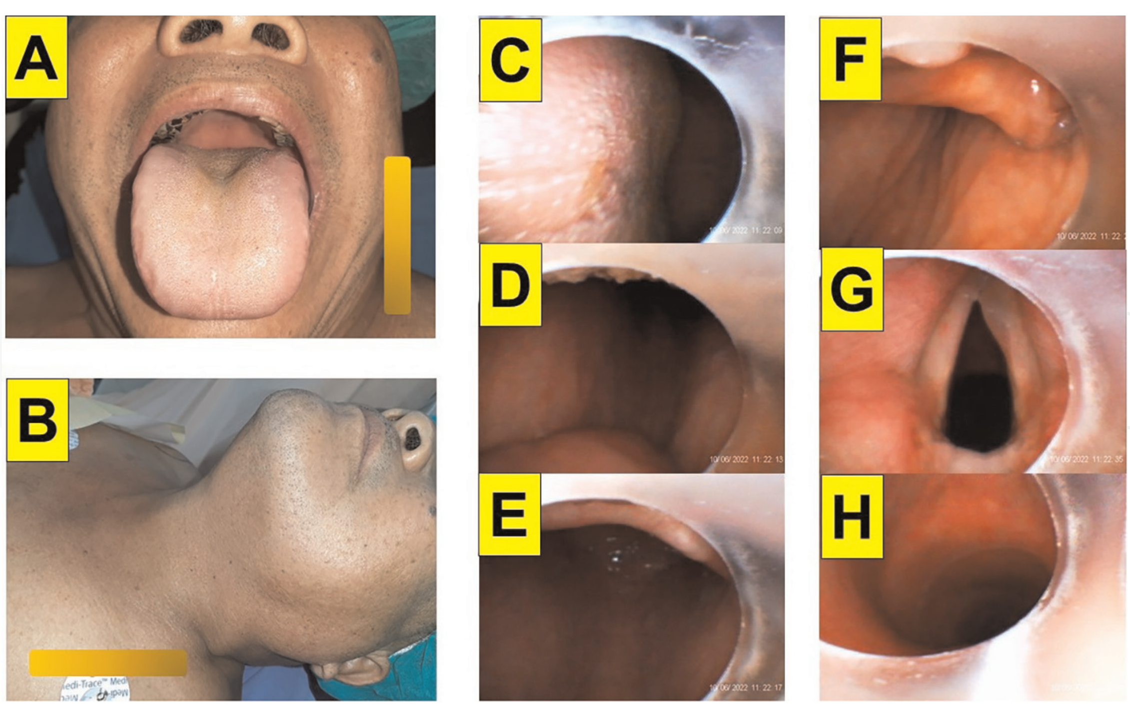

Figure 19.
A 65-year-old morbidly obese man with BMI 40.5 kg/m^2 (167 cm, 113 kg). (A) Modified Mallampati test: Class 3. Mouth opening 5.5 cm. (B) Thyromental distance: 6.5 cm. Sternomental distance: 11.5 cm. Neck circumference: 47 cm. Upper lip bite test: Class 1. (C–H) Serial views from VS camera. (C) View of oropharynx. (D, E) laryngeal inlet is crowded with LQS score grade 1. (F) Without jaw-thrust maneuver, the LQS class is grade 2. (G, H) Clear visualization of glottis and tracheal rings. The intubation time (for demonstration) is 30 s. (Also see the Supplementary Materials Video S16).

Figure 20.
Serial close-up views from VS in three typical morbidly obese patients. (A) BMI 36.6 kg/m² (170 cm, 106 kg). A 37-year-old man underwent laparoscopic hernioplasty. The intubation time is 20 s. (B) BMI 49.9 kg/m² (165 cm, 136 kg). A 37-year-old woman underwent laparoscopic sleeve gastrectomy. The intubation time is 20 s. (C) BMI 58.4 kg/m² (167 cm, 163 kg). The intubation time is 22 s. It is interesting to note that the LQS grading scores in all these three morbid obesity cases are grade 1. It is noted that laryngeal tissues are crowded. (Also see the Supplementary Materials Video S17–S19).

intubation with VS technique was smooth and fast. The "video-video paired technique" will be presented in the latter part of this article.

4.3 Restricted cervical spine mobility

Restricted cervical spine (C-spine) mobility is a major risk factor for difficult airway in various prediction algorithms. Although awake/asleep/anesthetized flexible fiberoptic bronchoscopy is the gold standard for airway management, other airway modalities and tools have been proposed in the literature [133]. Among all the airway tools, VL has drawn the most attention as a useful tool for restricted C-spine motion. This technique has been tested in patients with a simulated restricted C-spine condition (with manual in-line stabilization or rigid cervical collar) [44, 134–145], in real patients undergoing C-spine surgeries [146, 147], and in mannequin simulation model [148, 149]. Recently, VS has also been tested in patients with simulated restricted C-spine motion [31, 78, 80, 81, 84, 150, 151].

Our single-institute clinical experience (more than 600 C-spine surgeries a year) indicates that the VS technique is a very useful technique in this patient population. **Figure 21** shows a case when cervical spine mobility was restricted by the neck collar. Another example of limited C-spine mobility is in patients receiving stereotactic neurosurgeries with a head frame mounted before tracheal intubation can occur. **Figure 22** shows such a scenario.

4.4 COVID-19 pandemic

The COVID-19 pandemic created a major challenge in airway management for both patients and providers [152]. It was reported that VL "should be dedicated for

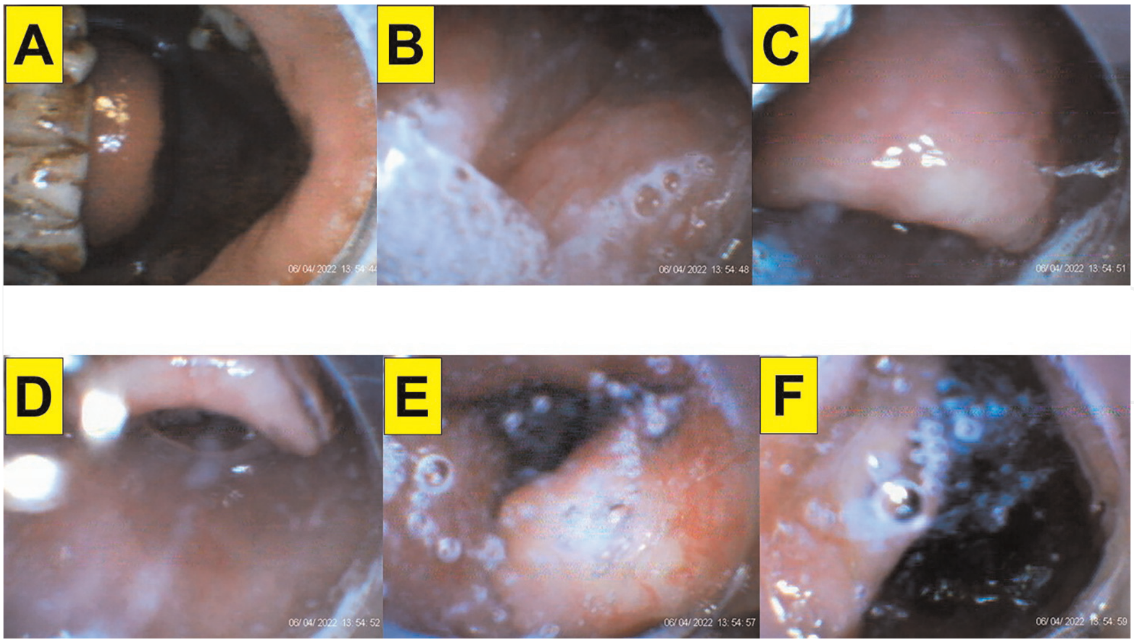

Figure 21.
Application of VS technique in a 42-year-old male patient (BMI 29.6 kg/m²) with cervical collar immobilization due to C4-5 contusion. (A) Fair mouth opening. (B) Copious saliva and secretions in the pharynx and larynx. (C, D) The immobilization process itself caused a worse glottic view (LQS scale: 2. No glottis structures can be seen at all). Fortunately, the space underneath the epiglottis is enough for passage of the stylet-ET tube. (E, F) The secretion bubbles disturbed the glottis view. The intubation time is 16 s. (Also see the Supplementary Materials Video S20).

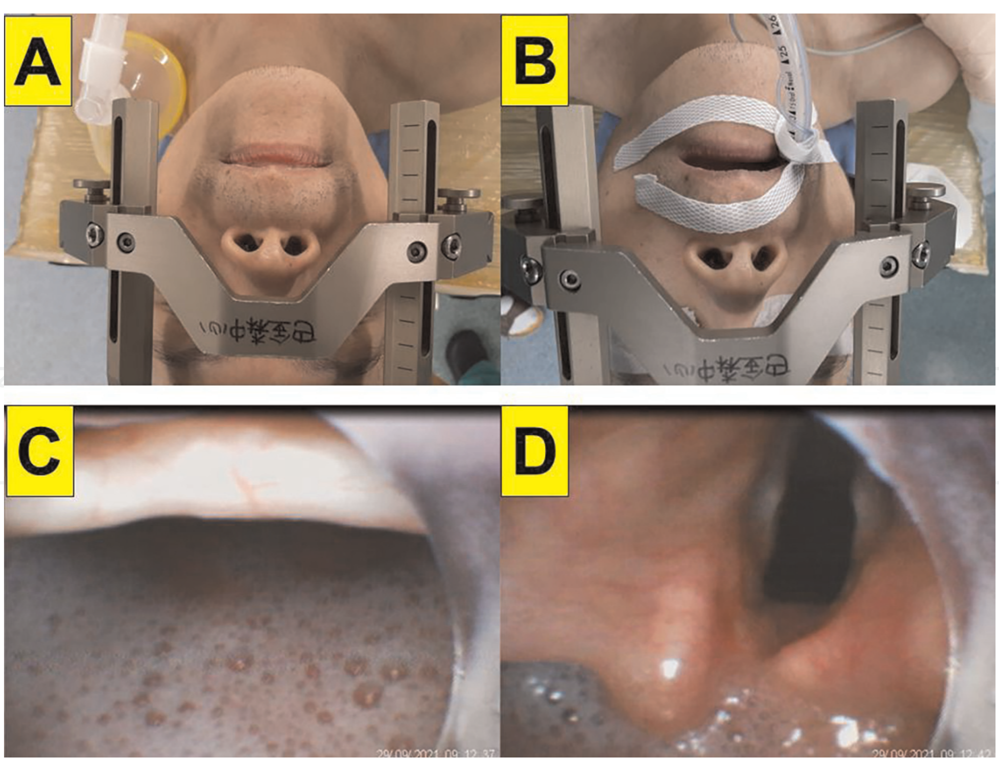

Figure 22.
Application of VS technique in a patient undergoing stereotactic neurosurgery. This 59-year-old man with genetic torsion dystonia and Parkinson's disease (BMI 20.2 kg/m²) underwent frame-based stereotactic procedure for bilateral subthalamus nucleus electrodes implantation. (A) Prior to anesthesia induction, a head frame was mounted and secured. (B) Tracheal intubation was performed with VS technique. (C) Close-up views in front of epiglottis and glottis (D). Copious saliva and secretions were present. The intubation time is 14 s. (Also see the Supplementary Materials Video S21).

use in patients with COVID-19, where this is feasible, and disposable VL blades are preferred" [153]. In reality, for practical reasons, DL was still used in certain cases during the COVID-19 pandemic [154–156].

At the very beginning of the outbreak of COVID-19, it was intuitive to use VL in the management of patients with COVID-19, both in emergent and non-emergent tracheal intubation [157–161]. On the other hand, the safety (transmission rate to the airway managers and team members) and efficacy (e.g., first-pass success rate, intubation time, complications) of VL and DL had not yet been validated in COVID-19 cases [162, 163].

When considering the factors (close proximity of operators and assistants to the patient airway, intubation speed, quality of airway view obtained, or degree of hypoxia during the tracheal intubation) it seems intuitive that VL would be superior to DL (if healthcare resource availability is not an issue). Because of extensive clinical experiences with VS, we applied that technique during the COVID-19 outbreak in Taiwan [65–70]. Since 2020, we have been hit by three outbreak waves (**Figure 23**, time points A, B, and C). From April 2022 to June 2022 22 cases called for tracheal intubation in the negatively pressurized isolation wards and 28 tracheal intubations for emergency surgeries in the negative pressure-operating room. All the tracheal intubations were accomplished with VS technique and a plastic shield (**Figures 24** and **25**). Because our staff (anesthesiologists and residents) are proficient in the use of VS technique (**Table 2**), it seems that COVID-19 intubations did not cause extraordinary mental loading, stress, or technical difficulties for the airway managers.

4.5 Rapid sequence intubation

During the COVID-19 pandemic, it was recommended that PPE be worn by airway managers and airways should be secured in a rapid sequence induction (RSI) or modified RSI [154, 157, 159]. The intubation first-attempt and overall success rates were acceptable. It is inconclusive, however, that RSI itself consistently shows better clinical outcomes than not doing so [164–167]. Moreover, combined use of VL with RSI maneuver does not necessarily shows superiority over DL [168–171].

In our hands, the VS technique provided a higher first-attempt intubation success rate with RSI. The intubation time for VS was non-significantly shorter than DL [73]. Since the benefits of cricoid pressure (CP) is not conclusive, usually we conducted RSI without applying CP. It has been reported that BURP does not help, and jaw-thrust is the most effective maneuver to provide better laryngeal view and shorter intubation time [31]. **Figure 26** shows a tracheal intubation performed using VS technique under RSI protocol. **Figure 27** shows a similar RSI-intubation process in a confirmed COVID-19 positive patient undergoing emergency surgery. In both cases, the intubation process was smooth and swift, and the operators felt safe and better protected against virus exposure.

4.6 Double-lumen endobronchial tube

The clinical role of VL on tracheal intubation with double-lumen endobronchial tube (DLEB tube) for thoracic surgeries has been reviewed [172, 173]. For tracheal intubation with double-lumen endobronchial tube, VL was found either to be superior or equivalent to DL [174–179]. When various outcome parameters were used as comparators (e.g., glottis view, time to intubate, first-pass success rate, complications, ease to use), different types of VL might exhibit their own advantages and

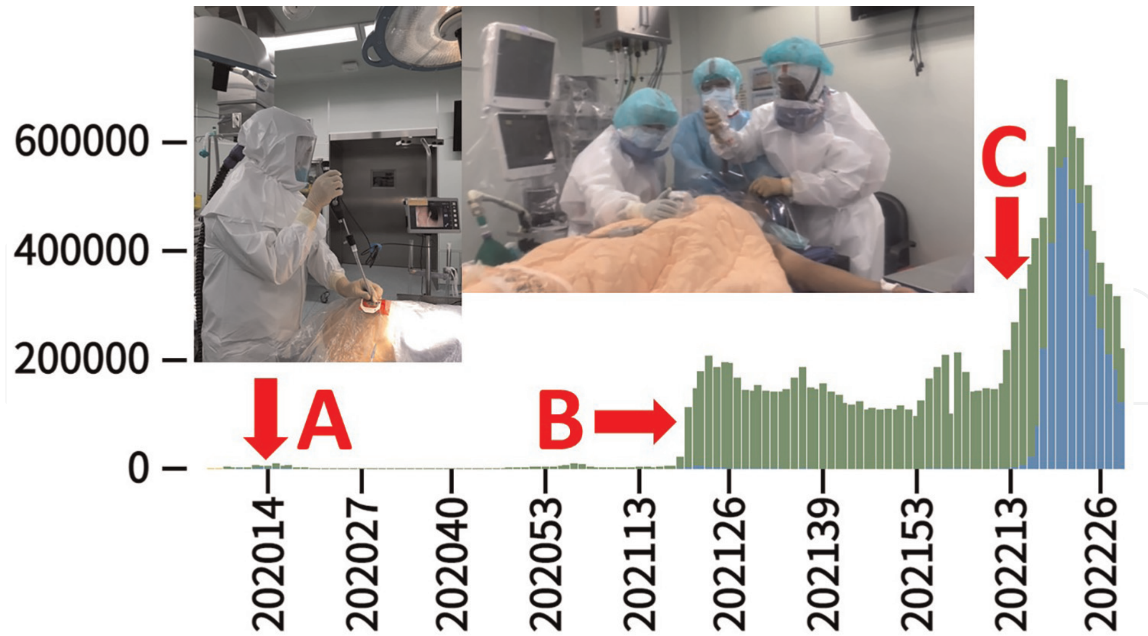

Figure 23.
Application of VS technique to intubate patients at our institute during COVID pandemic in Taiwan. The inset photo (left) shows the operator equipped with PPE intubating with a C-MAC VS (Storz, Germany) in a mannequin simulation model. The inset photo (right) shows the real world when tracheal intubation was conducted with VS technique in an omicron-positive patient. Time point A: February 2020 [65]. Time point B: May 2021 [69]. Time point C: April 2022 [70]. X-axis: The weekly report series number; Y-axis: The patient number. Green and blue colors indicate the surveillance reporting number and confirmed cases number, respectively. Data was modified from Taiwan CDC press release (https://www.cdc.gov.tw/En; data retrieved on July 20, 2022).

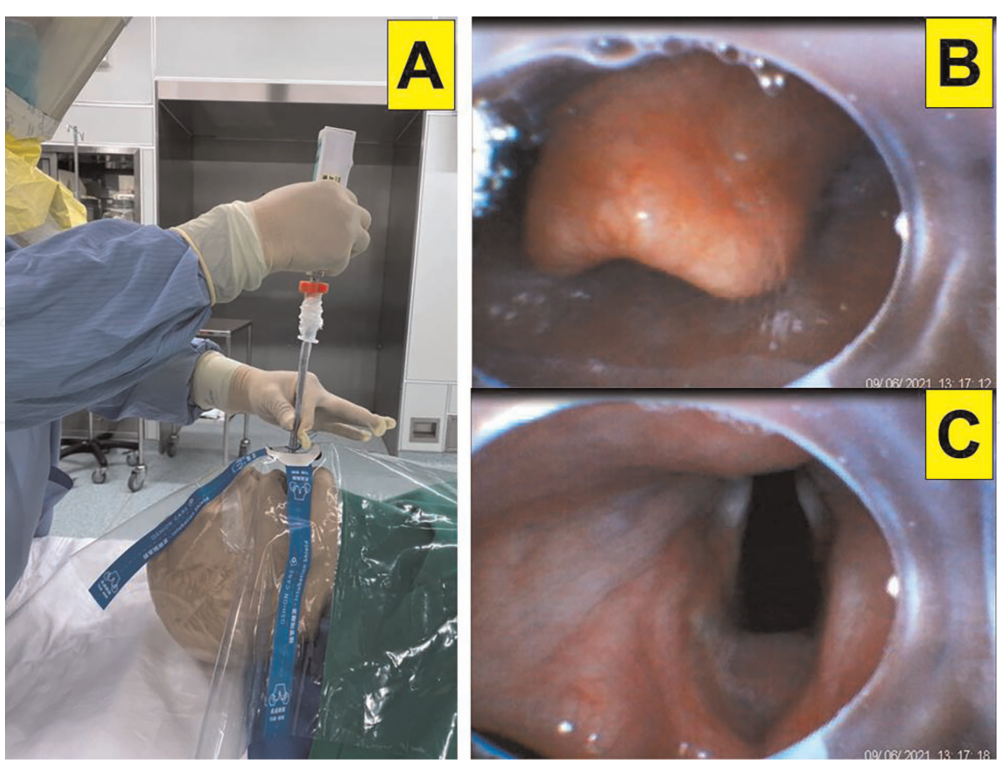

Figure 24.
Combined use of a piece of transparent plastic sheet and VS technique in a mannequin model (A) and in 52-year-old man during COVID-19 pandemic (B and C). The intubation time: 20 s. the detailed technique for this combination method can be seen in the reference [67]. (Also see the Supplementary Materials Video S22).

Figure 25.
Combined use of a plastic sheet barrier and VS technique in an omicron-positive patient undergoing emergency neurosurgery for intracerebral hemorrhage. This is a 77-year-old woman (BMI 23.2 kg/m²) with medical history of diabetes and brain tumor. The airway managers wore PPE and a piece of plastic sheet was used as a physical barrier against possible contamination from the patient's airway. The tracheal intubation was smoothly and swiftly achieved with VS technique. The intubation time is 10 s. (Also see the Supplementary Materials Video S23).

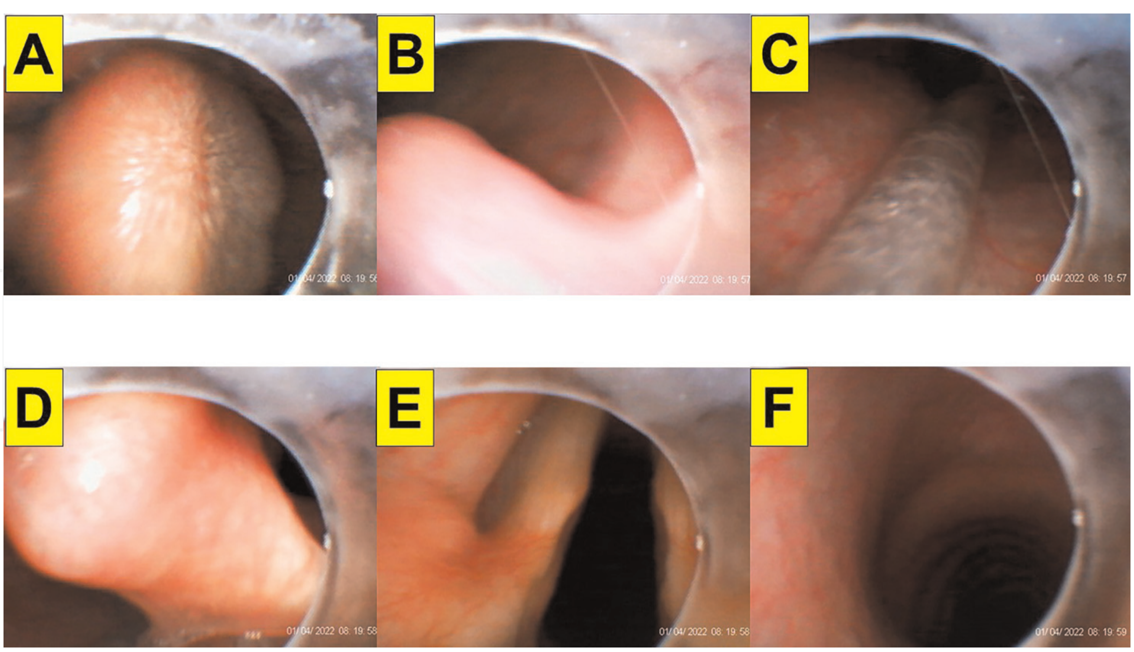

Figure 26.
Application of VS technique with rapid sequence intubation in a patient undergoing emergency abdominal surgery. This 57-year-old man (BMI 26.2 kg/m²) with medical history of duodenal adenocarcinoma (pT4N1) had received a Whipple operation 1 day prior to this emergency surgery. Acute abdominal distention, leukocytosis, and elevated C-reactive protein indicated an intra-abdominal infection. Acute abdominal distention, leukocytosis, and elevated C-reactive protein indicated intra-abdominal infection. Anesthesia induction was conducted using rapid sequence intubation with VS technique. Serial images of oropharynx and larynx (A–C) and glottis-vocal cords-trachea (D–F) are shown. A nasogastric tube is seen in (C). A. The intubation time is 5 s. (Also see the Supplementary Materials Video S24).

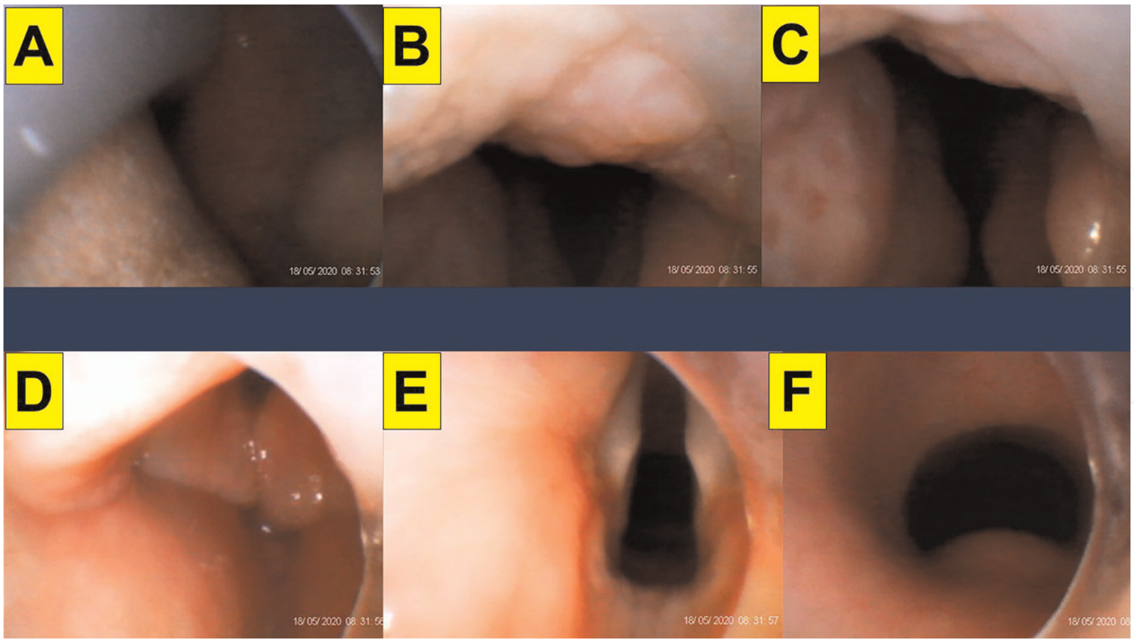

Figure 27.
Application of VS technique with modified rapid sequence intubation in a morbidly obese (BMI 53.3 kg/m², height 150 cm, weight 120 kg) COVID-positive patient undergoing emergency surgery. The intubation time is 7 s. (Also see the Supplementary Materials Video S25).

shortcomings [178, 180]. Not surprisingly, VS technique was alternatively applied for double-lumen endobronchial tube insertion [90, 181, 182]. It was found that VS is quicker, easier, has better glottic visualization, less complications, and was a useful alternative airway tool for placement of DLEB tube. In our single-institute experience, the volume of video-assisted thoracic surgeries using double-lumen endobronchial tube (few using blockers) is about 100 a year. The VS technique has been routinely applied for double-lumen endobronchial tube intubation. **Figure 28** shows such a case. The intubating process is smooth, quick, and with a clear glottis visualization. It should be emphasized that the stick of the VS for DLEB tube intubation should be longer and thinner in order to cope with the design of the DLEB tube.

4.7 Cardiopulmonary resuscitation

It is still a matter of debate whether VL is superior to conventional DL for tracheal intubation during emergency or critical situations. It is generally believed that, if the study outcome parameters are glottis visualization and first-pass success rate, both airway modalities could be equivalent [183–190]. Various factors can come into play including experience, in-hospital/out-of-hospital or emergency room/ICU setting, normal/difficult airway, routine use/rescue alternative, etc. [44, 191–197]. The comparison between VL and DL has been widely conducted [7, 198–202]. Quite often, it was found that VL provides better glottis visualization but does not improve the first-attempt success rate (which is highly experience-dependent) [203]. It is a consensus that uninterrupted, high-quality chest compressions during CPR is crucial to patient outcomes. A "hands-off time" less than 5 s while securing the airway without interruptions of chest compressions during CPR is beneficial for maintaining vital organ perfusion. Meanwhile, during cardiac massage maneuver, it is crucial to avoid unrecognized esophageal intubation [204, 205]. The role of VS has been tested and trained in a mannequin model in the emergency department [206]. Our single-

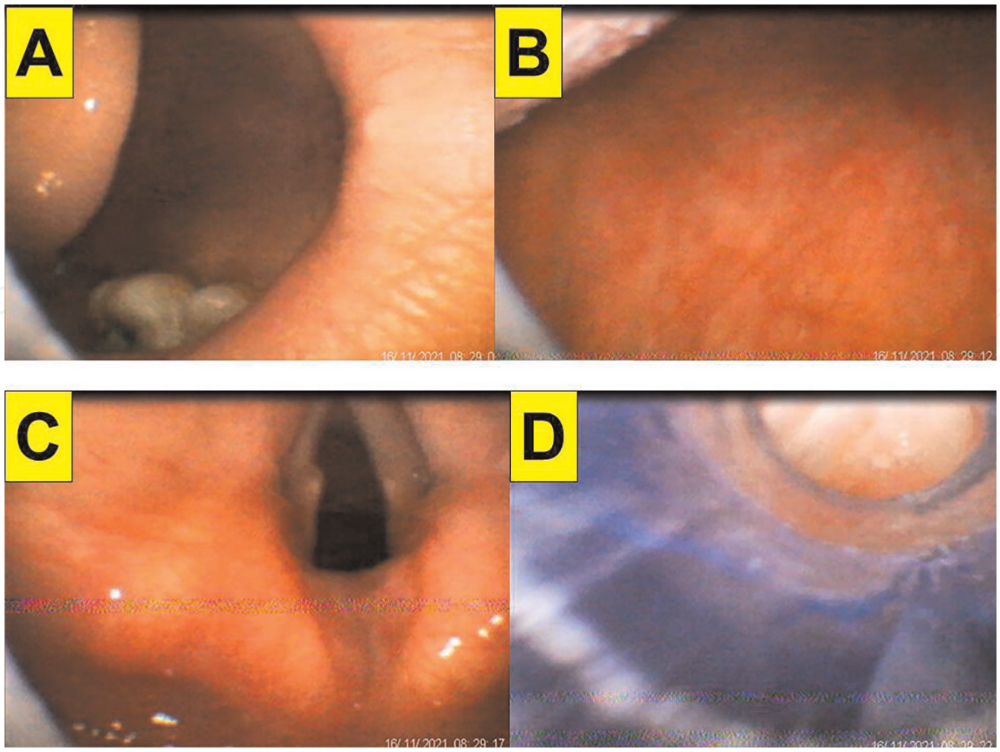

Figure 28.
Application of VS technique for placement of double-lumen endobronchial tube. This is a 71-year-old man (BMI 16.5 kg/m²) who underwent esophageal reconstruction due to esophageal cancer (after definitive concurrent chemoradiotherapy). Although the patient's neck is stiff due to radiation fibrosis, the intubation is 23 s. (Also see the Supplementary Materials Video S26).

institute experience is that we always applied VS technique to rescue failed or difficult tracheal intubation in settings outside the operating rooms (e.g., ER, ICU, general wards, endoscopy room). **Figure 29** shows such an example in a 65-year-old man with terminal lung cancer. During the night shift, this patient was found in cardiac arrest and the night staff called code blue but failed to secure the airway after multiple attempts by non-anesthesiologists. Non-stop CPR was continued for 30 min before the anesthesiologist arrived. **Figure 29** shows the tracheal intubation with VS was completed in 6 s without interrupting the CPR course.

5. Pitfalls and tips

5.1 Learning curve for VS technique

It is intuitive to think that DL is a difficult skill to acquire and, VL must be an easier technique for novice trainees to learn. The studies of the learning protocol in normal airway and simulated difficult airway mannequin model usually results in superiority of VL over DL (e.g., better view; shorter intubation times, higher overall success rate, less dental trauma and esophageal intubation) [207–214]. Meanwhile, practicing may improve DL and VL skill competency and the rating of overall ease of use for DL/VL. Opposite learning results (DL faster than VL) in various simulation teaching programs were also reported [215, 216].

The VS technique has been tried in patients with difficult airway related to limited mouth opening [217]. Furthermore, the VS technique has been compared head to head

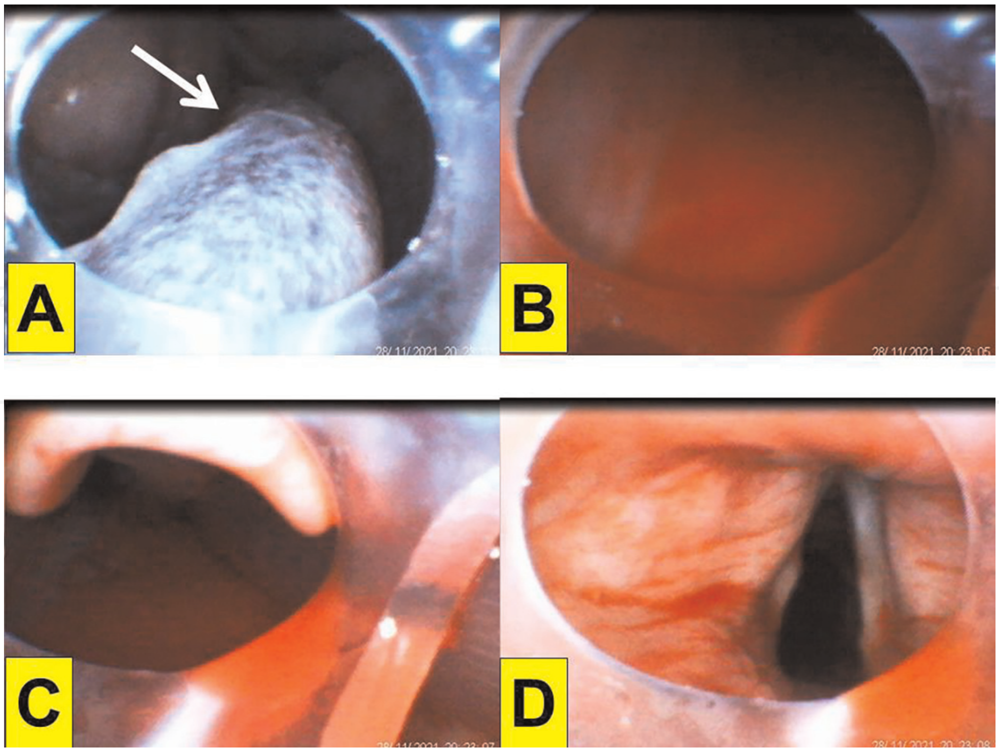

Figure 29.
Application of VS technique for tracheal intubation in a patient who was undergoing cardiopulmonary resuscitation (CPR). This is a 69-year-old man (BMI 24.2 kg/m²) with lung squamous cell carcinoma and tongue squamous cell carcinoma with metastasis. Neck mobility was limited due to prior tumor-wide excision and neck dissection. Code blue was announced due to massive hemoptysis and in-hospital cardiac arrest in this patient. After repeated attempts of tracheal intubation with VL/DL failed, the airway management rescue team successfully intubated the patient using VS technique while CPR was uninterrupted. The intubation time is 6 s. White arrows denote a suction catheter. (Also see the Supplementary Materials Video S27).

with VL in a normal airway vs. difficult airway due to limited mouth opening mannequin-based study. However, in the difficult airway model, VS was quicker to intubate [149, 218]. Similar results were reported when VS was compared with DL [64, 219, 220]. A semi-rigid VS had the advantages of better maneuverability, superior view of the glottis, and shorter intubation time than a rigid VS. However, when compared with VL in real surgical patients, semi-rigid VS was not superior to VL on intubation time and first-pass success rate [221].

The learning curve for proficiency with optical stylets is reported to be from 10 to 20 uses. In real world experience, we found that the learning curve for performing VS technique by novice trainees (interns and residents) is great. Usually, with a reasonable person standard for these learners, they can accomplish the tracheal intubation task in patients with normal airway. The performance on the task is evaluated by their number of attempts. Usually, the number of trials ranges from 1 to 10 (a steep learning curve). It should be mentioned that our novice trainees always receive structured training courses on cadaver and mannequins before performing on actual patients. **Figures 30** and **31** shows the tracheal intubation with VS technique by an intern.

5.2 Mucus, saliva, secretion, blood

All the optical intubating tools are affected by heavy mucus, secretions, liquid, and gross blood. Simple suctioning is effective in removing these contaminants which easily obscure the optic aperture of the stylet (VS) or scope (VL) and prevent

Figure 30.
Application of VS technique for tracheal intubation in a morbidly obese patient (BMI 34.7 kg/m², 167 cm, 97 kg) who underwent percutaneous nephrolithotomy for renal stones. His past medical history includes heart failure due to idiopathic dilated cardiomyopathy, diabetes, hypertension, and he has an implanted cardioverter–defibrillator. Airway management was performed by a competent intern who had a quick learning curve on face mask ventilation and VS technique.

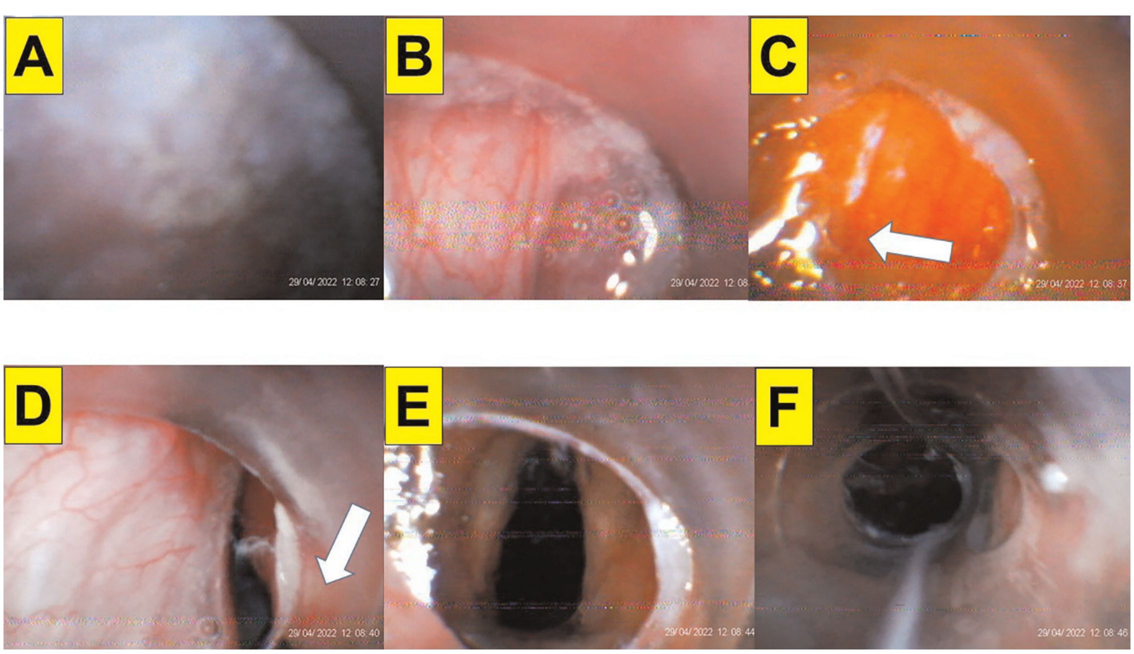

Figure 31.
Application of VS technique for tracheal intubation by a novice trainee (intern). The same patient as in ***Figure 30****. (A) Tongue. (B) Soft tissue. (C) Vallecula (arrow). (D) In front of the epiglottis (arrow). (E) Vocal cords. (F) Entry into trachea. The intubation time is 25 s. Also see the Supplementary Materials Video S28).*

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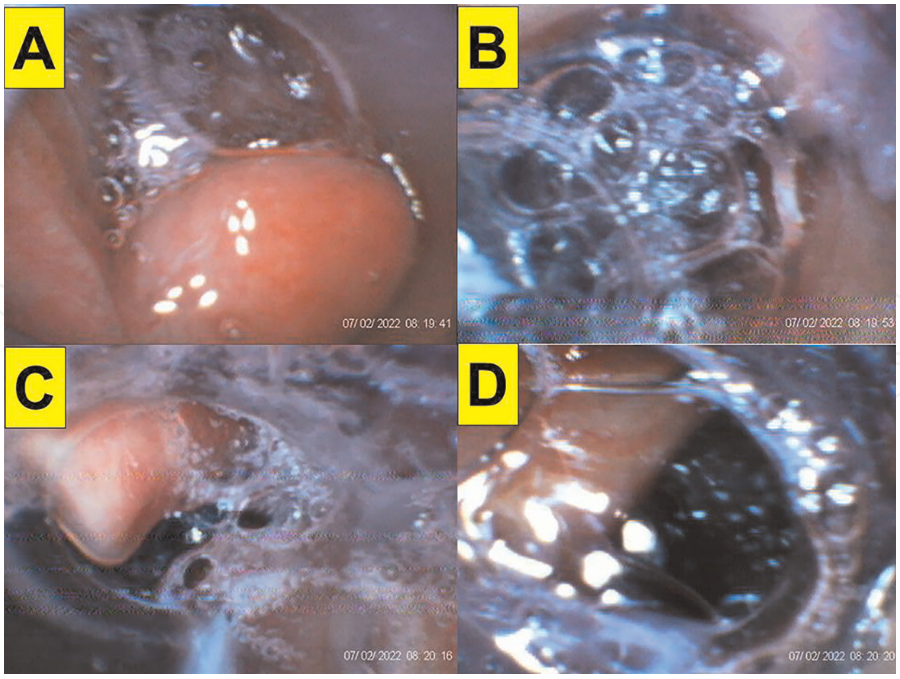

Figure 32.
Application of VS technique for tracheal intubation in a patient with copious secretions in the airway. This is a 65-year-old man with BMI 27.8 kg/m^2. Prior surgical history included cervical spinal laminoplasty (C4-7 stenosis). The intubation time is 42 s. (Also see the Supplementary Materials Video S29).

Figure 33.
A case complicated by copious secretions and bleeding during tracheal intubation. This is a 49-year-old man (BMI 31.8 kg/m^2) with cirrhosis of liver, pneumonia, and respiratory failure. Debridement was performed for gouty tophi and infection in his extremities. (A) The patient was resting in the ward prior to operation. (B) Before induction of anesthesia. (C) After tracheal intubation was accomplished. (D) Mixture of mucus, saliva, and secretions removed from the patient's airway after intubation.

adequate visualization. In addition to good suctioning, some have proposed that oxygen insufflation will help clear secretions and lead to a better view [222].

Prior to induction of anesthesia, we always ask patients to clear their throat by swallowing any saliva. In addition, if not contraindicated, we would give an anti-sialagogue to reduce the secretions. Usually, this is enough to obtain a clean and clear airway for insertion, advancement, and maneuvering the VS inside of the patient's oropharynx. **Figure 32** shows a patient who had copious secretion during tracheal intubation process.

When patients are bed-ridden or in critical or emergent conditions, it is quite common that they have a significant amount of saliva, mucus, and/or blood in their airways. **Figure 33** shows an unexpected worst-case scenario in a patient in critical condition. Prior to VS, it was not recognized that the patient had a huge amount of mixed secretions, mucus, and blood in his oropharynx. When the picture obtained from VS optical lens appeared onto the video screen, nothing was easily identified (**Figure 34**). We were still able to navigate in the oropharyngeal space and advanced the stylet into the glottis eventually (**Figure 34**). In the same patient, after his airway was secured by VS, it was still a struggle to clear the copious secretions to obtain a view by VL of the glottis and ET tube (**Figure 35**).

There are occasional cases with head and neck cancer where FOB is advisable over VS. In such a patient with laryngeal cancer who had received multiple radiation therapies, the mouth opening was limited, the neck was stiff, and the hypopharynx and glottis were swollen (**Figures 36** and **37**). VS was tried after induction of anesthesia (**Figure 38**). However, copious mucus, secretions, and saliva seriously obscured the visualization of the spotted optic lens on the VS. The epiglottis could not be lifted up at all. The airway

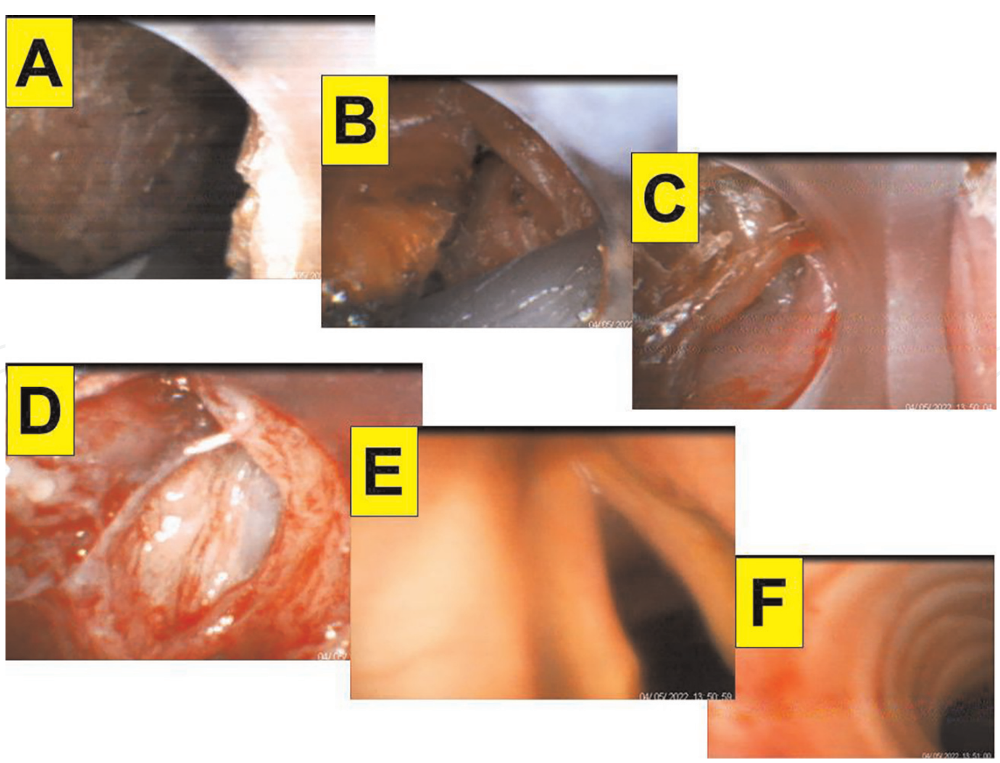

Figure 34.
A case complicated by copious secretions and bleeding during tracheal intubation. The same patient as in ***Figures 33*** *and* ***35****. Serial close-up view from VS camera. A bunch of mucus and blood mixtures were seen and blocked the view for advancement of the stylet (A–D). After struggling, a clear glottis view was eventually obtained (E) and ET tube was successfully secured into trachea (F). The intubation time is 80 s. (Also see the Supplementary Materials Video S30).*

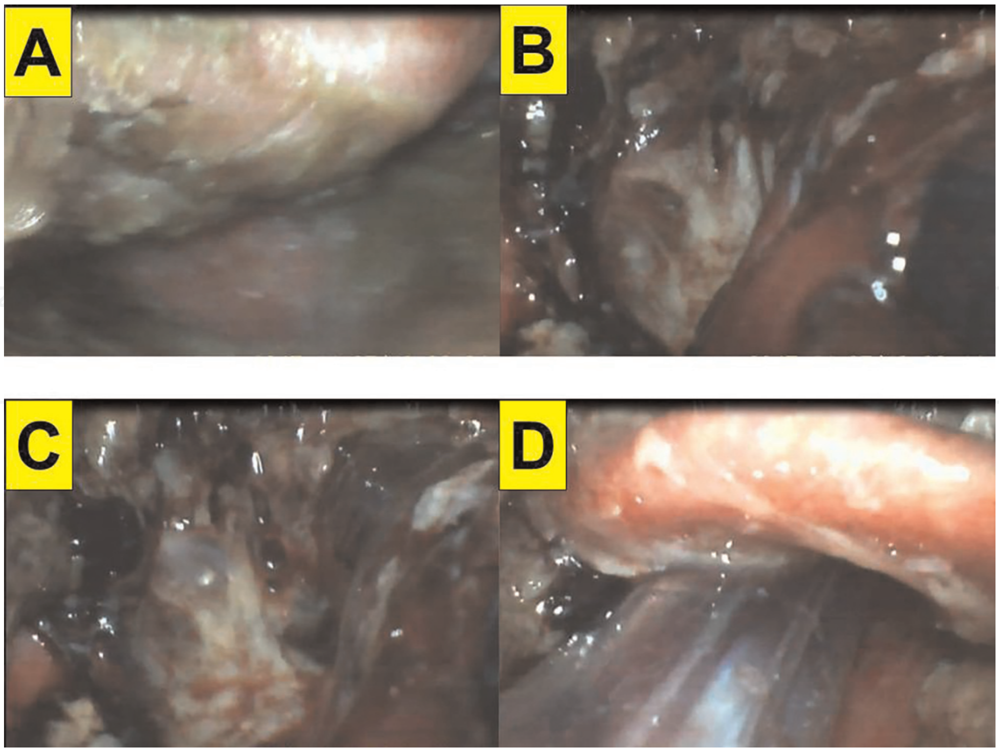

Figure 35.
*A case complicated by copious secretions and bleeding during tracheal intubation (the same patient as in **Figures 33** and **34**). After airway secured by VS, VL was used to examine patient's airway. (A–C) Serial close-up views from VL camera show a bunch of mucus and blood mixtures blocking the view in the patient's airway. (D) After adequate suction, the views became clearer. (Also see the Supplementary Materials Video S31).*

was eventually secured with FOB (**Figure 39**). **Figure 40** shows the intubation images of the same patient during his elective tracheostomy 3 weeks later. Tracheal intubation was performed by FOB. This extreme clinical case should be regarded as the limit of using VS technique in comparison to the conventional role of FOB.

5.3 Video-video paired technique

Combined use of DL/VL with FOB has been a common alternative in certain anticipated difficult airways [223–231]. Similarly, it has also been thought to combine VL and a particular shaped stylet (or bougie-kind of introducer). When lighted or optical stylets became available, it was natural to combine both for tracheal intubation in scenarios like ankylosing spondylitis, morbid obesity, or certain congenital anomalies involving orofacial or head/neck regions. Using an appropriate videolaryngoscopic blade may create better oropharyngeal space and laryngeal views and therefore may reduce stylet use in patients with normal airway [8], but not replace stylet use in morbidly obese patients [123].

In a patient with a difficult airway, after several attempts at laryngoscopy had failed, endotracheal intubation was accomplished by the combined use of a laryngoscope and the Bonfils rigid fiberscope [232, 233]. This successful combo technique involved two airway managers. One used a laryngoscope to displace the patient's tongue to the left ventral part of the mouth and cleared the airway by suctioning. The other one inserted the Bonfils rigid fiberscope, followed the blade of the laryngoscope to the larynx, obtained a good view of the vocal cords, and railroaded the ET tube into the trachea. It was reported the intubation time was 20 s. Although it was not known

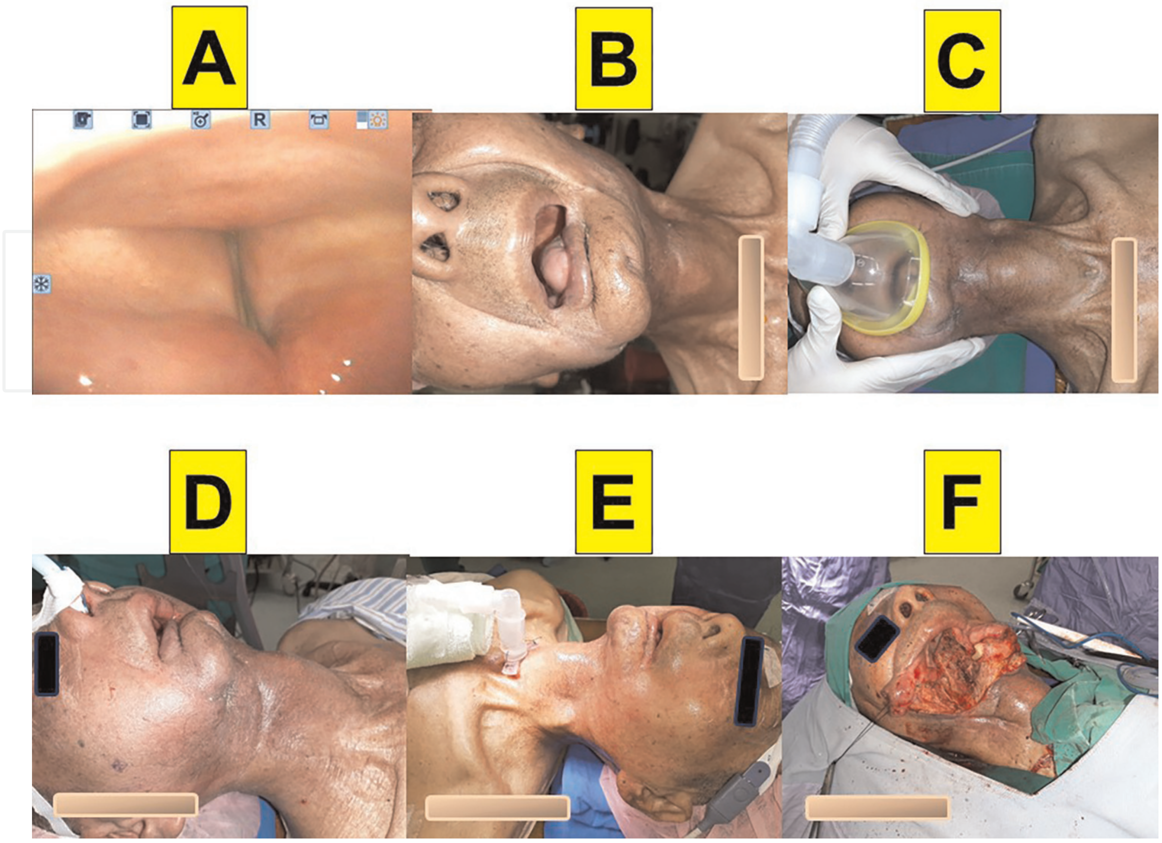

Figure 36.
An extreme and anticipated difficult airway in a patient with mandibular sarcoma. Repeated surgical treatments (tumor wide excision, neck dissection, mandibulectomy, free flap reconstruction) and concurrent chemoradiotherapy were performed. (A) Pre-operative endoscopic examination showed swollen glottis. (B, C) Limited mouth opening and stiff neck due to radiation therapy. The face mask ventilation was adequate to maintain oxygenation. (D) After nasal tracheal intubation using fiberoptic intubation. (E) After tracheostomy. (F) During surgery.

the exact underlying cause for the several failed attempts at laryngoscopy in this patient, successful rescue with VS in 20 s is reasonably acceptable.

The shape of the stylet may affect the effectiveness and performance of VL in patients with normal airways [234]. The combined use of VS and VL has been helpful in patients with normal [235] and difficult airways [14, 34, 35, 236]. While VS has been used as an adjunct to DL/VL, we prefer to reverse the ancillary relationship between VS and VL/DL. Namely, we proposed the DL/VL play an adjunct to VS. The role of DL/VL is to open the airway, create minimal oropharyngeal space, lift up the epiglottis, and finally allow VS to pass through under the epiglottis and acquire a better glottis view. It is worthy to mention that this combination method (VS-VL) has been applied in many difficult cases at our institute. One example involves a patient with mucopolysaccharidosis (MPS) who also had prior C-spine surgery and was receiving a corneal transplantation. He had a limited mouth-opening and flaccid epiglottis which could not be lifted up by jaw-thrust maneuver at all. However, with the aid of VL, tracheal intubation was smooth and swift with VS technique. Another case involved a morbidly obese patient (BMI 56 and 60) who underwent two separate operations (UPPP and bariatric surgery) at our institution. Several attempts at tracheal intubation with various intubation tools failed. With the aid of VL, tracheal intubation was eventually accomplished by VS technique without complications.

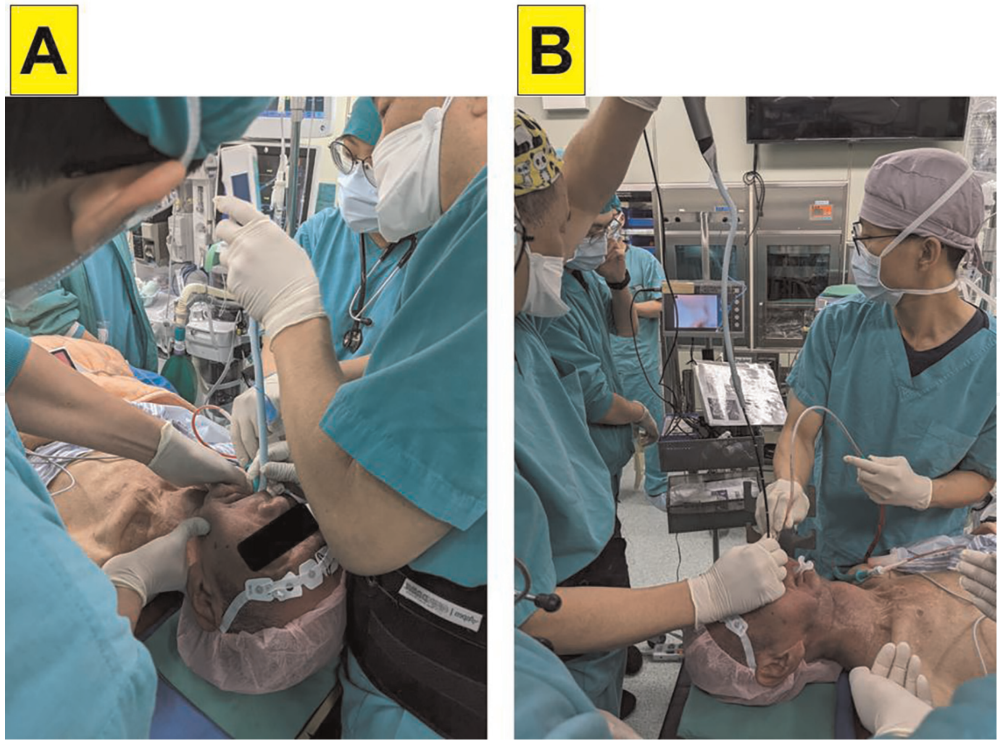

Figure 37.
Adoption of VS (A) and FOB (B) in the same patient as in ***Figures 36–40****. It is noted that, after failure of VS technique, FOB was used to establish nasal tracheal intubation.*

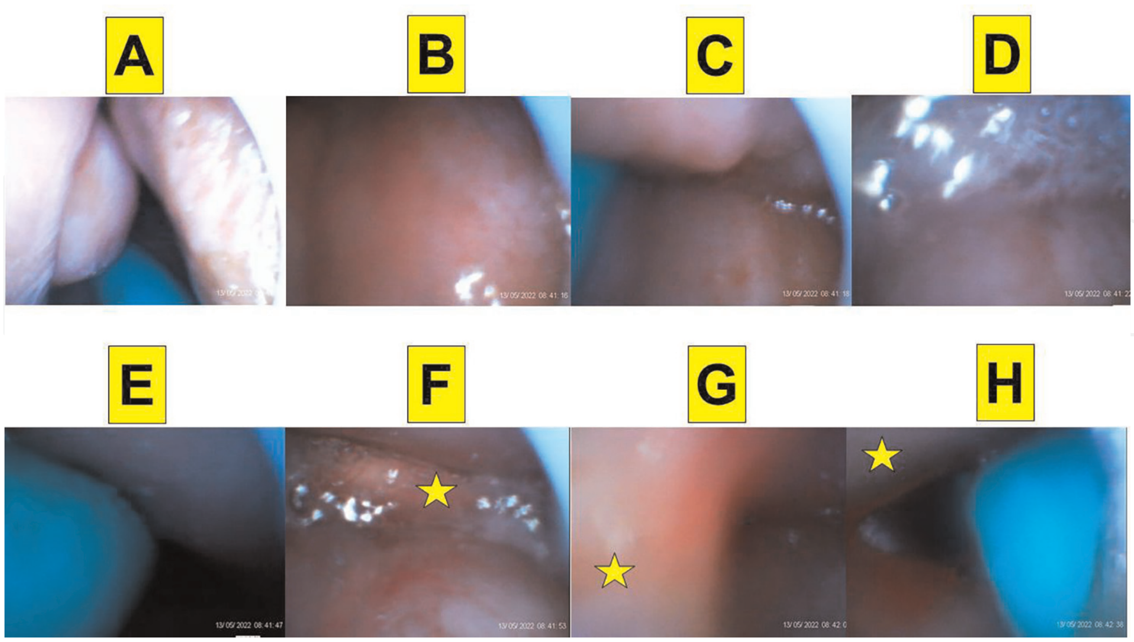

Figure 38.
Serial views from VS camera during tracheal intubation (same patient in ***Figures 36–40****). (A–C) The oropharynx was crowded due to radiation fibrosis of the neck. (D–F) Copious secretions and saliva were noted. The epiglottis (labeled by the yellow star) was firmly attached to the posterior pharyngeal wall when the patient was anesthetized and paralyzed (E–H). The maneuverability of the VS was seriously hindered by the limited mouth opening and rigid neck. Intubation failed after several attempts.*

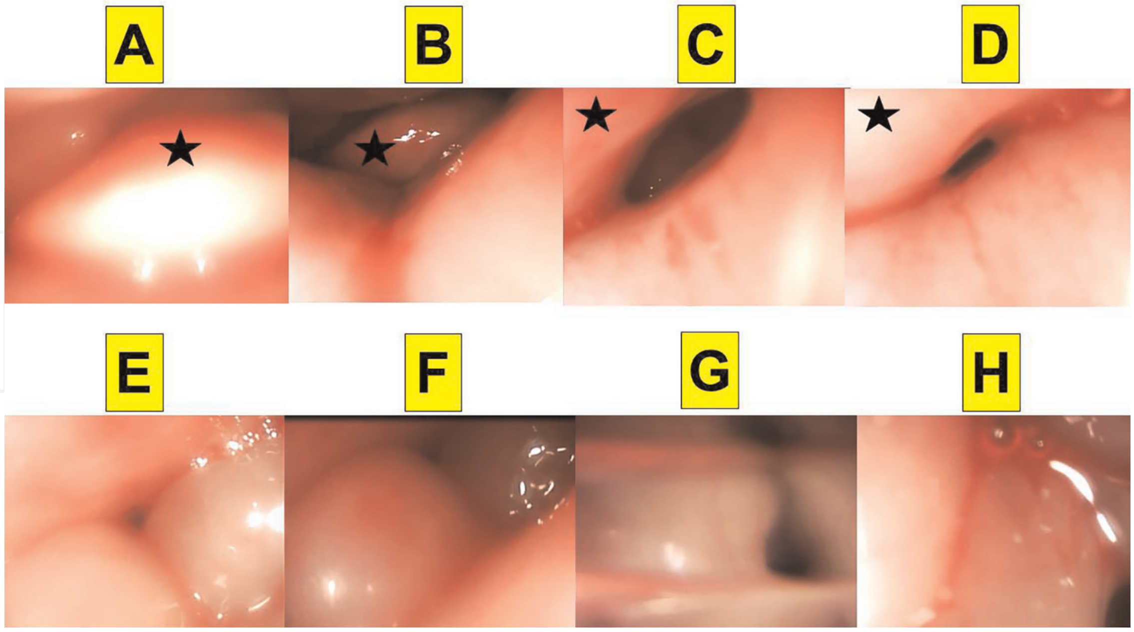

Figure 39.
Rescued intubation with FOB when the patient's controlled ventilation was reverted back to spontaneous respiration. (A–D) The epiglottis (labeled by the black star) was firmly attached to the posterior pharyngeal wall. (C, D) There appeared a tiny slit only when the patient exhaled. The airway operator then took this chance to sneak the FOB tip through this tiny slit and passed under the epiglottis. Subsequent views of swollen glottis (E, F) and vocal cords (G, H). Same patient as in ***Figures 36–40****.*

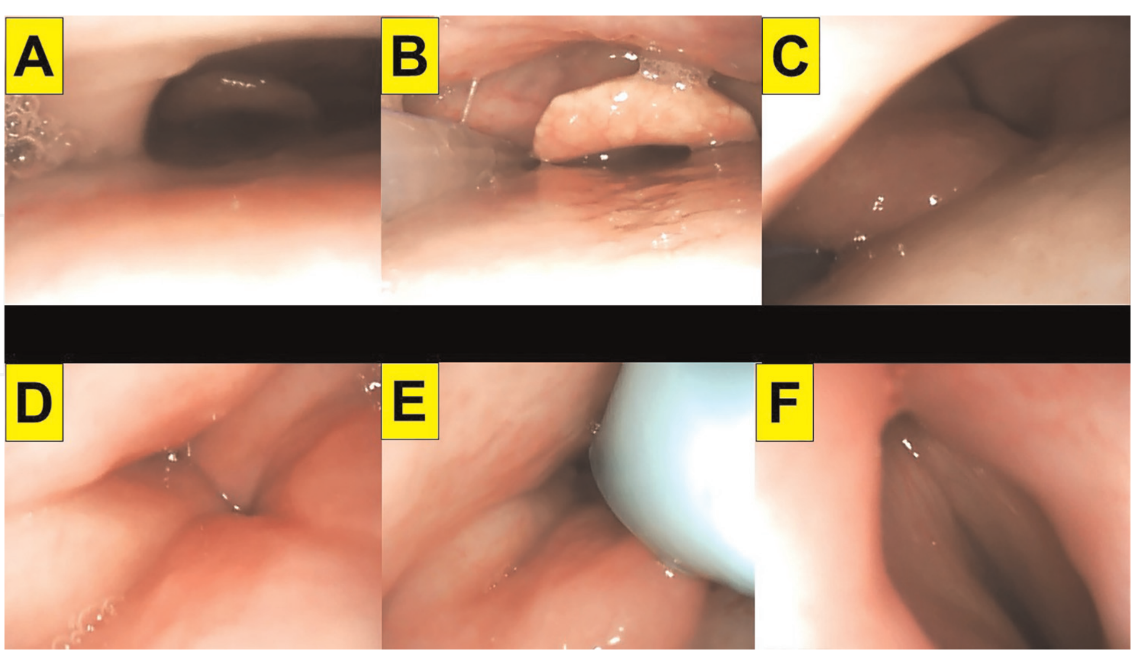

Figure 40.
Awake FOB under light sedation was performed in the same patient 3 weeks later. Elective tracheostomy was scheduled because it became progressively more difficult for the patient to breathe. (A, B) The epiglottis was lying against the posterior pharyngeal wall and there was a very narrow space to allow air to breathe out. A nasogastric feeding tube was seen. (C) A partial view of glottis under the epiglottis. (D) View of closed vocal cords. (E) The tip of a suction catheter was seen and it was withdrawn back later. (F) Vocal cords was in the closed status before the fiber's entry into trachea. Same patient as in ***Figures 36–40****.*

In contrast to previous experiences of using the combined VS/VL technique in difficult airway clinical scenarios [34, 35] and in mannequin models [237], we have routinely applied this technique in normal airways in our daily practice. Included among our routine use of VS-VL for daily practice are cases of intraoperative neurophysiologic monitoring (IONM) during thyroidectomy [238]. The IONM allows confirmation of the functional integrity of the recurrent laryngeal nerve as well as facilitates identification of the RLN before visualization during operations. While VS technique provides an accurate and swift tracheal intubation (e.g., especially in the presence of a giant goiter), VL ensures the contact surface of a specialized EMG endotracheal tube (e.g., Xomed and TriVantage Nerve Integrity Monitoring (NIM) ETTs, Medtronic Xomed Inc., Jacksonville, FL, USA) can been seen and placed in the correct spot between the vocal cords.

Here we demonstrate two cases of using the VS-VL paired technique in patients with normal airways during our routine practice. **Figures 41** and **42** shows a patient with a flat epiglottis and **Figures 43** and **44** shows another patient with an omega-shape epiglottis. Neither epiglottis prevented the convenience and ease of using VS-VL paired technique to intubate.

6. Future perspectives

VL for tracheal intubation has been the norm for tracheal intubation for several decades [50, 239]. Since the introduction of the Shikani video-associated stylet technique for intubation in 1999 [6], numerous commercially available video-assisted intubating stylet products have been brought to market. Some of the advantages of the

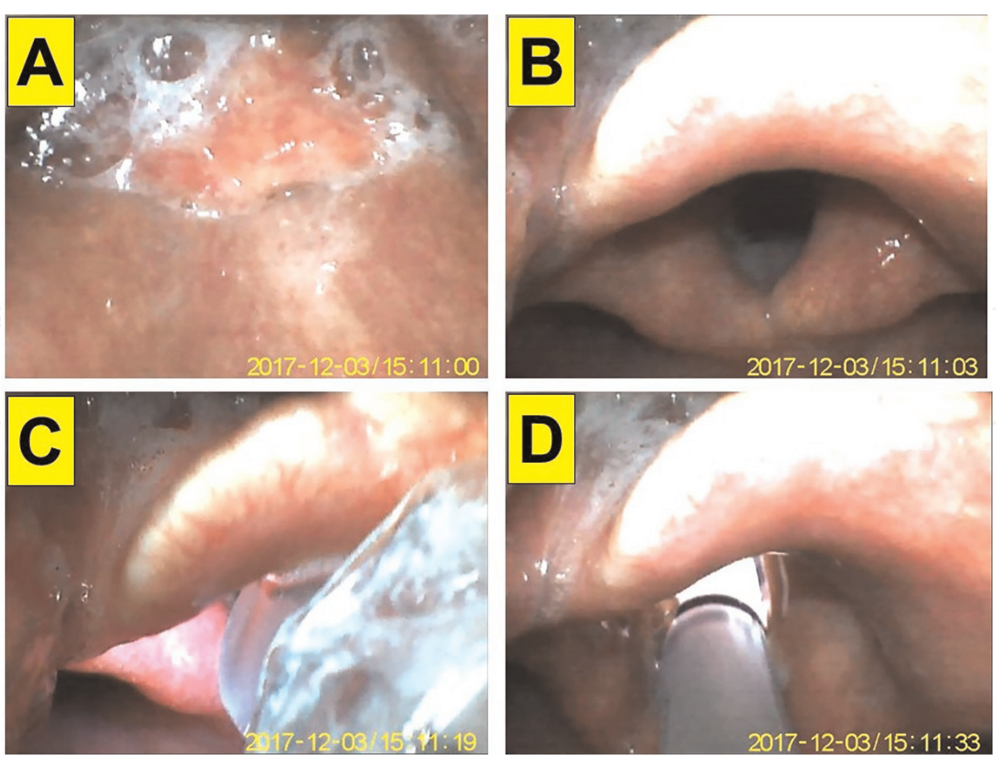

Figure 41.
Video-video paired technique for tracheal intubation. This is a 68-year-old man with BMI 25.9 kg/m². Vitrectomy was scheduled for recurrent total retinal detachment. VL was used as an adjunct to VS. (A) A flat epiglottis. (B) Cormack-Lehane grade IIa. (C) Passage of the VS stylet-ET tube into vocal cords. (D) Entry of the ET tube into trachea. The same patient as in ***Figure 42****. (Also see the Supplementary Materials Video S32).*

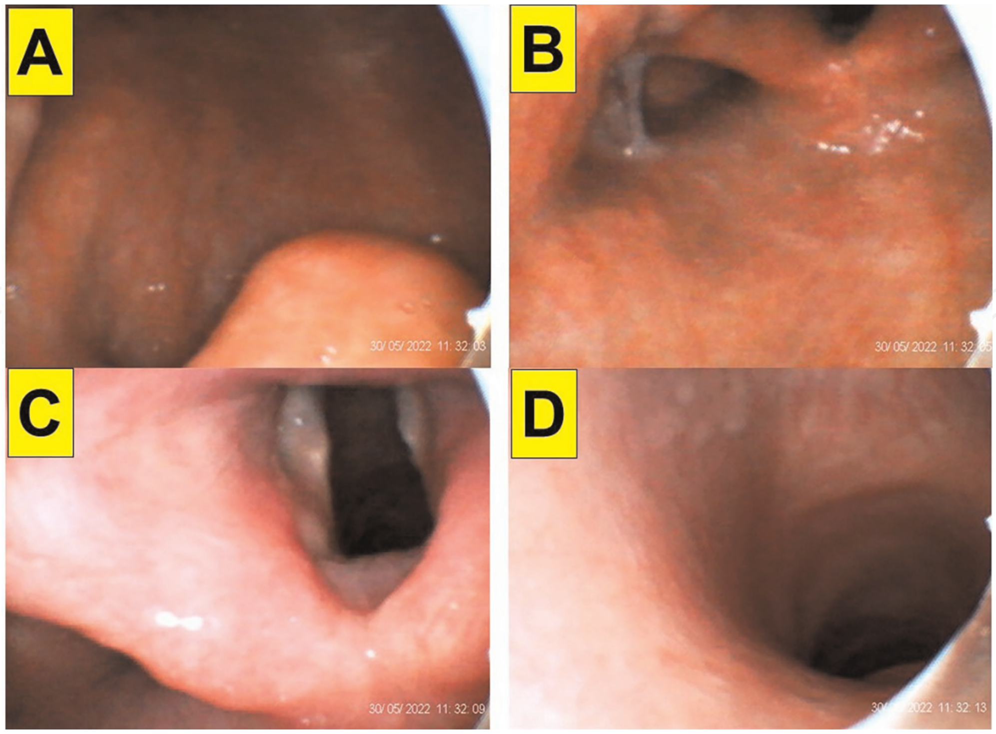

Figure 42.
Views from VS camera. The same patient as in ***Figure 41****. After glottis views were obtained by VL, the VS was inserted and advanced. (A) Oropharynx. (B) Larynx. LQS score grade 1. (C) Full glottis view. (D) Entry into trachea. It is noted that, with the help of VL, the airway is wide open and a perfect glottis view is easy to obtain. The intubation time is 14 s. (Also see the Supplementary Materials Video S33).*

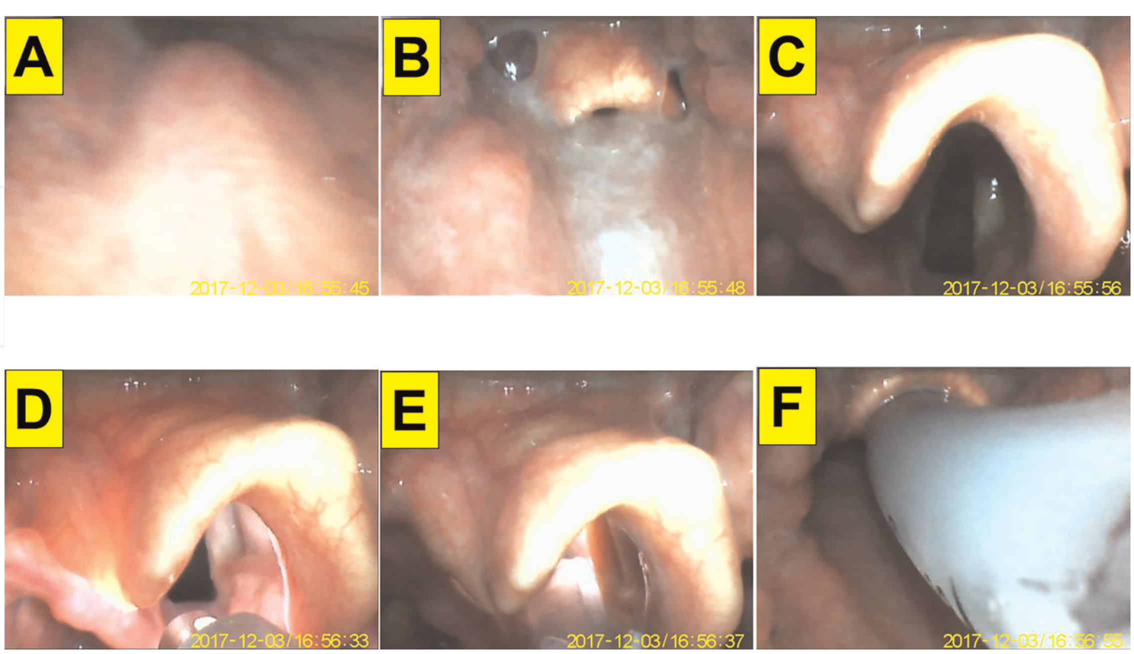

Figure 43.
Video-video paired technique for tracheal intubation. This 68-year-old man (BMI 26.8 kg/m²) underwent a bipolar hemiarthroplasty due to femoral neck fracture. Past history includes lung adenocarcinoma and cervical spine stenosis (C3-6). VL was used as an adjunct to VS. (A) Uvula. (B–E) An omega-shaped epiglottis. (C) Cormack-Lehane grade I. (D, E) Passage of the VS stylet-ET tube into vocal cords. (F) Entry of the ET tube into trachea. The same patient as in ***Figure 44****. (Also see the Supplementary Materials Video S34).*

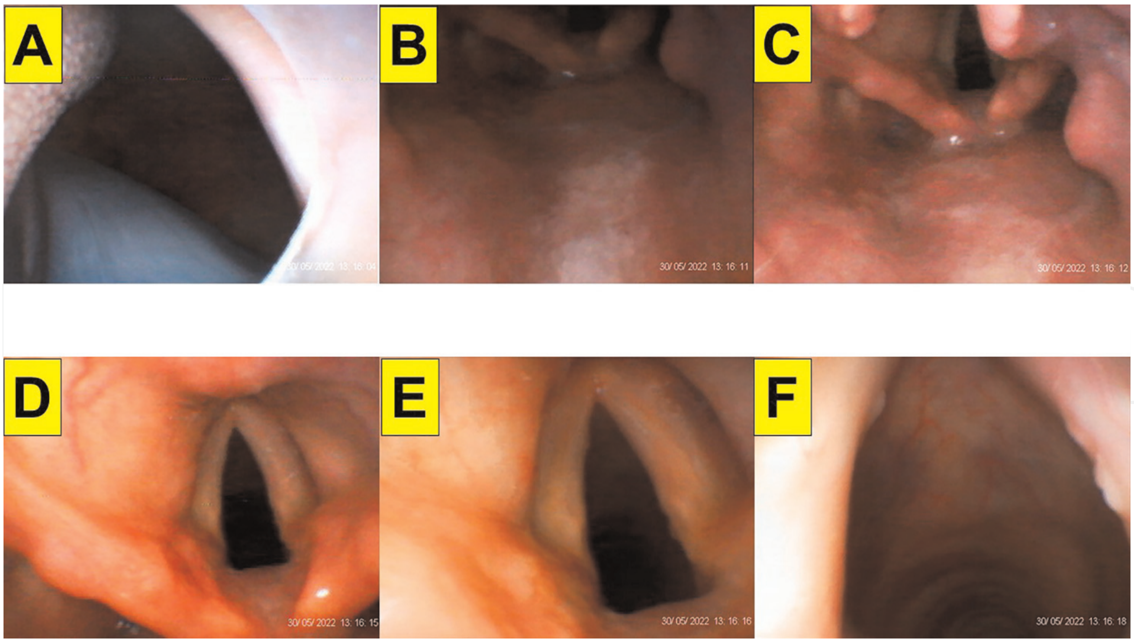

Figure 44.
*Views from VS camera. The same patient as in **Figure 43**. After glottis views were obtained by VL, the VS was inserted and advanced. (A) Oropharynx. (B, C) Larynx. LQS score grade 1. (D, E) Full glottis view. (F) Entry into trachea. The intubation time is 15 s. (Also see the Supplementary Materials Video S35).*

VS technique include maneuverability, better visualization, the ability to negotiate a confined oropharyngeal space, the ability to avoid any trauma to the airway or the teeth, ease of use, and affordability. A high first-attempt success rate, shorter intubation time, and less trauma are additional advantages which lead to less autonomic stimulation. These advantages are why VS has been overwhelmingly accepted and the most prevalent intubating tool in Taiwan since 2016. We hope that this review article will educate intubation providers from various regions of the world and make VS accepted universally. It is still to be determined whether VS will become a first-line technique in the airway guidelines for routine intubations, or whether it will be restricted to more challenging airways situations.

7. Conclusion

In this review article, we presented the application of the Shikani video-assisted stylet technique for intubation in various clinical scenarios and practice settings. In our experience, VS has proved to be an effective and sometimes invaluable method for managing both normal and difficult airways.

Acknowledgements

The author (HN Luk) acknowledged the full support from Hualien Tzuchi Medical Center, Hualien, Taiwan. Special thanks to Professor Dr. Shinn-Zong Lin, MD, PhD, CPI, Fellow of AAAS and AANS.

The authors declare no conflict of interest. Written informed consents were obtained from all the patients (or their legally authorized representatives) for the use of their clinical data in this review article. Patient's privacy and data confidentiality

were protected in compliance with the Declaration of Helsinki and local human research ethics regulations.

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