Review

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Review

Styletubation-The Ultimate Holy Grail for Endotracheal Intubation?

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Abstract

Laryngoscopy technique for endotracheal intubation has been developed and evolved for many decades. Among various conventional laryngoscopes and blades, videolaryngoscopes (VL) have been applied in a variety of patient populations, including certain difficult airways. The safety and effectiveness of VL have been repeatedly and extensively studied in both normal and difficult airways scenarios. The superiority of VL then has been observed, reported, and is advocated as a standard of care and possibly for routine first-line application. In contrast to laryngoscopy, the development of video intubating stylet (VS, also named as styletubation) has been noticed two decades ago. Since then, sporadic clinical experiences of clinical use have appeared in literature. In this review article, we presented our vast use experiences of the styletubation (more than 63,537 patients from 2016 to 2024). We found this technique is swift (the time to intubate: from 3 s to 10 s), smooth (first-attempt success rate: 100%), safe (no airway complications), and easy (high subjective satisfaction and fast learning curve for the novice trainees) in the majority of normal airway scanrios. Even in seemingly and identified difficult airway scenarios, the intubating time is acceptable (e.g., 30 s) with first-pass success. We therefore propose styletubation technique can be feasibly applied as universal routine use for endotracheal intubation.

Keywords: styletubation; video intubating stylet; laryngoscopy; videolaryngoscope; Shikani technique; endotracheal intubation; orotracheal intubation; nasotracheal intubation; airway management; emergency; critical care; intensive care unit; non-operating room anesthesia

1. From Direct to Indirect Laryngoscopy

Conventional laryngoscopy, i.e., direct laryngoscopy (DL) and videolaryngoscopy (VL), has been one of the essential clinical skills for medical staff that green airway manager practitioners must learn quickly and master proficiently since centuries ago (for review, see [1-3]). Laryngoscopy, in addition to other airway devices, has been advocated as the mainstream technique for endotracheal intubation. Such laryngoscopy technique has been widely applied for anesthesia and airway management in the various hospital settings (e.g., operating rooms (OR), non-operating rooms anesthesia (NORA), emergency rooms (ER), intensive care units (ICU), general wards) and field intubation by emergency medical services (EMS) personnel in the pre-hospital setting [4-8]. Meanwhile, it is not surprising that laryngoscopy has always been compared with all the available

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airway management tools in patients under different physiological and anatomical difficult airway scenarios.

The medical purposes (e.g., for diagnosis and treatment) of using DL for ear-nose-throat (ENT) professionals are different from that for anesthesiologists (i.e., for endotracheal intubation and general anesthesia) [9]. Therefore, the functions and the roles of laryngoscope-blade devices for endotracheal intubation have been re-designed and re-shaped by many pioneers since then. Together with such various shape of the laryngoscope blades, the legendary principle of indirect elevation of the epiglottis to optimally expose the glottis and then acquire a perfect visualization was demonstrated [10].

In order to successfully pass an endotracheal tube (ET tube) under direct vision by DL, seven technical tips for endotracheal intubation under general anesthesia have been proposed [11]. Since then, several recommended accessary techniques (e.g., proper head/neck positions, appropriate insertion and lifting of the laryngoscope blades) have been repeatedly demonstrated to be crucial and important to a smooth and successful DL-endotracheal intubation. The learning curve and performance of DL technique by the green airway operators/practitioners, unsurprisingly, appears to be a focused issue consistently [12]. In order to easily acquire an optimal glottis visualization for subsequent placement of the ET tube into trachea, most of the time, a significant upward lifting force on the DL handle-blade unit be required by the airway operator. Such upward lift force may indirectly elevate the epiglottis and expose the glottis in a reasonable way, while such lifting force might also affect or be limited by patient’s cervical spine motion or anatomical structures around head-neck regions [13,14]. Under direct vision with DL, therefore, the incidence of difficult airway (DA) and difficult intubation (DI) occur with varied incidence rates among different clinical scenarios, e.g., 1.41% [15], 4.5% [16], 4.46% [17], 4.7% [18], and 22.3% [19]. Various clinical predictors for difficult laryngoscopy have been reported, such as age, body mass index (BMI), neck circumference, snoring and obstructive sleep apnea (OSA) syndrome, neck mobility, thyro-mental and sterno-mental distance [20,21].

Both the laryngeal exposure and mechanics of actual ET tube advancement, delivery and insertion are important key factors for a successful endotracheal intubation with DL. In contrast to DL, the various commercial product designs of VL have been ingeniously designed and excellently shown to reduce failed-intubation rates and higher first-attempt success rates with comparable or superior glottic visualization [22,23]. For VL, the condition of a direct line of sight based on the conventional three-axes or two-axes alignment theory is not prerequisite to acquire an excellent or optimal glottis view [24,25]. Different types of the laryngoscope blade resulted in different lifting forces acting on pharyngeal and laryngeal tissues [14]. Even so, difficult laryngoscopy incidents may still be encountered by such excellently innovated VL. Several modifiable factors are constantly reported to be related, e.g., head and neck position and provider’s experience [26,27]. Since the invention and application of VL for endotracheal intubation two decades ago, its clinical role as a standard and routine airway modality has been extensively and repeatedly advocated and challenged [28,29]. Recently, VL appears to be a preferable approach for intubating patients undergoing surgical procedures in the operating rooms [30] and among critically ill adults (in an emergency department or intensive care unit) [31,32]. In comparison with the invincible role of flexible fiberoptic bronchoscope (FFB), it is still too early to claim VL be the holy grail of airway management [33].

2. The Quest for the Holy Grail in the DA Management

Although the FFB technique has been considered as the gold standard for DA, it is not too surprising that the combination technique with FFB and VL be advantageous in several DA scenarios [34,35]. Meanwhile, other types of the optic/video devices for endotracheal intubation have emerged onto the airway management, including rigid/semi-rigid optical stylets [36,37]. It is also interesting to note that a lightwand design (Trachlight) has been invented and proved to be a useful alternative for endotracheal intubation [38-40].

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Rigid stylet scopes are reported as a useful alternative to flexible fibreoptic scopes for predicted or unpredicted difficult airway management [36; 41-44]. Currently, there are more than 20 similar kinds of video intubating stylets (VIS) available and affordable in the market (**Figure 1**). The sale price of each kind of such VIS products ranged from few hundreds to thousands of US dollars.

Since 2016, we have systematically implemented the styletubation (video intubating stylet technique) (**Figure 2**) for routine and first-line endotracheal intubation [45-49]. In Taiwan, such styletubation technique has ubiquitously been adopted for endotracheal intubation in many medical centers, regional hospitals, and some local private clinics and has been applied in more than a million of patients. In our own clinical utilization experience, the universal use coverage of styletubation is increasing exponentially during these years (**Table 1**). In this review article, we attempt to demonstrate the clinical scope of utilization (styletubation technique), pearls and pitfalls of such intubation technique, and areas for future advancement and research.

Figure 1. The emergence of video intubating stylets onto the airway management tools market. The basic structures of such optic intubating devices include a video monitor, handle, and a J-shaped (or hockey stick-shaped) semi-rigid/rigid stylet.

Figure 2. The styletubation (video intubating stylet technique for endotracheal intubation). Left panels: (upper) Video intubating stylet with a endotracheal tube (ET tube); (middle) The ET tube is mounted onto the intubating stylet with/without a stopper; (lower) The tip of the intubating stylet contained a high-resolution CMOS camera lens and LEDs light source at the tip of the malleable intubating stylet and connected to a detachable video

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monitor. The resolution of the acquired image is perfect. It should be emphasized that the video intubating stylet is situated inside the ET tube. Right panel: Six different commercial products of video intubating stylets are ubiquitously available in each operating room in our department.

Table 1. Universal use coverage of styletubation technique for routine first-line tracheal intubation in the Department of Anesthesia, Hualien Tzuchi Medical Center, Hualien, Taiwan between 2016 and 2024.

	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total anesthesia number	16077	17831	17998	19307	19721	19244	19765	22438	25046
GA number	15339	16893	17497	18481	19009	18574	19061	22099	24368
LMA-GA number	5544	5134	5816	5902	5863	5714	4932	5763	6585
ET-GA number	5953	6504	6920	6966	7418	6982	7602	8329	8889
VL	0	0	20	100	635	336	305	280	350
Styletubation	**5953**	**6504**	**6900**	**6866**	**6783**	**6646**	**7297**	**8049**	**8539**

GA: general anesthesia. LMA: laryngeal mask airway. ET: endotracheal tube. VL: videolaryngoscope. There are 19 operating rooms in the surgical theatre. The anesthesia team is composed of 16 anesthesiologists and 65 certified registered nurse anesthetists.

3. Technical Evolution of Styletubation

Figure 3 demonstrates an evolution from DL to VL, and eventually to styletubation since last century. **Figure 3A** displays a fact that direct inspection and good visualization of the vocal cords have been the major issues for the airway managers (i.e., laryngologists, anesthesiologists, and others) for years when DL is generally applied. Anticipated and unpredicted difficult and even failed laryngoscopy and intubation might be more than often encountered. The successful performance of DL technique itself, therefore, might take very much long time to describe than to proficiently carry out and, is basically claimed to be a not-difficult maneuver if certain simple straight anatomical rules (e.g., sniff position) are obeyed in anesthetized patients [11].

In the real world, “a good endotracheal intubation” with DL by airway novices/trainees required a relatively slow learning curve (e.g., more than 47 attempts) and several criteria are required for success (e.g., proper insertion and lifting of the laryngoscope, in addition to proper sniff position) [12]. Fortunately, with the invention of VL (**Figure 3B**), a consistently comparable or even superior glottic view compared with DL was observed, despite the limited or lack of prior experience with the device [28]. Most important, successful intubation was generally achieved even when DL was expected to be moderately or considerably difficult. Nevertheless, expertise in VL skills and competency may require prolonged training and practice [50].

As mentioned earlier, a semi-rigid intubating stylet (a hockey-stick type of seeing-stylet scope) for endotracheal intubation appeared even before invention of VL [36]. It should be noted that such new seeing-stylet scope was proposed to be used for management of difficult airway in both adult and pediatric patients by improving the maneuverability of the stylet-ET tube unit and a better glottis visualization. In addition, without the need of a rigid laryngoscope blade to retract the tongue base, the risks of airway injuries would be minimized. Later, such styletubation was also demonstrated to be an effective instrument for orotracheal intubation in normal subjects, including retromolar approach [42,51]. **Figure 3C** shows such performance of such styletubation technique in the real world operation. In comparison to the DL and VL, the styletubation shows more advantages and superiority, including the extremely high first-pass success rate, shortest intubation time, strong subjective easiness and satisfaction, and particularly fast learning curve.

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Figure 3. Evolution of endotracheal intubation techniques from (A) conventional direct laryngoscopy (DL), to (B) videolaryngoscopy (VL), and to (C) styletubation. In addition to better acquired glottis visualization on the monitor, the styletubation technique can allow the airway operator to keep a safer distance away from the patient.

4. Pearls and Pitfalls of Styletubation

Both conventional midline approach and retromolar approach are the options to perform styletubation. It is noted that the midline approach could provide easier and better glottic exposure and shorter time to intubation when using VL for tracheal intubation [52]. When applying Bonfils intubating fiberscope, it is also proposed to advance the scope via midline until the epiglottis is visualized, in contrast to the originally proposed retro-molar approach [37,42]. Apparently, maintaining a midline position of the intubating stylet-ET tube unit along the oropharyngeal path is much easier for both the beginners and first-line airway managers to visually locate the glottis. In line with this first technical tip for video intubating stylet (e.g., Bonfils-type endoscope) [42], we also adopted such midline approach when standard styletubation for routine endotracheal intubation was conducted. In **Figure 4**, an apparently normal airway scene is sequentially demonstrated when styletubation was routinely applied in the real world practice. The anesthetized patient's mouth was open wide enough and the jaw was lifted up by an airway assistant (**Figure 4A**). Both the patient's hard/soft palate and uvula are easily visualized (**Figure 4B**). While a suction tube was used in advance to clear the secretions along the airway, some might still remain and air bubble formed. Then, the airway operator moved the intubating stylet-ET tube unit forward along the posterior pharyngeal wall until both the tongue base and the epiglottis were eventually observed (**Figure 4C**). In this case, the space between the flopped epiglottis and the posterior pharyngeal wall remained to be wide enough for passage of the assembly. At this point, the operator could easily and gently maneuver the intubating stylet-ET tube set downward, forward, and pass beneath the epiglottis. After the intubating assembly was passing under the epiglottis, the operator needed to lift it up and tilt the tip of the set until the full glottis view could be clearly acquired (**Figure 4D** and **4E**). Finally, the ET tube could be smoothly dislodged from the intubating stylet, advanced forward and placed into the patient's trachea, guided by the centrally located tracheal rings (**Figure 4F**). With these step-by-step tips for midline approach of styletubation, one can easily and smoothly accomplish the endotracheal intubation.

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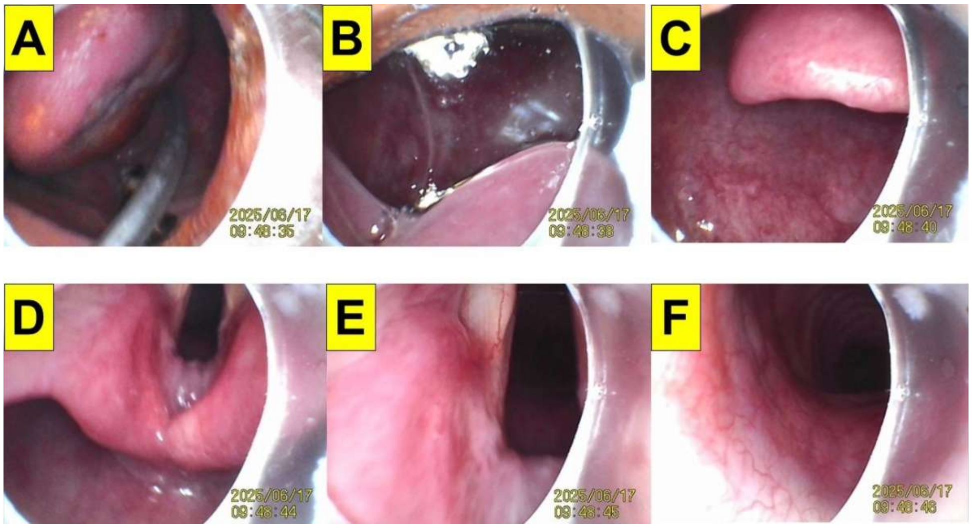

Figure 4. Midline approach of styletubation in a normal airway scenario. A 31-year-old man (body mass index-BMI: 28.0 kg/m^2) underwent reduction of nasal bone fracture and deep complicated facial wound debridement. (**A**) Wide mouth opening. (**B**) Uvula. (**C**) Epiglottis. (**D** and **E**) Glottic visualization. (**F**) Tracheal rings.

The composition of an airway management team for routine anesthesia can be varied, pending on the each individual medical infrastructures and policies of the local medical facilities. When difficult airway was anticipated or unexpectedly encountered during endotracheal intubation procedure, a call-for-help with additional assistants and a team-based approach should be implemented [21,53]. **Figure 5** illustrates three different clinical models to routinely conduct styletubation in the operating rooms and elsewhere clinical settings in the hospital: without (**Figure 5A** and **5B**) and with an assistant (**Figure 5C**). When there is only one airway operator at the scene to conduct endotracheal intubation, styletubation could be jointly performed either with a DL [54-56] or a VL [57-60] to facilitate opening of the airway and exposure of the glottis (**Figure 5A**). In combination of a VL, such double-vision obtained from a VL-styletubation combination technique can help the novice trainee a lot when a difficult scenario or situation was encountered (either expected or un-anticipated DA). Similarly, when styletubation is performed by a lone operator at the scene, one can then adopt the outstanding Shikani technique (**Figure 5B**) [36]. Briefly, the patient is placed in the conventional sniff position before endotracheal intubation proceeded. The operator then grabs the patient's mandible with the non-dominant hand for both mouth-opening and jaw-thrust maneuvers. Once patient's epiglottis is gently and indirectly lifted up by such jaw-thrust maneuver, hopefully, there would be an enough space created between the epiglottis and posterior pharyngeal wall. Then, the intubating stylet-ET tube assembly could be placed between the vocal cords. Finally, the ET tube can be dislodged from the assembly and be advanced into patient's trachea under continuous and direct visualization displayed on the video monitor screen. After that, the intubating stylet is smoothly withdrawn from the ET tube. Then, the operator smoothly advanced and placed the ET tube into patients' trachea at a proper depth. Alternatively and most often, when there is an airway assistant (or a trainee) to help, the main task of this helper is to perform maneuvers of effective jaw-thrust and mouth-opening on the patient (**Figure 5C**). The principal airway operator could then concentrate on performing styletubation in a stepwise manner. The ideal intubating process and sequence would be similar to the presentation in the **Figure 4**.

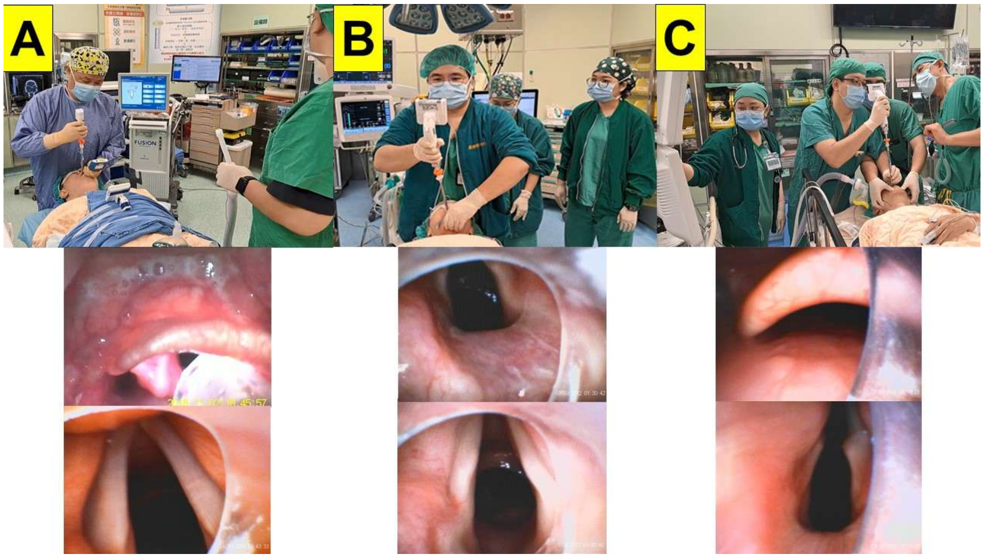

Figure 5. Three common techniques to perform styletubation. Upper panels: Airway operator's gesture & team-based approach for styletubation for trans-oral endotracheal intubation. Middle and lower panels: Video images of epiglottis, glottis and vocal cords. (**A**) One-person model with a styletubation-VL combined technique in a 16-year-old man (BMI: 30.7 kg/m²). Intubating time: 6 s. (**B**) One-person model with the Shikani technique in a 75-year-old woman (BMI: 26.7 kg/m²). Intubating time: 11 s. (C) Two-operator model in a 76-year–old man (BMI: 23.4 kg/m²). Intubating time: 18 s. (Both airway operators are PGY doctors).

The laryngeal/glottic visualization obtained by the laryngoscopy technique has been characterized into various degrees of clarity and subsequently correlated to difficult intubation, e.g., Cormack-Lehane classification [61,62]. Similarly, such laryngeal/glottic visualization acquired during styletubation can also be classified into three degrees (coined as the LQS grading system) [45-49]. Briefly, under the condition of a simple effective jaw-thrust maneuver, patient's epiglottis could be lifted up to certain degree and expose any part of the vocal cords (VC), it is then classified as LQS grade 1. (**Figure 6**, left panels). When no part of VC could be visualized at all, but still there is enough space between the epiglottis and posterior pharyngeal wall created by simple jaw-thrust maneuver, it is then defined as LQS grade 2 (**Figure 6**, middle panels). Both the grade 1 and grade 2 airway scenarios are usually regarded as the soft targets for (experienced or novel trainee) airway operators to intubate. In contrast, when the epiglottis can not be lifted up at all by simple jaw-thrust maneuver and therefore completely lying down against the posterior pharyngeal wall, no part of the glottis opening therefore can be visualized. Such austere scenario is then defined as LQS grade 3 (**Figure 6**, right panels). The grade 3 scenario, although rare and serious, could be difficult but not always impossible to accomplish endotracheal intubation by styletubation. Fortunately, the incidence of LQS grade 3 scenario is very low (< 0.5 %) and commonly occurred in patients with predicted difficult airway scenarios (e.g., limited cervical spine mobility, morbid obesity, radiation fibrosis, pharyngo-laryngeal tumors, etc.).

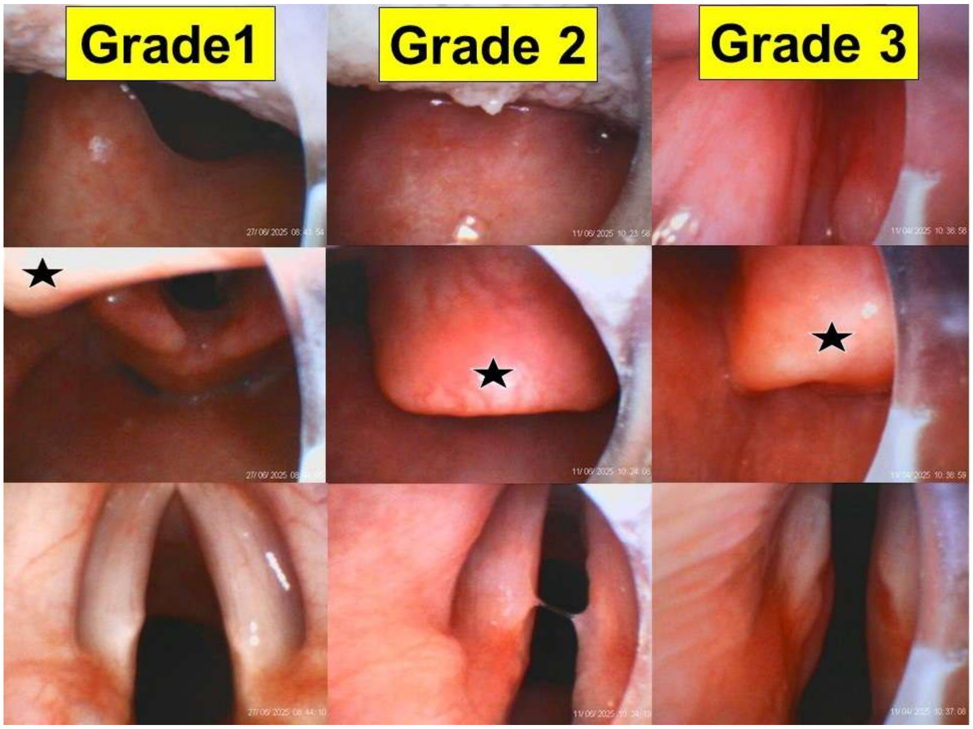

Figure 6. The LQS grading score on glottis visualization by styletubation technique. (**Upper panels**) Grade 1: Able to see any part of the vocal cords through the lower edge of the epiglottis (denoted by the white star) in a 64-year-old woman (BMI: 22.2 kg/m^2). Intubating time: 30 s (for demonstration). (**Middle panels**) Grade 2: None of glottis, except the epiglottis, can be observed in a 17-year-old man (BMI: 23.6 kg/m^2). Still, there is enough space left between the epiglottis and posterior pharyngeal wall to allow the ET tube-stylet set to pass through. Intubating time: 30 s (for demonstration). (**Lower panels**) Grade 3: A 48-year-old man (BMI: 20.5 kg/m^2); upper lip bite test (ULBT): class 2; modified Mallampati scoring (MMT): class IV; neck circumference 35 cm; sterno-mental distance (SMD) 16 cm). The space under the epiglottis is so narrow and restricted that the passage of ET tube-stylet unit appears to be challenging and difficult. Intubating time: 17 s.

When the clinical effectiveness of endotracheal intubation tools (e.g., VL versus DL) was compared, usually the intubation time (i.e., time to intubate) was adopted together with other clinical outcome comparators (e.g., first-pass success rate, total success rate, complications, autonomic nervous stimulation, etc.) [63,64]. The superiority of styletubation over laryngoscopy with a much shorter intubation time in patients with apparent DA has frequently been reported [65,66]. **Figure 7** shows an example of styletubation conducted in a patient with seemingly normal airway during routine endotracheal intubation on daily basis in the operating rooms. The time to intubation (defined as "from lip to trachea") in this patient is only 4 s. It is worthy to mention here that the shorter time to intubation should be only used as an auxiliary outcome parameter in such comparative clinical studies. Namely, the first-pass success rate and subjective easiness are more meaningful clinical outcome parameters. The faster intubation time (e.g., 3 s to 5s) should not be taken as the best quality and safety indicator for endotracheal intubation. Instead, a smooth working flow, including the checkpoint of the signposts along airway path, and final looking around the corner, should be the prime consideration in both normal straightforward airway and predicted difficult airway management. **Figure 8** shows such an example that a smooth and entire check of all the sign posts along the airway before accomplishing the endotracheal intubation within a reasonable and acceptable time frame (30 s in this demonstration).

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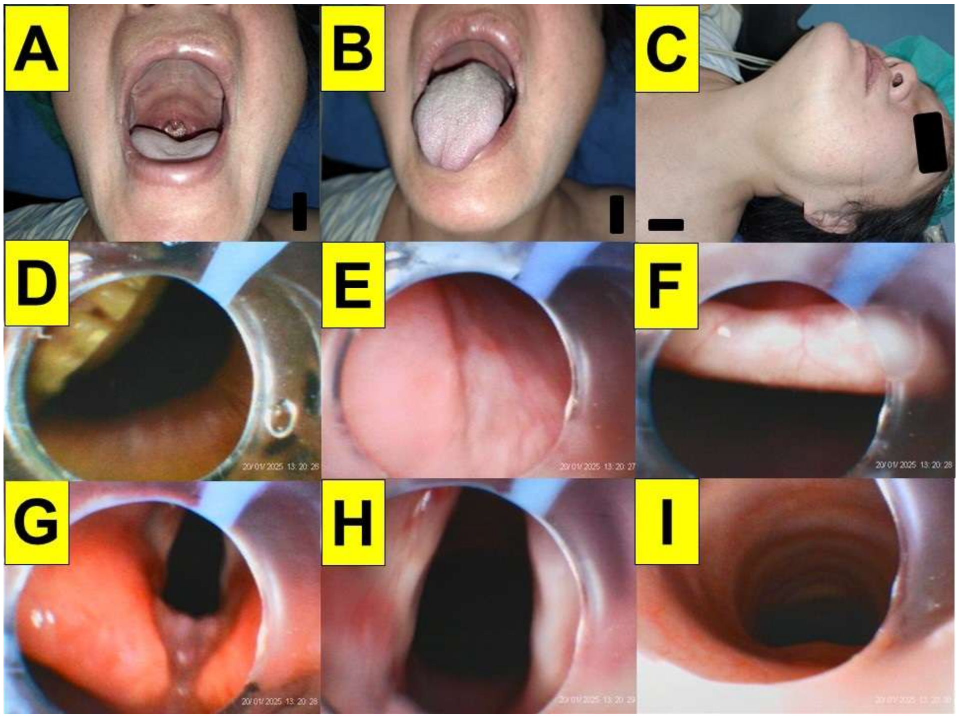

Figure 7. Examples of swift and easy endotracheal intubation by styletubation in normal airway scenarios. (**A**) Intubation time: 4 s. A 48-year-old woman with BMI: 20.5 kg/m^2 and MMC: class II.

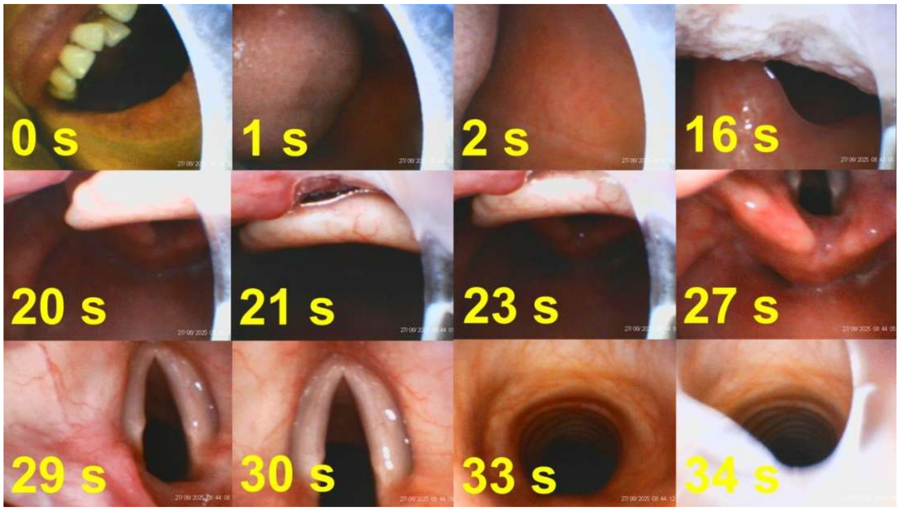

Figure 8. An example easy, smooth and look-around-the-corner process of styletubation. A 64-year-old woman (BMI: 22.2 kg/m^2). LQS grade 1. Time from lip to trachea is 30 s with first-pass success.

Any conventionally trained airway operator might experience or encounter the DA situations on daily basis. Failed to identify DA in advance and without plan-B or even plan-C for emergency airway management can lead to a disastrous outcome [67]. Among all the available clinical tests to predict DA, the upper lip bite test (ULBT) showed the most favorable diagnostic test accuracy properties [68]. The advantageous role of VL in patients with difficult airway, e.g., Pierre-Robin syndrome, has been reported [69,70]. **Figure 9** demonstrates a valid and useful application of styletubation technique in an obese patient with predicted DA scenario. This patient suffered morbid obesity and severe snoring. During styletubation, it is obvious that the collapsed airway, omega-shaped epiglottis, and LQS grade 2 glottis visibility were observed. Enlarged and hypertrophic ventricular folds (i.e., false vocal folds or plica ventricularis, folds of mucous membrane located above

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the true vocal folds in the larynx) were observed to compress the true vocal cords and interfere the opening of true vocal cords (**Figure 9E~9G**). Under styletubation, such hypertrophic plica ventricularis did not cause any difficulties for subsequent endotracheal intubation (**Figure 9H**). The intubating time was 30 s with first-pass success.

Figure 10 shows a patient with difficulty swallowing, hoarseness, and stridor due to concurrent chemoradiotherapy (CCRT) to treat his nasopharyngeal carcinoma (NPC) diagnosed 6 months ago. For this admission, he underwent functional endoscopic sinus surgery (FESS) under general anesthesia. The styletubation was smooth, and with first-pass success (intubating time: 38 s), even the patient's upper airway structures were so edematous and swollen that glottic visualization was almost impossible (**Figure 10D~10G**). The percentage of glottic opening (POGO) was zero (**Figure 10H**).

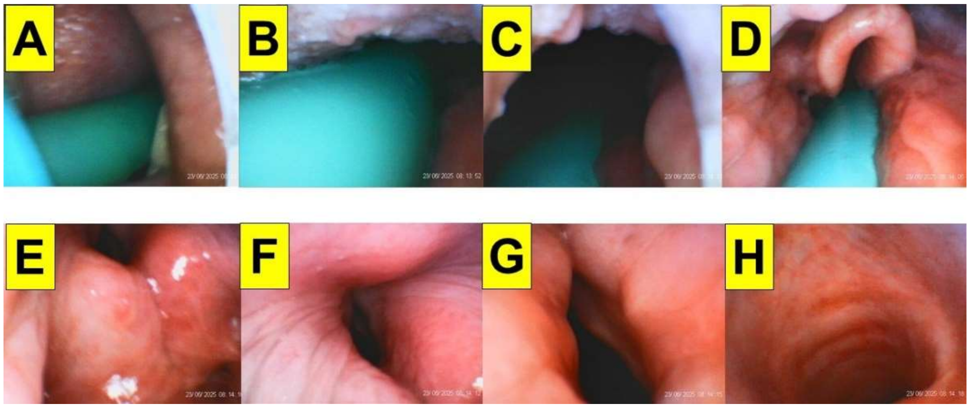

Figure 9. Application of styletubation in a morbid obesity patient. This is a 46-year-old man with a BMI 55.4 kg/m^2; MMC: class II. ; inter-incisor distance 4.5 cm; neck circumference 53 cm; sterno-mental distance (SMD) 15 cm; with OSAS history. (**A~C**) Narrow oro-pharyngeal space; (**D**) An omega-shaped epiglottis; (**E~G**) glottis visualization with plica ventricularis; (**H**) Tracheal rings. The nasal airway-suction tube assembly (in green color) was applied to clear the secretions and as a guide for subsequent styletubation. The intubating time was 30 s with first-pass success. .

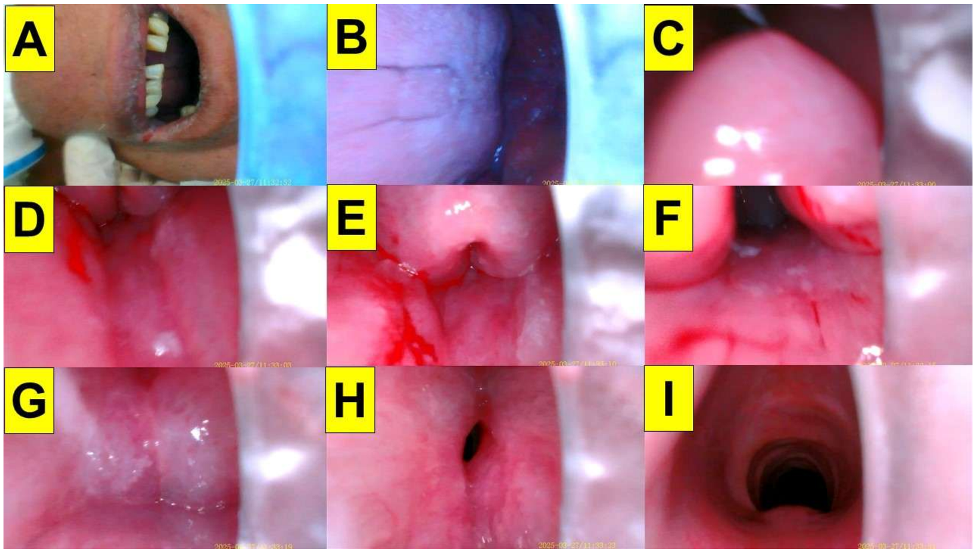

Figure 10. Usefulness of styletubation technique applied in a DA scenario. A 61-year-old man underwent bilateral functional endoscopic sinus surgery (FESS) under the impression of sinusitis and nasal polyps. He was diagnosed of nasopharyngeal carcinoma (NPC) with cT3N1M0 and completed concurrent chemoradiotherapy (CCRT) 6 months ago. Hoarseness, difficulty swallowing, severe neck stiffness and moderate stridor were noted after this admission. (**A & B**) Limited mouth-opening and tongue size. (**C**) Swollen uvula. (**D**) Narrow

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pharyngeal space. (**E**) Swollen folded and omega-shaped epiglottis. (**F** & **G**) Jaw-thrust maneuver could only lift up the epiglottis to a mild degree and only a culvert-shaped space was created. (**H**) Swollen glottis, a tiny glottic aperture, and no clear true vocal cords were observed. (**I**) Tracheal rings. Intubation was swift and smooth (38 s) with first-pass success.

Figure 11 shows the clinical performance and applicability of the styletubation in a variety of DA scenarios. **Figure 11A** shows a 26-year-old man (158 cm, 52 kg, body mass index [BMI] 20.8 kg/m^2) with giant cemento-ossifying fibroma. The tumor was extensive (14 cm × 11 cm × 10 cm in size) and invaded the left eye, nose, paranasal sinus, maxilla, and oral cavity, the flexible fiberoptic intubation through the nasotracheal path was impossible. An awake surgical tracheostomy was refused by the patient as the first choice. After careful evaluation of the airway and ventilation status, oral tracheal intubation with the styletubation technique was performed and succeeded (intubating time: 24 s).

Moderate to severe OSA and tonsillar hypertrophy/enlargement are reported to be associated with high risk of DA [71-73]. **Figure 11B** shows a man (BMI 32.1 kg/m^2) of grade-3 tonsillar hypertrophy and OSAS (obstructive sleep apnea syndrome) for tonsillectomy and uvulopalatopharyngoplasty (UPPP). Styletubation for oro-tracheal intubation was performed smoothly and effectively in this patient (intubating time: 20 s). In **Figure 11C**, a 42-year-old woman (BMI 28.8 kg/m^2) displayed prominent (buck) teeth with poor ULBT grade underwent laryngomicrosurgery (LMS) for removal of vocal polyps. In contrast to the potential dental injury by laryngoscopy [74,75], the buck teeth or receding chin (retrognathia) did not cause any difficulties for the performance of styletubation (24 s).

In obese patient populations, DA has been expected due to their unique predictive parameters (e.g., MMT score, thyromental distance, ratio of neck circumference/thyromental distance) [76,77]. Single or in combination of these DA risk factors have been regarded as more predictive than their individual counterparts. **Figure 11D** demonstrates the application of styletubation in an obese patient undergoing bariatric surgery (a 41-year-old woman with BMI: 64.0 kg/m^2). The short sternomental distance (SMD) and grade-3 Cormack-Lehane glottis exposure did not cause any difficulties and neither prevent the smooth and easy performance of styletubation in such patient (intubating time: 11 s). Ankylosing spondylitis might affect cervical spine mobility and caused DA during laryngoscopy [78-81]. **Figure 11E** shows a 61-year-old man with BMI: 27.4 kg/m^2) with ankylosing spondylitis (AS) underwent LMS due to hypopharyngeal carcinoma. The intubation process was smooth and easy (intubating time: 30 s), similar to the results in the previous clinical reports [82].

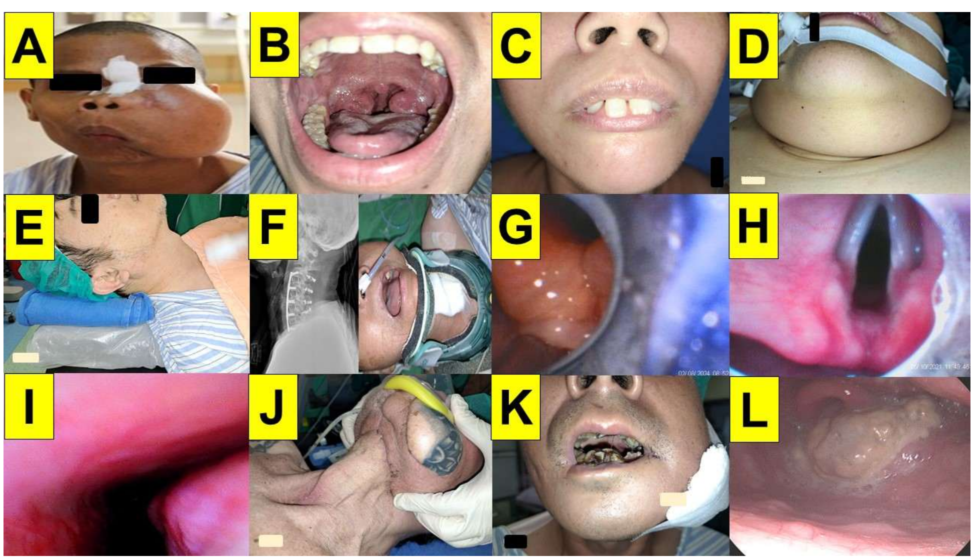

Figure 11. Application of styletubation in various DA scenarios. (**A**) Giant cemento-ossifying fibroma. Intubating time: 24 s. (**B**) Bilateral tonsillar hypertrophy, grade 3 and OSAS. Intubating time: 20 s. (**C**) Buck teeth. Intubating time: 24 s. (**D**) Obesity with OSA undergoing bariatric surgery. Intubating time: 11 s. (**E**) Ankylosing spondylitis

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undergoing LMS. Intubating time: 30 s. (**F**) Restricted cervical spine mobility with cervical collar. Intubating time: 12 s. (**G**) Double-lumen endobronchial tube intubation. Intubating time: 24 s. (H) Pediatric endotracheal intubation. (I) Naso-tracheal intubation in a patient with jaw necrosis. Intubating time: 30 s. (**J**) Retromolar approach of styletubation in a patient with prior buccal carcinoma and reconstruction flap. Intubating time: 20 s. (K) Trismus in a patient with lower gum cancer. Intubating time: 10 s. (L) Hypopharyngeal cancer. Intubating time: 38 s.

Similarly, restricted cervical spine mobility occurred in those undergoing cervical spine surgery wearing cervical collar and regarded as a difficult airway scenario (**Figure 11F**). The performance of styletubation was smooth and swift as expected in this 64-year-old womant (BMI: 24.6 kg/m²; intubating time: 12 s). It should be mentioned that the roles of VL in the difficult airway scenarios involving morbid obesity-bariatric surgery and severely restricted cervical spine mobility has already been long discussed [83-89]. In contrast, the performance of styletubation in scenarios has only recently been called into attention [90-96].

The roles of VL for placement of a double-lumen endobronchial tube (DLEBT) for one-lung ventilation have long been discussed [97-101]. It has also recently been demonstrated that styletubation is useful for such clinical purpose [102-105]. We also applied styletubation as a routine first-line intubating modality for such DLEBT intubation for one-lung ventilation on daily basis. **Figure 11G** shows that a 35-Fr DLEBT was placed with styletubation technique in a 47-year-old woman with BMI: 18.0 kg/m² underwent single-port video-assisted thoracoscopic surgery. The intubating time was 24 s.

During pediatric airway management, it has been known that multiple intubation attempts and persistence with DL for endotracheal intubation are the serious risk factors for related complications in children with DA events [106,107]. Although the beneficial roles of VL have continuously been demonstrated in certain adult patients, such superiority over DL has not consistently been demonstrated in pediatric patients [108]. Even with improving glottis visualization in pediatric patients without predicted DA, VL is at the expense of prolonged intubation time and increased failure rates in comparison to DL [109]. Interestingly, in pediatric patients with DA scenarios, VL had the same intubation failure rates and intubation time as DL [110]. In neonates and infants, VL with standard blades in combination with supplemental oxygen might have better first-attempt rate of tracheal intubation than the performance of DL [111,112]. Similar beneficial effectiveness (higher first-attempt success rates) of VL for urgent intubation of newborn infants was observed [113]. Amazingly, the video stylet technique has long been applied in pediatric patients [36,114]. Such styletubation technique has been routinely applied in the pediatric patient populations in our medical institution. **Figure 11H** demonstrates such an example (An 11-year-old boy with BMI: 16.2 kg/m² underwent emergency laparoscopic appendectomy). Intubating time was --- smooth with first-pass success.

In anesthetized adult patients who underwent dental, oral, maxillofacial, or head and neck cancer surgery, the advantages of use of VL for nasotracheal intubation include a shorter intubation time, better glottis views, similar first-pass success rates, and less use of Magill forceps and the BURP maneuver (backward, upward, rightward, and posterior pressure on the larynx) [115]. In contrast to the roles of FOB and VL for nasotracheal intubation, the video stylet technique required significantly shorter intubation time and fewer airway-assisted maneuvers in adult patients undergoing head and neck surgery [116-118]. Similar application of video stylet for nasotracheal intubation has recently been reported [119-121]. **Figure 11I** shows the application of styletubation for nasotracheal intubation in a 67-year-old woman (BMI: 23.8 kg/m²) undergoing oral and maxillofacial surgery due to medication-related osteonecrosis of jaw (MRONJ). Her past history included recurrent and metastatic breast cancer with thoracic spines metastasis. The intubating time was 30 s with first-pass success.

Patients undergoing head and neck reconstructive surgeries usually present significant challenges on endotracheal intubation, especially with the anticipated higher incidence of DA scenarios (e.g., scar contracture with a reconstructed flap over the neck, pharyngo-laryngeal cancer) [122,123]. **Figure 11J** shows retromolar styletubation technique in a 63-year-old man with buccal cancer and prior reconstructive flap surgery. Although the DA was anticipated (limited mouth opening) and not applicable for laryngoscopy, the styletubation procedure was smooth and first-pass success (intubating time: 20 s). Similarly, patients undergoing oral cancer surgery usually display multiple predictors of anticipated DA for general anesthesia and present unique challenges [124]. Conventional airway management technique (e.g., laryngoscopy) may not reliably achieve endotracheal intubation where intubation has already failed after several attempts. Utilization of several other advanced airway management techniques for tracheal intubation has been recommended [125]. In **Figure 11K**, styletubation technique was applied in a 46-year-old man (BMI: 19.5 kg/m²) with lower gum cancer and severe trismus (less than 2 cm mouth opening). The styletubation procedure was smooth with first-pass success (intubating time: 10 s). Not surprisingly, patients with oropharyngeal/laryngeal cancers receiving head/neck radiotherapy (HNRT) may face significant threats and risks to airway management during tracheal intubation. While previous treatment with HNRT was not always associated with additional risk of DA, MMT score may be a sensitive predictor in this patient population [126]. Endotracheal intubation with VL after induction of general anesthesia can be a feasible alternative for managing DA in patients with supraglottic masses [127,128]. Instead, styletubation also plays a vital role in such patient population during airway management [65,129]. **Figure 11L** shows a 57-year-old man with recurrent hypopharyngeal squamous cell carcinoma (cT4N3B, stage IVB) undergoing elective tracheostomy and laparoscopic Stamm gastrostomy. Even with the help of styletubation technique, it was still challenging when the airway was occupied by the tumor lesions, soft tissue swelling, and copious secretions in such patient population. The styletubation procedure was timely and smooth with first-pass success (intubating time: 38 s)

A plethora of clinical studies have demonstrated VL (i.e., optimal glottic visualization by a video monitoring) is advantageous on the learning curve for airway novices practitioners and trainees, both for the simulated easy and difficult laryngoscopy scenarios [130-137]. Similar to the issues of DL/VL, the learning curves and performance for novices/trainees on the skills of styletubation have also been studied [138-141]. In our medical institute, we provided the novices/trainees (medical students, post-graduate doctors, residents) a full-scale training curriculum and hands-on courses. After completing the introductory courses (airway mannequins and cadavers), the novices/trainees had a bed-side observation opportunity. And then, starting from the second week of training in the operating rooms, the trainees had the chances to try the styletubation in patients with seemingly easy airway conditions under the supervision of an experienced anesthesiologist. **Figure 12** shows two individual examples of the trainees on learning the styletubation. An undergraduate student (clerk) had a shallow learning curve with first-pass success rate of 26.6%. In contrast, a post-graduate year-2 doctor (PGY-2) had an outstanding performance with first-pass success rate of 87.5%.

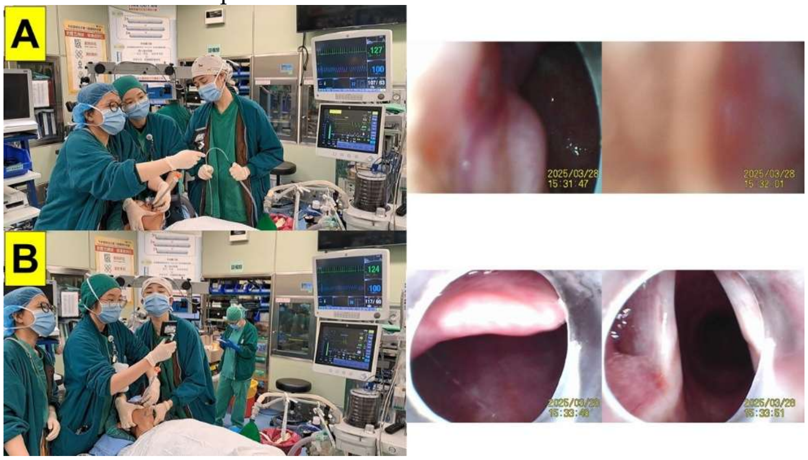

Figure 12. The learning curve for the "green" airway management trainees in the real world. The patient is a 36-year-old woman (BMI 20.4 kg/m²) undergoing dilation of the Eustachian tube (balloon tuboplasty). (**A**) A clerk medical student, who has gone through the regular airway training program, failed to intubate this patient with

styletubation (the trial duration was 60 s). The first-pass success rate for her all experience in styletubation is 26.6% (failure in 11 cases out of 15 intubated patients) during her two-week training course) (**B**) A post-graduate year 2 (PGY-2) doctor had previous experiences of using laryngoscopy. The time to intubation was 10 s with first-pass success in the same patient as that in (**A**). The first-pass success rate for her experience in styletubation is 87.5% (failure in 8 cases out of 64 intubated patients during her 4-week training course).

5. Discussion

Although airway management is mostly uncomplicated and uneventful, the clinical situations can swiftly deteriorate and finally result in patient harm and mishap. During the last two decades, the role of VL has often been shown to be superior over that of DL, based on the commonly applied comparators such as first-pass intubating success rate, failed intubation rate, intubating time, laryngeal visualization, airway-related complications, operators' subjective satisfaction, learning curve, etc. [142,143]. While the better performance of VL has been reported to serve as a rescue airway device in DA scenarios and in critically ill patients [21,144,145], a first-intention technique with VL as the routine airway management option is still a pro-con debate [146-149].

The defects and limitations of laryngoscopy, which might partially attribute to the DA, sometimes cause difficulty acquiring an optimal oro-pharyngeal space, imperfect glottic visualization, difficulty advancing and placing the ET tube into trachea, etc. With same advantages of VL, the new intubating technique with video-assisted intubating stylets (i.e., styletubation), however did not require a direct line of sight (e.g., axes of alignment theory). Above all, the styletubation might be performed under the condition that the exposure of oropharyngeal space is restricted (e.g., oral-facial tumor, tumor around neck region, cervical spine immobility, morbid obesity, etc.). The general comparative features and characteristics between laryngoscopy and styletubation are listed in the **Table 2**.

Table 2. Comparison between (video)laryngoscopy, flexible fiberoptic endoscope, and styletubation.

	Laryngoscopy	FOB	Styletubation
Require wide enough mouth-opening	+++	-	+
Require displacing the tongue to expose glottis	+++	+	+
Require high-grade Cormack-Lehane score	+++	-	-
Need a blade	Yes	No	No
Need a stylet	Sometimes	No	No
Good POGO score	Sometimes	Always	Always
External laryngeal maneuvers are helpful	Often	No	Occasionally
Maneuverability along the airway path	Limited	High	High
First-pass success rate	Moderate to high	Excellent	Excellent
Overall success rate	Moderate to high	High	High
Time to intubate	Moderate	Long	Swift
Subjective feeling of easiness to operate	Acceptable	Varied	Excellent
Impinge on arytenoid / vocal cords	Sometimes	Often	Rare
Dental damage/soft tissue injuries	Sometimes	Seldom	Rare
Impacted by secretions/blood/vomitus	Yes	Yes	Yes
Over-stimulation on airway	Often	Less	Much less
Require an adjunctive tool	Sometimes	Sometimes	Seldom

Learning curve	Reasonable	Slow	Steep
Affordability	Yes	Expensive	Yes
Availability	Yes	Limited	Yes
Speedy preparedness, easy maintenance	Yes	No	Yes
Applicability to awake or asleep intubation	Yes	Yes	Yes
Real time imaging/video recording/documenting	Yes	Yes	Yes

Table 3. Performance of styletubation in the real world airway scenarios.

	Easy Airway	**Difficult Airway**
Laryngeal view	Always excellent	Could be difficult
First-pass success rate	Near 100%	Acceptable
Overall success rate	Near 100%	Acceptable
Intubating time (routine operation)	3 sec to 10 sec	30 sec to 120 sec
Intubating time (for demonstration purpose)	30 sec to 60 sec	NA
Hypoxemia	Very rare	Depends
Airway injuries	Very rare	Acceptable
Learning curve	20% to 90%	-
Awake/asleep intubation	NA	Applicable
Combined with laryngoscopy	NA	Applicable

While the comparison has always been made between DL and VL, we present our own clinical experiences of styletubation in various airway management conditions, including normal and predicted difficult airway scenarios (**Figure 4** ~ **Figure 11**). Basically, there are two main technical advantages of using styletubation for endotracheal intubation. One is the ease to acquire clear glottis view and the other is the ease to advance the ET tube into trachea. With these two strengths of styletubation, the adopted clinical performance indicators are outstanding.

The Bonfils endoscope is a prototype of such device as a rigid and straight fiberoptic stylet with a 40-degree curved tip, originally designed for a retromolar approach in pediatric DA scenarios (e.g., Pierre Robin syndrome) [42]. With the advantages as both optical and slim stylet shaped, which provides clear visualization and better maneuverability along the course of airway, such product design became promising and useful for difficult and normal airway [36,150]. Similar to other optic intubating tools, the common pitfalls and limitations of applying such kind of tools (VL or video stylets) include impacts from fogging, soft tissue contact, or secretions/blood stained the lens and therefore obscured the laryngeal views [42]. We therefore emphasize the role of proper suction along the airway to adequately clear the airway be crucial for styletubation. Another pitfall during the styletubation procedure is inadequate or difficulty lifting patient’s epiglottis and therefore failed to acquire a clear glottis visualization for subsequent entry of the ET tube into trachea. In order to make sure to get enough space between the epiglottis and posterior pharyngeal wall, the following technical tips are useful. Namely, (1) effectively conducting maneuvers of jaw-thrust and mouth-opening by an airway assistant; (2) lifting up patient’s mandible using the Shikani technique; (3) using laryngoscope blade to facilitate lifting up the epiglottis; and (4) using a soft nasal airway tube as a lead conduit to pass the stylet-ET tube unit underneath the epiglottis [151].

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6. The Future Perspective

The total annual number of airway management clinical studies has increased over time during the last two decades. Meanwhile, several ethics concerns of study designs of such research purposes have been noted during the course [152]. In addition to the roles of animal/bench models, human cadavers, manikins, the acceptable ethics consensus guidelines for human airway management research have been proposed [153]. Not surprising, the ethics boundaries include the restricted inclusion criteria to recruit study participants only in ASA status 1–2, excluding those with past history of DA or potentially/predicted difficult airways, limiting the number of trial attempts at securing the study subject's airway, etc. Recent clinical results suggest that VL may be a preferable approach for intubating patients undergoing surgical procedures in the operating rooms [30]. Interestingly, the clinical experience of styletubation has recently been reported [66,154-156]. Our local clinical experiences applying styletubation as the routine first-line tracheal intubation modality are unique (63537 cases from 2016 to 2024) and show excellent performance/outcome indicators (i.e., first-attempt success rate, intubating time, failed intubation rate, complications, etc.). However, large-scale prospective head-to-head clinical comparative studies, regarding the evidence of clinical effectiveness and safety of styletubation against laryngoscopy, are still awaiting.

7. Conclusions

With our own local vast experiences since 2016, styletubation has already revolutionized the concept and empowered practice for airway management, and significantly improve patient clinical outcomes and safety. The striking objective evidence for its clinical benefits and advantages over laryngoscopy is ever-increasing and repeatedly demonstrated as a basic standard of care for tracheal intubation since then. We have presented that the universal full-scale adoption of styletubation into our local routine clinical practice as the first-line airway management technique instead of laryngoscopy. However, future large-sized prospective clinical trials results to support such notion are still demanding and awaiting. Continuously improving clinical demonstration, education and hands-on training of the concept and technique of styletubation are not only fundamentally useful in achieving a widespread awareness of its superiority, but also crucial in maximizing its clinical effectiveness and ensuring its sustained and ubiquitous clinical utilization in the near future.

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