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Review Article

Videolaryngoscopy Assisted Intubation — New Era for Airway Management

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ABSTRACT

Aim of review: The aim of this article is to review the recent literatures regarding videolaryngoscopes, compare performance of videolaryngoscopy versus direct laryngoscopy, discuss the role of videolaryngoscopy in clinical airway management and provide the measures that can improve the performance of videolaryngoscopy and decrease complications associated with videolaryngoscopy.

Methods: The literatures about the use of videolaryngoscopes in the clinical airway management, published in the past decades, were searched from the Pubmed and Cochrane databases and reviewed, in order to determine their performance, and identify their limitations and find appropriate alternate techniques to overcome their shortcomings and failures.

Recent findings: Videolaryngoscopes are promising intubation devices, which are easy to use, and the skills involved are easy to obtain by either novices or experienced intubators. In the current practice, videolaryngoscopes are commonly used as main devices of predicted difficult airways and as rescue tools of difficult or failed direct laryngoscopy. For patients with difficult airways, videolaryngoscopy can provide an improved laryngeal visualization and achieve a higher intubation success rate compared with direct laryngoscopy. Moreover, videolaryngoscopy has the potential to increase patient safety by facilitating learning, teaching, and success of tracheal intubation. Despite the very good laryngeal visualization, the insertion and advancement of the tracheal tube with videolaryngoscopy may occasionally fail, and the airway injuries associated with videolaryngoscopy can occur.

Summary: The introduction of videolaryngoscopy has resulted in a dramatic transformation of clinical airway management and is seen as the evolutionary step in intubation technology. There are several different types of videolaryngoscopes available. Each device's features may offer advantages or disadvantages, depending on the situation the anesthetist has to deal with. To get the best out of videolaryngoscopy, all anesthetists must be trained in the use of videolaryngoscopes and such devices should be available in all sites where tracheal intubation is performed.

The direct laryngoscopy has been the device most commonly used for intubation since its invention by Foregger in the 1940s (1). However, intubation via direct laryngoscopy is a complex technical skill, and proper insertion of the laryngoscope blade and proper lifting are essential components to competency with direct laryngoscopy (2). It is reported that success rate of tracheal intubation using direct laryngoscopy is only 50% in novices (3) and a success rate of 90% cannot be expected until 50 intubations have been performed. Moreover, 18% of trainees still require assistance after 80 intubations (4). Thus, difficulty in tracheal intubation is a common problem in anesthesia practice. A difficult or failed intubation itself is not life-threatening, but is frequently associated with serious complications, such as pulmonary aspiration and difficult facemask ventilation (5). Furthermore, repeated intubation attempts may damage the upper airway and result in facemask ventilation difficult and "cannot intubate cannot oxygenate" situation (6).

According to the closed claims analysis conducted by the American Society of Anesthesiologists (7), a leading cause of anesthesia-related injury is the inability to intubate the trachea and secure the airway. In 85% of these cases, moreover, the outcome is either death or brain damage. In a review of litigation related to anesthesia in the National Health Service hospitals in the UK from 1995 to 2007, airway and respiratory related events account for 12% of all anesthesia claims, 53% of deaths and 27% of cost, and are involved in 10 out of the 50 most expensive claims (8). In addition, about half of incidents reported to the fourth National Audit Project (NAP4) of the Royal College of Anaesthetists and the Difficult Airway Society describe airway complications that follow primary problems with intubation, including failed intubation, delayed intubation, and "cannot intubate cannot oxygenate" situation (9). These facts have greatly facilitated progress of clinical airway management and resulted in the development of several alternative intubation techniques, such as tracheal intubation through the intubating laryngeal mask airway, use of different laryngoscope blades, gum-elastic bougies, lightwands, rigid or flexible fiberoptic intubation. However, some of these techniques have important shortcomings such as complexity, low reliability, high cost and limited availability. Furthermore, some of them are blind techniques, as they do not provide visualization of the tracheal tube when it passes through the glottis (10). Although flexible fiberoptic bronchoscope remains the "gold standard" tool for difficult airway management because of its ability to be manually manipulated and see around corners, it is even more skill- intensive than direct laryngoscopy. This skill is not uniformly possessed by anesthetists, and may be more properly considered as an expert's tool (1).

Videolaryngoscopy may be seen as an evolutionary step in intubation technology. The first of these devices was the GlideScope videolaryngoscope, first presented in 2003 (11). Since then, several different types of videolaryngoscopes were also introduced into the clinical practice, each with a different blade shape, user interface and geometry, and tube insertion strategy (10). Recently, videolaryngoscopy-assisted intubation has been used widely in patients with difficult airways or as rescue tools in failed intubation attempts with direct laryngoscopy. Moreover, using videolaryngoscopy as a standard care to replace direct laryngoscopy is continually appealed by airway experts (12). The aim of this article is to provide a brief review of the literature on videolaryngoscopes and discuss their role in current airway management.

Types of Videolaryngoscopes

Videolaryngoscopes contain miniature videocameras, enabling the operator to visualize the glottis indirectly, with a wide viewing angle and without the need for alignment of the oral, pharyngeal, and tracheal axes. As yet, there are more than 10 commercial videolaryngoscopes availably, with the number constantly increasing and many existing devices being modified (Table and Figure 1). Most of currently available videolaryngoscopes can be broadly classified into the following four groups, with possible advantages and disadvantages (13-18).

Macintosh blade type: Storz V-MAC/C-MAC videolaryngoscope (Karl Storz Endoscopy, Tuttlingen, Germany), GlideScope Titanium videolaryngoscope (Verathon Medical, Bothwell, WA,

Figure 1. Examples of Different Types of Videolaryngoscopes. A. C-MAC videolaryngoscope; B. V-MAC videolaryngoscope; C. GlideScope Titanium videolaryngoscope; D. AP Advance normal airway blade videolaryngoscope; E. McGrath MAC videolaryngoscope; F. GlideScope Original videolaryngoscope; G. GlideScope Cobalt videolaryngoscope; H. GlideScope Ranger videolaryngoscope; I. Storz D-Blade videolaryngoscope; J. McGrath series 5 videolaryngoscope; K. UEscope; L. Pentax-AWS; M. Airtraq laryngoscope; N. KingVision videolaryngoscope; O. AP Advance difficult airway blade videolaryngoscope.

USA), AP Advance normal airway blade videolaryngoscope (Venner Medical International, St Helier, Jersey, UK), McGrath MAC videolaryngoscope (Aircraft Medical, Edinburgh, Scotland), X-Lite videolaryngoscope (Rush, Tuttlingen, Allemagne), and Coopdech portable VLP-100 videolaryngoscope (Daiken Medical Co, Osaka, Japan) belong to this category. These devices have the same blade shape as a standard Macintosh laryngoscope. A main difference is that these devices have a Macintosh blade combined with video technology. Furthermore, the camera is placed distally on the blade, providing a slightly more distal and wider viewing angle than that achieved by Macintosh laryngoscopy. The blades of these devices are inserted into the upper airway using the standard Macintosh laryngoscopic procedure, and the glottis can then be seen either under direct vision or on a monitor. Thus, a main advantage of these devices is that they can be used either as a direct laryngoscope or as an indirect videolaryngoscope. This feature may be useful in the case of video failure or secretions on the lens (10, 14). Due to the use of a Macintosh blade, however, a shortcoming of these devices is the frequent need for alignment of three airway axes and external laryngeal pressure to obtain a good laryngeal view during videolaryngoscopy.

Angulated blade type: This category includes three GlideScope videolaryngoscopes (Original, Cobalt and Ranger), McGrath series 5 videolaryngoscope, Storz D-Blade videolaryngoscope, and UEscope (UE Medical Corp, Zhejiang, China). They are characterized by a larger curve than the Macintosh blade. The large curvature of the blade can provide an improved laryngeal view on the monitor screen with minimal movement of the patient's head and neck for alignment of three airway axes, but these devices can only provide an indirect videolaryngoscopic view of the glottis and require the use of a pre-shaped, styleted tracheal tube during intubation (14, 15). Only providing an improved indirect view of the glottis maybe one of reasons why they are useful for difficult intubations but slowdown easy intubations and a good videolaryngoscopic view of the glottis does not guarantee easy and successful intubation (10).

It must be noted that angulated blade is originally designed for use in the difficult airway, particularly if a more anterior laryngeal position is suspected. However, there are subtle differences between those angulated blades. The camera of GlideScope videolaryngoscope is located at a marked inflection point from which the distal blade continues straight forward for another 58 mm at a 60° angle, while the optical component of the Storz D-Blade is carried more distally than it is on the GlideScope. This difference in the projected video image may have presented a challenge for tube passage for some providers when using the Storz D-Blade, particularly for those that are more experienced with the more proximal lens location of the GlideScope videolaryngoscope. With an upwards angulation of about 40°, however, the blade design of UEscope differs significantly from blades of GlideScope and Storz D-Blade videolaryngoscopes (Figure 1). Furthermore, the camera location of UEscope and inflection point of blade are between GlideScope and Storz D-Blade videolaryngoscopes. These features of UEscope are designed for improvement of intubation performance and for use in the normal and difficult airways.

Tube guide channel type: These devices have anatomically shaped blades with a tube guide channel, which directs the tracheal tube towards the glottis. Airtraq laryngoscope (Prodol, Vizcaya, Spain), Pentax-Airway Scope (Pentax-AWS, Hoya, Tokyo, Japan) and KingVision videolaryngoscope (Kingsystems, Nobles-ville, IN, USA) belong to this classification. The AP Advance difficult airway blade (Venner Medical International, St Helier, Jersey, UK) is an exception of this classification, with a tube channel on the angulated blade. Pentax-AWS and KingVision videolaryngoscope have a screen mounted on their handles. The Airtraq laryngoscope does not rely on a camera *per se* but uses an optical system to provide the laryngeal viewing. Although Airtraq laryngoscope is not a videolaryngoscope by definition, it can be equipped with a video-camera and thus function as a videolaryngoscope. With these devices, the tracheal tube is preloaded to the tube guide channel. Then, the videolaryngoscope is inserted into the upper airway in the midline, without displacing the tongue laterally, and advanced slowly until the epiglottis comes into the view. The tip of the blade is then positioned posterior to the epiglottis, directly elevating it, so that the glottis is visualized. Then, tracheal tube is inserted into the trachea via the tube guide channel (14-18). Because the tube tip is captured on the monitor even before insertion of the device, the location of the tube tip can continuously be confirmed during the total course of tracheal intubation.

Recently, Airtraq laryngoscope and KingVision videolaryngoscope without the tube guide channels are also available (Figure 2) (19, 20). Strictly speaking, the two devices should be regarded as the videolaryngoscope with an angulated blade, as the procedure for orotracheal intubation with them is similar to that of the videolaryngoscope with an angulated blade. Before intubation, an intubating stylet is inserted into the tracheal tube and the distal end of the tracheal tube and the intubating stylet are bent anteriorly to a 90° angle, which corresponds to the blade curvature of the unchannelled devices. After the distal end of the device is positioned in the vallecula and the glottis is visualized, the styletted tracheal tube is introduced in the midline and advanced along the right side of the blade into the glottis under direct vision When the tracheal tube tip is confirmed to have passed the glottis, the intubating stylet is gently withdrawn from the tracheal tube, and the tracheal tube is then advanced downward into the trachea (21).

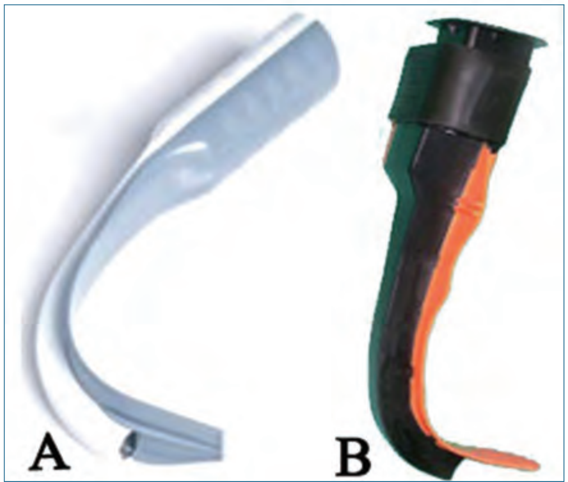

Figure 2. Airtraq Laryngoscope (A) and KingVision Videolaryngoscope (B) without the Tube Channel.

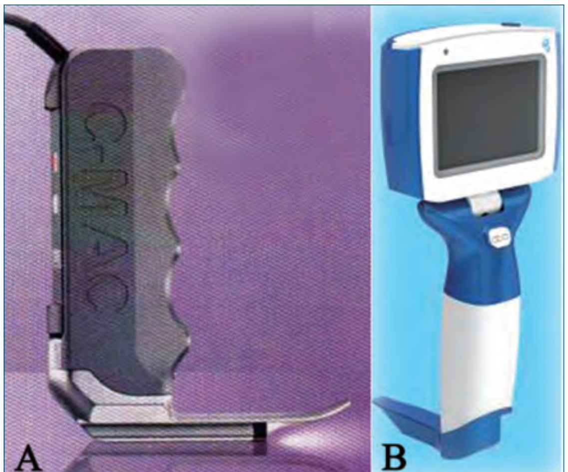

Figure 3. Examples of Pediatric Videolaryngoscopes with Miller-Like Blades.
A. Storz videolaryngoscope; B. UEscope.

Miller blade type: Although there is not currently available adult videolaryngoscope with a Miller blade, a few manufacturers provide the pediatric videolaryngoscopes with Miller blades in sizes that may be used in children younger than 2 years of age. Typically, Storz videolaryngoscope and UEscope are available with two reusable Miller blades, size 0 and 1 (Table and Figure 3). This Miller-like blade can be used in small in-

Table. Features of Different Videolaryngoscopes.

Videolaryngoscopes	Blade shape	Monitor	Portability	Disposability	Size range	Anti-fog
McGrath MAC	Macintosh	Integrated, 1.7 in. LCD	Yes	Single-use	3 adult sizes	No
Storz V or C-MAC	Macintosh	Separate, 7 in TFT or 2 in pocket LCD	Yes when using pocket monitor	Reusable	Sizes 2-4	Yes
Glidescope Titanium	Macintosh	Separate, 7 in. LCD	No	Reusable or Single-use	Sizes 3 and 4	Yes
AP Advance normal airway blade	Macintosh	Integrated, 1.8 in. LCD	Yes	Single-use	One size	No
Glidescope original	Angulated	Separate, 7 in. LCD	No	Reusable	Sizes 2-5	Yes
Glidescope Cobalt	Angulated	Separate, 7 in. LCD	No	Single-use	Sizes 1-4	Yes
Glidescope Ranger	Angulated	Separate, 3.5 in. LCD	Yes	Reusable or Single-use	Reusable: 3-4; Single-use: 1-4	Yes
Storz D-Blade	Angulated	Separate, 7 in TFT or 2 in pocket LCD	Yes when using pocket monitor	Reusable	Sizes 3 and 4	Yes
McGrath Series 5	Angulated	Integrated, 1.7 in. LCD	Yes	Single-use	3 adult sizes	No
UEscope	Angulated	Integrated, 2.5 in. LCD	Yes	Reusable or Single-use	Reusable: 1-4; Single-use: 2-4	Yes
Pentax-AWS	Anatomically shaped blade with a tube channel	Integrated, 2.4 in. LCD	Yes	Single-use	1 adult size and 1 pediatric Size	No
Airtraq	Anatomically shaped blade with a tube channel	External monitor (when used as a videolaryngoscope)	Not when used as a videolaryng oscope	Single-use	7 sizes	Yes
KingVision	Anatomically shaped blade with a tube channel	Integrated, 2.5 in. LCD	Yes	Single-use	One size	No
AP Advance difficult airway blade	Angulated blade with a tube channel	Integrated, 1.8 in. LCD	Yes	Single-use	One size	No
Storz Miller	Miller	Separate, 7 in TFT	No	Reusable	Sizes 0 and 1	Yes
UEscope Miller	Miller	Integrated, 2.5 in. LCD	Yes	Reusable	Sizes 0 and 1	Yes

fants with very limited mouth openings because of the small height of the blade (only 5 mm) and the distally located lens. It allows the tip to be placed in the vallecula or used to lift the epiglottis during intubation. As the blade is straight, the view on the screen is similar to what is seen when looking directly into the mouth. Interestingly, the pediatric videolaryngoscopes with Miller blades can be used without a stylet in the tracheal tube. Namely, the tracheal tube is advanced along the right side of the blade under direct vision until it comes into view on the monitor; it is then moved further into the trachea (13).

Performance of Videolaryngoscopy versus Direct Laryngoscopy

Videolaryngoscopes provide a large visualization of the larynx, which is superior to that obtained by direct laryngoscopes (22). Recently, several systematic reviews and meta-analyses have compared the performance of videolaryngoscopy with direct laryngoscopy for tracheal intubation in adult and pediatric patients with normal and difficult airways. Griesdale et al. (23) performed a meta-analysis comparing Glidescope videolaryngoscopy with direct laryngoscopy in 17 clinical trials with a total of 1,998 adult patients published until June, 2011. They show that compared to direct laryngoscopy, Glidescope videolaryngoscopy is associated with improved laryngeal visualization, particularly in patients with potential or simulated difficult airways. In a meta- analysis comparing five videolaryngoscopes (GlideScope, X-Lite, Storz, McGrath and Pentax-AWS) with direct laryngoscopy, Su et al. (24) included 11 randomized clinical trials with a total of 1,196 adult patients. This reveals that compared with direct laryngoscopy, videolaryngoscopy provides a better laryngeal view, a same high success rate of intubation and a shorter time of intubation when difficulty is encountered.

In a meta-analysis including 64 studies identified during the 2015 search that enrolled 7,044 adult participants and compared a videolaryngoscope of one or more designs with a Macintosh laryngoscope, Lewis et al. (25) show that videolaryngoscopes may reduce the number of failed intubations, particularly among patients presenting with a difficult airway. Furthermore, videolaryngoscopes improve the laryngeal view and may reduce laryngeal/airway trauma. However, there is no evidence to indicate that use of a videolaryngoscope reduces the number of intubation attempts or the incidence of hypoxia or respiratory complications, and affects time required for intubation.

In a systematic review and meta- analysis including 17 randomized controlled trials with a total of 1,801 patients, Hoshijima et al. (26) compared the Pentax-AWS versus Macintosh laryngoscope for tracheal intubation in adult patients. They find that the Pentax-AWS offers a superior laryngeal view, but little clinical benefit over the direct laryngoscope. Su et al. (27) published a systematic review and meta-analysis comparing performance of the Airtraq laryngoscope and Macintosh laryngoscope, in which 12 randomized controlled trials (published between 2006 and 2011) with a total of 1,061 patients were included. They conclude that compared with the Macintosh laryngoscope, the Airtraq laryngoscope provides a significantly shorter intubation time when used by both experienced anesthetists and novices and a higher success rate at the first attempt when used by novices. Furthermore, the incidence of oesophageal intubation is significantly reduced by the Airtraq laryngoscope. In a meta- analysis including 20 randomized controlled trials with a total of 2,370 patients, Hirabayashi et al. (28) assessed the efficacy of the channeled videolaryngoscopes including Airtraq laryngoscope and Pentax-AWS in routine tracheal intubation. Their results show that compared to the Macintosh laryngoscopy, the channeled videolaryngoscopy offers advantages for novices, while these benefits are not seen with experts' hands in normal airways. Even with experts' hands, the channeled videolaryngoscopy improves the success rate of first intubation attempt in difficult conditions.

In a meta- analysis comparing the efficacy of videolaryngoscopes (Glidescope, Airtraq and Pentax- AWS) and Macintosh laryngoscopy for adult nasotracheal intubations, Hirabayashi et al. (29) included 7 randomized controlled trials with 294 intubations by videolaryngoscopes and 253 intubations by Macintosh laryngoscopy. They demonstrate that the videolaryngoscopes provide a higher intubation success rate and a shorter intubation time compared with the Macintosh laryngoscope.

Su et al. (30) carried out a meta- analysis of 14 randomized controlled trials comparing pediatric videolaryngoscopes (GlideScope, TruView, Storz, Bullard, and Airtraq) versus direct laryngoscope. Their results demonstrate that compared to direct laryngoscope, videolaryngoscopes are associated with improved laryngeal visualization in children either with normal airways or with potentially difficult airways. However, a surprising result from this meta- analysis is that with pediatric videolaryngoscopes, the intubation time is prolonged and the incidence of failed intubation is increased significantly. This meta-analysis was criticized by us in a comment (31). In our view, incomplete inclusion of related literatures and pooling of results from studies evaluating different videolaryngoscopes in pediatric patients with normal and potentially difficult airways would be possible reasons of their fantastic findings. To determine the efficacy and safety of videolaryngoscopy compared to direct laryngoscopy in decreasing the time and attempts required and increasing the success rate for tracheal intubation in neonates, Lingappan et al. (32) searched for randomized controlled trials evaluating videolaryngoscopy for neonatal tracheal intubation in May 2013 and did not find any completed studies for inclusion, but identified three ongoing trials and one study awaiting classification. Thus, they conclude that there is insufficient evidence to recommend or refute the use of videolaryngoscopy for tracheal intubation in neonates.

By a systematic review and meta-analysis including 3 randomized controlled trials and 6 observable trials with a total of 2,133 participants, De Jong et al. (33) compared performance of videolaryngoscopy versus direct laryngoscopy for orotracheal intubation in the intensive care unit. The results indicate that videolaryngoscopy helps to reduce difficult intubation and esophageal intubation, improves laryngeal visualization grades, and increases success rate at the first attempt, but does not reduce the incidences of severe hypoxemia, severe cardiovascular collapse, or airway injury during intubation.

It must be pointed out that there are some limitations in above meta-analyses. First, the high heterogeneity among the selected trials, including intubators with different levels of experience and skill with the studied devices, and different definitions of successful or failed intubation, makes it difficult to pool all data together (31). Second, there is evidence of publication bias in the used primary outcomes, suggesting that the studies favoring direct laryngoscopy are not being published (15). Third, most of the studies included in meta-analysis are performed on patients without difficult airways. As a result, an important question that remains unanswered is whether videolaryngoscopy equals or surpasses direct laryngoscopy in the difficult airway management (14). Fourth, none of the randomized trials included in above meta-analyses is double-blinded because it is impossible to make the anesthesiologist unaware of the devices they would use for intubation.

According to the current literatures comparing videolaryngoscopy and direct laryngoscopy, the following conclusions can be achieved. a) Tracheal intubation in most patients with normal airway can be completed rapidly and cost efficiently with direct laryngoscopy (14). b) In difficult airway management, videolaryngoscopy improves laryngeal visualization grades and provides a higher intubation success rate with a less time, compared with direct laryngoscopy (10). c) Videolaryngoscopy is associated with a higher intubation success rate and a faster intubation time for novices, but it provides no benefit in either of these outcomes with experienced intubators (23, 34). d) Despite the very good laryngeal visualization, the insertion and advancement of tracheal tube with videolaryngoscopy may occasionally fail (10, 35).

The Role of Videolaryngoscopy in the Current Airway Management

Just like Paolini et al. said (15), "*anesthesiologists like videolaryngoscopes because they make their life somewhat more serene*."

The available literature provides compelling evidence that videolaryngoscopes are easy to use, and the skills involved are easy to obtain by either novices or experienced intubators (10). Furthermore, videolaryngoscopy usually implies a very good to excellent laryngeal visualization. Thus, most of current algorithms for difficult airway management recommend videolaryngoscopes as rescue tools for difficult or failed direct laryngoscopy (36-38). Perhaps an important question of most clinical relevance is: Can videolaryngoscope be a solution for difficult or failed direct laryngoscopy? The available literature provided some data that might help answer this question. In a retrospective study including 2,004 patients, Aziz et al. (39) demonstrate a 97% success rate of intubation using the Glidescope videolaryngoscope when direct laryngoscopy has failed. The study by Malin et al. (40) included 47 patients, in whom two intubation attempts by senior anesthetists with a Macintosh laryngoscope failed. They show that subsequent intubation is achieved with the Airtraq laryngoscope in 36 patients (80%). After two failed direct laryngoscope attempts, Asai et al. (41) report a 99.3% success rate of intubation with the Pentax-AWS as a rescue device. After failure of Macintosh laryngoscopy in 61 patients with a Cormack and Lehane grade 3 or 4 laryngeal view, Noppens et al. (42) studied the performance of McGrath Series 5 videolaryngoscope as a rescue device and showed that this device improved laryngeal view and enabled tracheal intubation in 95% of cases. Recently, Aziz et al. (43) retrospectively studied 1,427 patients in whom one of the five rescue devices was used after failed intubation using a direct laryngoscope. As a result, a videolaryngoscope, which is most frequently chosen among the five devices, is associated with a significantly higher success rate (92%) than the other devices including a supraglottic airway device (78%), a fiberoptic bronchoscope (78%), a lighted stylet (77%), and an optical stylet (67%). Thus, it may be reasonable to regard videolaryngoscopes as the first choice when direct laryngoscopy has failed.

Other than the use of videolaryngoscopes as rescue tools for difficult or failed direct laryngoscopy, current algorithms for difficult airway management also recommend that the videolaryngoscopes can be applied for intubation in patients with predicted difficult airways (36- 38). Even awake fiberoptic intubation, which is generally considered as the gold standard technique in the management of predicted difficult airways, has recently been challenged by videolaryngoscopy (15). In available literatures, Glidescope videolaryngoscope (44), McGrath videolaryngoscope (45, 46), Pentax-AWS (47), Airtraq laryngoscope (48) and KingVision videolaryngoscope (49) have been successfully used for awake intubation in patients with anticipated difficult airways, as they are less stimulating for the patient than direct laryngoscopes and do not require head and neck manipulation (10). The study by Moore et al. (44) described awake intubation using the GlideScope videolaryngoscope in 50 patients undergoing bariatric surgery, and concluded that videolaryngoscopy- assisted awake intubation was a useful scheme for airway management of the morbidly obese patients. Rosenstock et al. (45) compared performance of flexible fiberoptic intubation with McGrath videolaryngoscope for awake orotracheal intubation in adult patients with predicted difficult airways and found no difference between the two techniques in intubation time and success rate. In the recent article by Mendonca et al. (47) comparing the flexible fibrescope and Pentax-AWS for awake orotracheal intubation in adult patients with a predicted difficult airway, the total intubation time with Pentax-AWS was shorter, without significant differences in the ease of intubation by the anesthetist or patients' comfort between the two devices.

Although the videolaryngoscope hops to replace the flexible fibrescope as the gold standard of difficult airway management, the problem here is that a videolaryngoscope should always be used when difficult or failed intubation with direct laryngoscopy occurs. Evidently, the answer is no because of several causes: a) Videolaryngoscopy provides a high success rate of rescue intubation after failed direct laryngoscopy, but does not achieve a 100% success rate. For example, Aziz et al. (39) described the two-centre experience of using the GlideScope videolaryngoscope. Interestingly, the device had a 3% failure rate when used in patients with anticipated difficult airways and a 6% failure rate when used to rescue the failed direct laryngoscopy. In a recent study by Aziz et al. (43), tracheal intubation could not be achieved with a videolaryngoscope in 10% of patients with a failed direct laryngoscopy. Moreover, Brown et al. (50) compared direct laryngoscopy and C-MAC videolaryngoscopy in 198 emergency department patients and showed that 6% of all intubation attempts with videolaryngoscopy failed. Cavus et al. (51) evaluated the C-MAC videolaryngoscopy during prehospital emergency intubation performed by physicians and found a failure rate of 7.5%. The common causes of failed videolaryngoscopy include a limited mouth opening, a large tongue, a tumor in the oropharynx or blurred vision by fogging, secretions, blood, or vomitus, cricoid pressure, etc (43, 49-54). b) Because videolaryngoscopes are larger than flexible fibrescope, they exert more tractions on the upper airway, and may therefore induce gagging and uncomfort in awake patients, independent of the type of the local anesthetic used (45). c) There are several different types of videolaryngoscopes available (10, 14, 15). So far, there is inconclusive evidence to indicate which videolaryngoscope design is more advantageous in various clinical situations (14). In fact, no one technique is better than others in all situations, because each device has unique features that may be advantageous in some conditions, but disadvantageous in others. Thus, the open question remains: how do anesthetists judge which device is most suitable by identifying the cause of difficult airway in each patient. d) There is still no evidence- based airway algorithm where tracheal intubation relies mainly on videolaryngoscopy (10). Thus, another pertinent problem we are facing is what one should do in the case of a difficult or failed videolaryngoscopy. e) The recent works show that universal introduction of videolaryngoscopy does not result in a reduced rate of fiberoptic intubation, and flexible fibrescope is still preferred for awake intubation in patients with difficult airways (54,55). Given that above problems exist, we argue that practitioners must master several different airway devices and should use the techniques that they are mostly experience and competence in managing a difficult airway.

How to Get the Best out of Videolaryngoscopy

Training and Practicing: Standardization of equipment is associated with improved performance and patient outcomes. As with all new intubation devices, experience and competency with videolaryngoscopy are critical for its successful use in clinical practice. Although some described a very short learning curve of videolaryngoscopy (10), Cortellazzi et al. (56) reported that 76 intubations with a GlideScope videolaryngoscope were needed to achieve competence. Moreover, the learning curve for most airway devices is biphasic; namely, reasonable competence can be achieved within 30 cases, but performance continues to improve even after 100 cases (57). However, a pitiless fact is that new airway devices are often used without formal teaching and without reading instructions; practitioners teach themselves, without applying best practice (58, 59). Undoubtedly, this can lead to poor techniques and possible harm to patients.

It must be pointed out that the intubation procedure using videolaryngoscopy, particularly with angulated and conduited blades, is significantly different from that using direct laryngoscopy, and manufacturers' recommended techniques for many videolaryngoscopes significantly differ from each other (14). That is, a skilled operator at the use of direct laryngoscope cannot be expected to have the ability to complete tracheal intubation with videolaryngoscopy effectively without training and practice (60). For experienced operators skilled at direct laryngoscopy, the main challenge during intubation with videolaryngoscopy is to become familiar with the view on the monitor, and to coordinate the eyes and hands appropriately (10). In addition, experience and competency with one videolaryngoscope does not mean that operators can effectively use others, even if they are devices within a defined group (e.g. Airtraq and Pentax-AWS). Thus, the 2015 difficult Airway Society guidelines emphasize that all anesthetists should be trained in the use of videolaryngoscopes (37). Ideally, such devices should be available in all sites where tracheal intubation is performed (14). The most important factors for successful use of videolaryngoscopy will be knowledge of the device limitations, and practice, practice, practice.

Selection of videolaryngoscopes: Although there is few evidence about which videolaryngoscope should be chosen for which situation, a systematic review by Healy et al. (61) assessing the role of videolaryngoscopy in successful orotracheal intubation provides some data. Other than perfect experience and competency with videolaryngoscopy, the intubators should consider causes of intubation, efficacy of each device for various causes of difficulty, and the risk associated with the use of each device when making a decision which device is effective. Here, I would also like echo some views of Kelly and Cook (60). If a videolaryngoscope is used for everyday practice, the devices with the option of using both a Macintosh blade and an angulated blade may be best choice. In patients at higher risk of difficult laryngoscopy, the Airtraq laryngoscope, GlideScope videolaryngoscope, Pentax AWS and C-MAC videolaryngoscope are appropriate devices to achieve successful intubation (61).

If a videolaryngoscope is chosen as a rescue tool when intubation with direct laryngoscopy has failed, it is better to choose a device with the angulated blade (with or without a conduit), as it can provide an improved laryngeal view by seeing 'round the corner' in this situation. If a videolaryngoscope is planned to use when there are blood, vomit or secretion in the airway, a device that can be used for both direct laryngoscopy and videolaryngoscopy may be the most suitable. If a videolaryngoscope is used for emergency intubation in a prehospital setting, a device with the monitor attached to the handle and one with the monitor that is visible in direct sunlight is possible to be more practical.

Difficulty in device insertion: As some videolaryngoscopes have large handles, cables emerging from the top of the handle and sharply angulated blades, the operator may encounter difficulty when the blades are inserted using the conventional way, especially in patients with a limited head and neck movement and obese patients with large chests or breasts. In these cases, the initial insertion of videolaryngoscope should be performed diagonally, with subsequent positioning of the blade. Furthermore, further extending the atlanto-occipital joint and rotating the handle by 90° to the right are the useful measures to facilitate the insertion of the blade (10, 61, 62).

Difficulty in tube insertion: When the tracheal intubation is performed with videolaryngoscopy, the ability to exposure the larynx does not correlate with successful intubation; namely, a good videolaryngoscopic view of the glottis does not guarantee easy and successful intubation (63). This is especially true for videolaryngoscopes with sharply angulated and channelled blades (60).

This troublesome problem with sharply angulated blades is because the laryngeal visualization does not require the alignment of three airway axes and the tracheal tube has to be introduced around the curve of the blade at the base of the tongue (17). In this way, the operator needs to pre-shape the tracheal tube with a rigid stylet, to an angle to match the blade's curvature (63). This great tube bend angle can create tube passage problems with the videolaryngoscopy as the tracheal tube tends to be directed into the larynx with an angle almost perpendicular to the axis of the trachea (10). Because there is the difference between the inclination of the trachea and the curvature of the tongue, moreover, the anterior tracheal wall may further add a mechanical impediment to tube passage with the videolaryngoscopy (17). In the case of this troublesome with sharply angulated blades, the operator can withdraw the stylet by about 4 cm, withdraw the blade by 1-2 cm and rotate the tracheal tube slightly, to facilitate tube passage into the trachea (10). Even the manufacturer of the GlideScope videolaryngoscope advocates the use of a special tracheal tube, the GlideRite® tracheal tube (Highlands Ranch, CO), to address this troublesome (17). It has been shown that compared with the standard tracheal tube, the GlideRite® tracheal tube significantly improves intubation with the GlideScope videolaryngoscope, as measured by decreased time for tube insertion and increased ease of tube insertion assessed by a visual analog scale (65).

When videolaryngoscope with a channelled blade is used, obtaining an optimal view of the larynx is required because this can ensure that the tracheal tube is directed correctly through the guide channel towards the glottis. A partial or non-optimal view will lead to the conduit reliably directing the tube away from the glottis. Furthermore, some operators have advocated the use of a tube introducer, a stylet, or adjustment maneuvers to assist with tube insertion when using the Pentax-AWS and Airtraq laryngoscope (60). In addition, these devices require a tube of suitable type and size for a given conduit for successful intubation (60).

It is worth to note that a bougie may not be a good solution for difficult intubation with videolaryngoscopy, as the bougie often tends to uncurl during passage towards the glottis and leads a failure. This is particularly true when modern disposable bougies without the plasticity are used (60).

Decreasing complications associated with videolaryngoscopy: As compared with direct laryngoscopy, videolaryngoscopy provide a better laryngeal view and requires a less upward lifting force to achieve adequate laryngeal exposure (10). It is out of question that less airway injuries can be expected if less force is applied to the upper airway tissues. However, reports of the upper airway injuries associated with videolaryngoscopy are increasing in the literature. In a retrospective study including 2,004 GlideScope videolaryngoscope uses, approximately 1% of patients underwent complications, usually minor tissue damage. Minor complications included lip or gum lacerations (n=13); more serious complications (n=6) are vocal cord trauma, tracheal injury, trauma to the hypopharynx, tonsillar perforation and two dental injuries (39). Even Greer et al's review of airway injuries in anesthesia records of the Madigan Army Medical Center shows that the rate of the upper airway injuries associated with videolaryngoscopy is significantly higher compared to direct laryngoscopy, suggesting that inherent design of videolaryngoscopy may contribute to the potential for upper airway injuries (65).

According to available literatures, the possible reasons of airway injuries associated with videolaryngoscopy include (10, 65-67): a) The monitor may attract the operator' s visual attention from the mouth; b) When the blade is inserted, upward force in order to expose the glottis may stretch the palatopharyngeal arch; c) The digital camera of a videolaryngoscope with angled blade is installed at a position close to the tip of the blade, resulting in a 'blind spots' on the lateral aspect of the blade. Due to the existence of a blind spot, when tracheal tube is advanced under videolaryngoscopy, the operator will lose direct sight of the tube tip until it comes into the camera's visual field, making it possible that airway mucosal trauma occurs. d) The use of too large blades, rigid stylets or unnecessary force during the insertion of the tracheal tube is the established risk factor of airway injuries associated with videolaryngoscopy. e) Operator inexperience, haste, or inattentiveness may increase the chance of airway mucosal damage during intubation with the videolaryngoscopy.

To minimize the risk of airway injuries associated with videolaryngoscopy, the intubators should insert both the videolaryngoscope and the tracheal tube into the mouth under direct vision without using undue force (10, 62, 65, 66). When performing intubation using a videolaryngoscope with sharply angulated blade, moreover, a useful four-step technique has been recommended (65, 68). Step 1: looking in the mouth. The videolaryngoscope is inserted into the mouth and gently advanced towards the base of the tongue. Step 2: looking at the screen. The position of the videolaryngoscope is optimized. Step 3: looking in the mouth. The tracheal tube with the stylet is inserted gently and placed as close to the tip of the laryngoscope as possible. Step 4: looking at the screen. The tracheal tube is directed towards glottis and between the vocal cords.

Conclusions

The approach to airway management has undergone dramatic transformation since the advent of videolaryngoscopy. Undoubtedly, videolaryngoscopy is a milestone in airway management (35). Compared with direct laryngoscopes, videolaryngoscopy generally provides an improved laryngeal view and a higher success rate of tracheal intubation in patients with difficult airways (10). Thus, videolaryngoscopes have significant roles in management of difficult airways. Furthermore, videolaryngoscopy has the potential to increase patient safety by facilitating learning, teaching, and success of tracheal intubation (23). However, there are a number of videolaryngoscopes commercially available; each particular device has different features, which may constitute advantages or disadvantages, depending on the situation that anesthesiologists have to deal with (10, 14). To ensure that clinical use of videolaryngoscopes makes a positive contribution to patient safety, more studies are still needed to define their limitations and appropriate alternate techniques to overcome their shortcomings and failures (69). As acquisition costs decrease over time, moreover, these devices will become increasingly popular (69, 70). It can be predicted that the next logical step in the evolution of the videolaryngoscopy will be for use in patients with a normal airway as a replacement for direct laryngoscopy (12, 13, 71). I believe that with increasing use of videolaryngoscopy in clinical airway management, its potential benefits of patients will be numerous and significant.

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