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Review Article

Video-laryngoscopes in the adult airway management: a topical review of the literature

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The aim of the present paper is to review the literature regarding video-laryngoscopes (Storz V-Mac and C-Mac, Glidescope, McGrath, Pentax-Airway Scope, Airtraq and Bullard) and discuss their clinical role in airway management. Video-laryngoscopes are new intubation devices, which provide an indirect view of the upper airway. In difficult airway management, they improve Cormack–Lehane grade and achieve the same or a higher intubation success rate in less time, compared with direct laryngoscopes. Despite the very good visualization of the glottis, the insertion and advancement of the endotracheal tube with video-laryngoscopes may occasionally fail. Each particular device's features may offer advantages or disadvantages, depending on the situation the anaesthesiologist has to deal with. So far, there is inconclusive evidence indicating that video-laryngoscopy should replace direct laryngoscopy in patients with normal or difficult airways.

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According to the American Society of Anesthesiologists, a leading cause of anaesthesia-related injury is the inability to intubate the trachea and secure the airway.[1–3] In 85% of these cases, the outcome is either death or brain damage.[1] In patients who undergo difficult intubation, the morbid nonfatal events are also increased.[4,5] The reported incidence of difficult intubation is 1.15–3.8% in the general population, while failed intubation is rarer (0.13–0.3%).[2,6] Worldwide, up to 600 patients are estimated to die annually as a result of the complications that occur during tracheal intubation.[7]

These facts have led to the development of several alternative techniques, such as intubation through the intubating laryngeal mask airway, use of different laryngoscope blades, gum-elastic bougies or stylets, retrograde intubation, blind oral or nasal intubation, a variety of rigid fibreoptic techniques and flexible fibreoptic intubation.[8] However, many of these techniques have important disadvantages such as complexity, low reliability, high cost and limited availability. Moreover, some of them are blind techniques, as they do not provide visualization of the endotracheal tube (ETT) as it passes through the glottis.[9–11]

Video-laryngoscopes are new intubation devices, which contain miniature video-cameras, enabling the operator to visualize the glottis indirectly. Their design is similar to conventional laryngoscopes, enabling clinicians familiar with direct laryngoscopy to use them successfully, without the need for any special training.[10] Several video-laryngoscopes with differing specifications, user interfaces and geometries have been developed. Each particular device's unique characteristics make it either advantageous or disadvantageous in different situations. The aim of this article is to provide a topical review of the literature on indirect rigid video-laryngoscopes and discuss their clinical role in airway management.

Methods

The PubMed was searched for relevant papers, using the keywords Storz video-laryngoscopes, Glidescope, McGrath, Pentax video-laryngoscope, Bullard and Aitraq. All human and manikin case reports, case series and randomized-controlled studies were included in our search, as only a few randomized-controlled studies comparing video-laryngoscopy with direct laryngoscopy have been published.[12] Animal studies and paediatric cases were not included. The last literature search was performed in January 2010.

The major outcomes we were interested in were: the laryngeal view achieved at laryngoscopy, as described by Cormack and Lehane (C/L grades), intubation success rate and intubation time. C/L grade III (only the epiglottis visible) and C/L grade IV (neither the glottis nor the epiglottis visible) were considered to indicate difficult airways, whereas C/L grade I (full view of the glottis) and C/L grade II (partial view of the glottis or arytenoids) were considered to indicate easy airways.[13]

The major difficulty, when assessing the data, was that most of the studies had included unselected patients and in many studies, patients predicted to be difficult were excluded on purpose.[12,14] This is a paradox, as the main question to be answered is whether video-laryngoscopes perform better than direct laryngoscopes in difficult airways. Several definitions for the 'difficult airway' have been used, but a frequent definition is 'patients with a C/L grade of glottic view >II'. However, grade III views are usually intubated successfully with a combination of a standard laryngoscope and a gum elastic bougie, whereas grade IV views are very rare.[15] Only 0.1–0.5% of the general population is likely to be truly difficult. This means that many unselected patients, or patients who are known to be difficult to intubate, need to be studied.[12] However, it is not easy to identify pre-operatively patients who may be difficult to intubate, as all the diagnostic tests have low sensitivity and positive predictive value.[16]

Types of video-laryngoscopes

The specific features and characteristics of the video-laryngoscopes, presented in this article, are summarized in Table 1.

Video-laryngoscopes with standard Macintosh blades

These devices have the same blade shape as a standard laryngoscope. The difference lies in the inclusion of a camera. They are inserted into the oral cavity using the standard direct laryngoscopic technique. After insertion, the operator sees an enlarged image of the upper airway on the screen. As Storz video-laryngoscopes have the same curvature as Macintosh, the operator has the alternative choice of directly viewing the anatomical structures, as if he were using a standard laryngoscope. This feature may be useful in the case of video failure or secretions on the lens.[17]

There are two different Storz video-laryngoscopes. The older one, the V-Mac, consists of a laryngoscope, an LCD screen, a light source and a camera control unit. The laryngoscope's handle incorporates a camera. A short fibre light bundle exits the handle and enters into a metal tube, on the blade. A fibre light cord and a camera cable emerge from the top of the handle. These connect to the light source and the camera control unit, respectively. The monitor is usually positioned over the patient's chest, allowing the operator to work and observe in one axis.[18] The latest model, C-Mac, consists of only two parts, a laryngoscope and a monitor, connected via a single cable. Therefore, it is portable, more robust and less expensive compared with the V-Mac.

Video-laryngoscopes with angulated blades

These devices resemble regular scopes, with the exception of their blade, which has an extra curve, making it impossible to see what is happening at its tip, unless a camera shows it. They are introduced into the middle of the oral cavity, without tongue displacement, gliding along the palate and the posterior pharynx until their tip is inserted into the vallecula or posterior to the epiglottis, if the epiglottis obscures the glottis. Then a pre-curved styletted ETT is pushed through the glottis. When the tip of the ETT reaches the vocal cords, the stylet is withdrawn by an assistant and the ETT is advanced downwards.[9,10]

As video-laryngoscopes with angulated blades do not require the alignment of the three axes (oral, pharyngeal and tracheal) and the ETT has to be introduced 'around the corner', the operator needs to pre-shape the ETT to an angle of 60° to match the blade's curvature.[9,10] To aid in obtaining the right angulation, several adjuncts are available in the market, such as the GlideRite rigid stylet,[19] the Parker Flex-It Directional Stylet[20] and the Endoflex ETT.[21]

Glidescope video-laryngoscopes. Three types of Glidescope video-laryngoscopes are available: Glidescope, Glidescope Cobalt and Glidescope Ranger. The original Glidescope is reusable and consists of a plastic handle, a curved blade with a 60° angle in the midline and a camera, located midway along

Table 1

Video-laryngoscopes' features.

Video-laryngoscope	Blade shape	Monitor	Portability	Disposability	Size range	Anti-fog mechanism
Storz V-Mac	Standard Macintosh blade	Separate, 8 in. LCD monitor	No	Reusable	Pediatric, adult	No
Storz C-Mac	Standard Macintosh blade	Separate, 7 in. TFT monitor	Yes	Reusable	Sizes 2–4	Yes
Glidescope original	Angulated blade	Separate, 7 in. LCD monitor	No	Reusable	Sizes 2–5	Yes
Glidescope Cobalt	Angulated blade	Separate, 7 in. LCD monitor	No	Single-use blades	Sizes 1–4	Yes
Glidescope Ranger	Angulated blade	Separate, 3.5 in. LCD monitor	Yes	Reusable or single-use formats	Reusable: 3–4 Single-use: 1–4	Yes
McGrath	Angulated blade	Integrated, 1.7 in. LCD monitor	Yes	Single-use blades	Three adult lengths	No
Pentax-AWS	Anatomically shaped blade with a guide channel	Integrated, 2.4 in. LCD monitor	Yes	Single-use blades	One size available	No
Bullard	Anatomically shaped blade	External monitor (when used as a video-laryngoscope)	Not when used as a video-laryngoscope	Reusable	Three sizes available	No
Airtraq	Anatomically shaped blade with a guide channel	External monitor (when used as a video-laryngoscope)	Not when used as a video-laryngoscope	Single-use device	Four sizes available	Yes

the bottom of the blade.[10] The image is displayed on a monitor, which is positioned on a mobile stand.[22] Glidescope incorporates a very effective anti-fog mechanism with multiple heating elements, and so the image can remain clear in difficult situations.[10]

The Glidescope Cobalt is a single-use version of the Glidescope video-laryngoscope. It consists of a handle, a video baton, a disposable transparent plastic blade (stat) and a non-glare monitor. The video baton is inserted into the stat. Cobalt's handle can be attached to the blade, after the blade has been inserted into the mouth.[23]

The Glidescope Ranger is a portable, compact, battery-operated version of the original Glidescope, with a trans-reflective screen, which allows the operator to use it in bright sunlight. It is designed for military or emergency use in the pre-hospital setting.[24]

McGrath Series 5 video-laryngoscope. The McGrath Series 5 consists of three main parts: the handle, the camera stick and the blade. The handle contains a battery to power the device. A monitor is mounted on the top of the handle, allowing the operator to focus on the patient's face and the monitor screen simultaneously.[25] The length of the camera stick can be adjusted for different-size patients. The McGrath blade is disposable and covers the camera stick completely, in such a way that no part of the handle or the camera comes in contact with the patient's mouth.[25,26]

Video-laryngoscopes with a tube channel

These devices are anatomically shaped and use a guide channel, which directs the ETT towards the glottis. The ETT is preloaded to the guide channel. Then, the video-laryngoscope is inserted into the mouth in the midline, without displacing the tongue laterally, and advanced slowly until the epiglottis comes into view. The tip of the blade is then positioned posterior to the epiglottis, directly elevating it, so that the vocal cords are visualized.[27,28] It is important to place the glottic opening in the centre of the monitor. The ETT is then inserted into the trachea via the tube channel.[29,30]

The Pentax Airway Scope (AWS) consists of a disposable blade, an image tube with a camera and a monitor.[31] The transparent blade (PBlade) is curve-shaped to match the anatomy of the upper airway. As the image tube is inserted into the PBlade, it is protected from oral contamination. The PBlade also incorporates two parallel channels alongside the image tube. The main channel houses the ETT and accepts ETTs with outer diameters ranging from 8.5 to 11 mm. The second channel acts as a route for suction and application of local anaesthesia. The monitor is built at the top of the handle and has a wide viewing angle.[27] A limitation of AWS is fogging. According to the manufacturer, fogging is not frequent, because the camera is protected by the PBlade, which is being slightly warmed by the camera light.[31] The fogging can be minimized by applying an anti-fog solution or by immersing the PBlade in warm water before its use.[32]

Optical laryngoscopes

Even though not video-laryngoscopes by definition, optical laryngoscopes can be equipped with a video-camera and thus function as video-laryngscopes with a remote screen.

The Bullard laryngoscope is a rigid, indirect, fibreoptic intubation device. It consists of a laryngoscope handle with a light source, an S-shaped blade and fibreoptic bundles that both illuminate and transmit the view from the blade tip to the proximal viewing eyepiece. The Bullard incorporates a channel that is bifurcated at its proximal end; one port allows suctioning, oxygen delivery or application of local anaesthetics, while the other accepts the proximal end of a nonmalleable stylet. The viewing eyepiece allows the attachment of a conventional video endoscopy camera. The battery light source handle can be replaced by a handle that allows the connection of a light cable from an external light source. In this way, the image can be transmitted to an external monitor and the Bullard optical laryngoscope may function as a video-laryngoscope.[33]

The Airtraq optical laryngoscope has an anatomically shaped blade, similar to the AWS blade, which contains two parallel channels, the optical channel and the guiding channel, which accommodates the ETT. The image is transmitted to a proximal viewfinder. The viewing lens allows visualization of the larynx and the tip of the ETT.[34] Airtraq has a warming element at the tip of the blade. The Airtraq light should be turned on 1 min before use, to allow heating of the lens and prevent fogging.[35]

Ease of learning

The V-Mac has a short learning curve for the practicing anaesthesiologist. Kaplan and colleagues demonstrated that anaesthesiologists without any previous experience with the V-Mac had a 99.6% intubation success rate when using it. Because of its resemblance to Macintosh, operators experienced in direct laryngoscopy had no difficulty in learning to use it. The only challenge for the operator was to become familiar with the view on the monitor, and to coordinate the eyes and hands appropriately.[18] According to a prospective randomized crossover study, 37 novices found it easier to intubate with the V-Mac than with the Macintosh.[36]

Nouruzi-Sedeh et al.[37] demonstrated that only a few intubations were needed for the inexperienced users to achieve proficiency with the Glidescope, while the learning curve to reach an intubation success rate of 90% in direct laryngoscopy requires 47–56 patients.[38] Glidescope has many features in common with direct laryngoscopes; therefore, experienced anaesthesiologists can use it successfully without the need for any special training. Anaesthesiologists with no previous experience with the Glidescope had a 100% intubation success rate, while 97% of the patients were intubated successfully at first attempt.[39] Furthermore, anaesthesiologists unfamiliar with the Glidescope found intubation of manikins with a simulated difficult airway easier with Glidescope than with Macintosh.[40]

AWS can be used easily, both by novice personnel and by experienced anaesthesiologists. Manikin studies demonstrated that both naïve operators[41] and experienced anaesthesiologists[42] found intubation with AWS easier than with Macintosh. A prospective randomized cohort study showed that AWS reduced the intubation time and the incidence of failed intubation by inexperienced users. Therefore, less operator skill was required with AWS than with Macintosh.[43] When AWS was compared with Glidescope, both in simulated normal and difficult airway scenarios, naïve operators found it easier to intubate with AWS.[44]

Bullard laryngoscope has a steep learning curve and additional training may be required.[45] Shulman et al.[46] showed that it was easier for anaesthesiologists to learn to use Bullard when a video system was used and an expert gave them feedback. Airtraq can be easily used by inexperienced intubators. It has a rapid learning curve and novices find the use of Airtraq easier than Macintosh, after minimal training.[34,47,48]

Two manikin studies demonstrated that paramedics found it easier to intubate with video-laryngoscopes than with Macintosh.[49,50] As emergency tracheal intubations, outside or even inside the hospital, are often performed by inexperienced operators, the availability of a video-laryngoscope would raise the possibility of a successful outcome.

Clinical performance in normal and difficult airways

Video-laryngoscopes offer great visualization of the larynx, which is superior to that obtained with direct laryngoscopes.[14] The Storz V-Mac provides improved views of the larynx when compared with Macintosh (Table 2). In 83.5% of the patients who had difficult laryngoscopy with Macintosh, a better visualization was provided using the Storz.[17] Glidescope is designed to offer the advantage of being able to 'look around the corner'; therefore, C/L grades III or IV in direct laryngoscopy can be improved to grades I or II with Glidescope (Table 3). The C/L grades obtained with McGrath are the same as or better than the views obtained with direct laryngoscopy (Table 4). In a group of patients, who had at least two criteria associated with poor laryngoscopic views, the views obtained with McGrath were C/L grade I and II.[26] AWS offers significantly better views of the glottis compared with Macintosh (Table 5). With AWS, all patients with C/L grades III and IV in direct laryngoscopy became grades I or II. Table 6 illustrates the success rates and time of intubation with video-laryngoscopes as well as with the conventional Macintosh blade.

However, the improved laryngeal views are not always matched with a higher intubation success rate. Despite the clear visualization of the glottis, the insertion and advancement of the ETT with video-laryngoscopes may occasionally fail. In order to achieve successful intubation with video-laryngoscopes, the operator should follow each manufacturer's guidelines, with respect to ETT's pre-shaping and the proper manoeuvres when resistance to advancement of the ETT occurs.[51]

Furthermore, video-laryngoscopes do not seem to offer anything more than Macintosh in easy laryngoscopy (C/L grades I or II). The percentage of successful intubations was approximately the same with Macintosh, while the intubation time was prolonged with video-laryngoscopes.[40,52–54] The benefits of video-laryngoscopy are more distinct in difficult airways (C/L grades III or IV), as it converts 'blind' intubations into intubations under visual control. In difficult airways, video-laryngoscopy achieved the same or a higher intubation success rate, while the intubation time was the same as or less than that of direct laryngoscopy.[32,40,53,55]

Cervical spine instability/ immobilization

According to two fluoroscopic comparisons between Glidescope and Macintosh, Glidescope does not significantly decrease the movement of the cervical spine, but improves glottic visualization in patients with manual in-line stabilization.[56,57] Furthermore, in patients with ankylosing spondylitis, the Glidescope provided a better laryngoscopic view than Macintosh and allowed the

Table 2

Successful intubations with Storz V-Mac.

First author	Number of patients	Operators' experience with Storz V-Mac	Laryngoscopy	Intubation with Storz V-Mac		
			Improvement in the C/L grade with V-Mac	Overall success (%)	Success in difficult airways (%)	Intubation time (s)
Kaplan[18]	235 adults	Lack of familiarity with Storz	–	234/235 (99.6)	18/18 (100)	–
Kaplan[17]	867 adults	5–10 intubations with Storz in humans	101 C/L III → 16 C/L I and 65 C/L II. 22 C/L IV → 11 C/L I, 9 C/L II and 1 C/L III	862/865 (99.7)	121/123 (98.4)	–
Maassen[63]	150 morbidly obese adults	Good experience in the use of Storz	Mean C/L = 2 ± 0.9 → Mean C/L = 1.1 ± 0.26	50/50 (100)	14/14 (100)	17 ± 9
van Zundert[74]	450 adults	30 intubations with Storz	Mean C/L = 1.68 ± 0.81 → Mean C/L = 1.01 ± 0.11	150/150 (100)	–	18 ± 12
Jungbauer[82]	200 adults	Lack of familiarity with Storz	26 C/L III and 10 C/L IV → 10 C/L III and 0 C/L IV	99/100 (99)	45/46 (97.8)	40 ± 31

C/L, Cormack–Lehane.

Table 3

Successful intubations with Glidescope.

First author	Number of patients	Operators' experience with Glidescope	Laryngoscopy	Intubation with Glidescope		
			Improvement in the C/L grade with Glidescope	Overall success (%)	Success in difficult airways (%)	Intubation time (s)
Cooper[9]	728 adults	Limited or no previous experience with Glidescope	20 C/L III → 15 C/L I and 1C/L II. 15 C/L IV → 9 C/L I and 2 C/L II	696/722 (96.3)	15/18 (83.3)	–
Rai[10]	50 adults	No previous experience with Glidescope	2 C/L III → 1 C/L I and 1 C/L II	47/50 (94)	–	40
Nouruzi-Sedeh[37]	200 adults	Only manikin training	37 C/L III and 13 C/L IV → 5 C/L III and 3 C/L IV	93/100 (93)	–	63 ± 30
Xue[39]	91 adults	No previous experience with Glidescope	17 C/L III and 2 C/L IV → 19 C/L I and II	91/91 (100)	27/27 (100)	38 ± 11
Stroumpoulis[14]	112 adults	Good familiarity with Glidescope	28 C/L III and 13 C/L IV → 9 C/L III and 2 C/L IV	110/112 (98.2)	39/41 (95.1)	44.9 ± 19.7
Malik[55]	75 adults	Good familiarity with Glidescope	6 C/L III and 2 C/L IV → 0 C/L III and IV	24/25 (96)	–	17 ± 12.31
Malik[52]	120 adults with c-spine immobilization	Good familiarity with Glidescope	5 C/L III → 0 C/L > II	30/30 (100)	–	18.9 ± 6
Maassen[63]	150 morbidly obese adults	Good familiarity with Glidescope	Mean C/L = 2.1 ± 0.8 → Mean C/L = 1.1 ± 0.24	50/50 (100)	17/17 (100)	33 ± 18
Liu[73]	70 adults with c-spine immobilization	Good familiarity with Glidescope	14 C/L III and 6 C/L IV → 0 C/L III and IV	31/35 (88.6)	–	71.9 ± 47.9
van Zundert[74]	450 adults	More than 30 intubations with Glidescope	Mean C/L = 1.68 ± 0.76 → Mean C/L = 1.01 ± 0.11	150/150 (100)	–	34 ± 20
Sun[53]	200 adults	Good familiarity with Glidescope	15 C/L III → 8 C/L I and 6 C/L II	100/100 (100)	15/15 (100)	46
Xue[83]	57 adults	Good familiarity with Glidescope	–	30/30 (100)	–	37.4 ± 9.9

C/L, Cormack–Lehane; c-spine, cervical spine.

nasotracheal intubation in the majority of these patients.[58] A recent study demonstrated that both Glidescope and AWS reduced the Intubation Difficulty Score, improved the C/L grade and reduced the need for optimization manoeuvres in patients with cervical spine immobilization, compared with Macintosh.[52] In addition, AWS performed better than Macintosh in patients with restricted neck mobility, even when a gum elastic bougie was used with Macintosh to aid intubation.[59] Videofluoroscopic studies have shown that the upper cervical spine movement was significantly decreased during intubation with AWS compared with Macintosh and McCoy direct laryngoscopes in patients with in-line stabilization.[60,61] When a gum elastic bougie was used to aid intubation with AWS, the extension of the cervical spine was even more reduced.[62] A recent manikin study, which compared the performance of Storz-VMac to Macintosh in a 'stiff neck scenario', showed that the percentage of glottic opening was significantly improved with V-Mac.[50]

Obese patients and awake intubation

When three video-laryngoscopes were used in morbidly obese patients, the Storz V-Mac had a better overall satisfaction score, intubation time, number of intubation attempts and necessity for extra adjuncts, compared with Glidescope and McGrath. McGrath showed the worst performance among the three.[63] Airtraq can be an effective intubation device in morbidly obese patients,[64] as

Table 4

Successful intubations with McGrath.

First author	Number of patients	Operators' experience with McGrath	Laryngoscopy	Intubation with McGrath		
			Improvement in the C/L grade with McGrath	Overall success (%)	Success in difficult airways (%)	Intubation time (s)
Shippey[26]	150 adults	20 intubations with McGrath on manikins	–	147/150 (98)	18/18 (100)	24.7
Maassen[63]	150 morbidly obese adults	Good familiarity with McGrath	Mean C/L = 2 ± 0.83 → Mean C/L = 1.1 ± 0.28	50/50 (100)	14/14 (100)	41 ± 25
van Zundert[74]	450 adults	30 intubations with McGrath	Mean C/L = 1.77 ± 0.83 → Mean C/L = 1.01 ± 0.08	150/150 (100)	–	38 ± 23
O'Leary[81]	30 adults in whom direct laryngoscopy failed	No previous experience with McGrath	12C/L > II → 2 C/L > II	25/30 (83.3)	–	–
Walker[84]	120 adults	Good familiarity with McGrath	0 C/L III and IV → 1 C/L III and 0 C/L IV	60/60 (100)	–	47

C/L, Cormack–Lehane.

Table 5

Successful intubations with Pentax-AWS.

First author	Number of patients	Operators' experience with Pentax-AWS	Laryngoscopy	Intubation with Pentax-AWS	
			Improvement in the C/L grade with Pentax-AWS	Overall success (%)	Intubation time (s)
Asai[31]	100 adults	Only manikin training	–	98/100 (98)	35
Suzuki[27]	320 adults	Good familiarity with Pentax-AWS	42 C/L III → 42 C/L I. 4 C/L IV → 3 C/L I and 1 C/L II	320/320 (100)	20.1 ± 9.6
Hirabayashi[29]	405 adults	Only manikin training	15 C/L III and 1 C/L IV → 16 C/L I and II	405/405 (100)	42.4 ± 19.7
Hirabayashi[30]	40 adults	Only manikin training	–	20/20 (100)	33 ± 12
Hirabayashi[43]	520 adults	No previous experience with Pentax-AWS	–	264/264 (100)	44 ± 19
Malik[55]	75 adults	Good familiarity with Pentax-AWS	6C/L III and 2C/L IV → 0 C/L III and IV	25/25 (100)	15 ± 8.31
Malik[52]	120 adults with c-spine immobilization	Good familiarity with Pentax-AWS	5 C/L III → 0 C/L > II	29/30 (96.7)	16.7 ± 7.6
Komatsu[59]	96 adults with c-spine immobilization	Over 50 intubations with Pentax-AWS	–	48/48 (100)	34 ± 13
Liu[73]	70 adults with c-spine immobilization	Good familiarity with Pentax-AWS	10 C/L III and 9 C/L IV → 0 C/L III and IV	35/35 (100)	34.2 ± 25.1
Asai[32]	293 adults	More than 10 intubations with Pentax-AWS	208 C/L III → 203 C/L I and 4 C/L II 48 C/L IV → 43 C/L I and 5 C/L II	290/293 (99)	–
Enomoto[54]	203 adults with restricted neck movement	No previous experience with Pentax-AWS	21 C/L III → 21 C/L I 1 C/L IV → 1 C/L I	99/99 (100)	53.8 ± 13.7
Malik[85]	90 adults with c-spine immobilization	Good familiarity with Pentax-AWS	2 C/L III and 0 C/L IV → 0 C/L III and IV	30/30 (100)	10 ± 8.15

C/L, Cormack–Lehane; c-spine, cervical spine.

it achieved rapid and safe intubation and its performance was superior to that of Macintosh.[65]

Although there are limited data, Glidescope,[66] McGrath,[67] Bullard[68] and Airtraq[69] have been used successfully in awake intubation, as they are less stimulating for the patient than direct laryngoscopes and do not require head and neck manipulation.

Table 6

Video-laryngoscopes vs. Macintosh direct laryngoscope.

First author	Number of patients	Type of video-laryngoscope used	Operators' experience with video-laryngoscope	Intubation with video-laryngoscope		Intubation with Macintosh	
				Overall success (%)	Intubation time (s)	Overall success (%)	Intubation time (s)
Jungbauer[82]	200 adults	Storz V-Mac	No previous experience with V-Mac	99/100 (99)	40 ± 31	92/100 (92)	60 ± 77
Nouruzi-Sedeh[37]	200 adults	Glidescope	Only manikin training	93/100 (93)	63 ± 30	51/100 (51)	89 ± 35
Malik[55]	75 adults	Glidescope	Good familiarity with Glidescope	24/25 (96)	17 ± 12.31	21/25 (84)	13 ± 8.23
Malik[52]	120 adults with c-spine immobilization	Glidescope	Good familiarity with Glidescope	30/30 (100)	18.9 ± 6	28/30 (93.3)	11.6 ± 6
Sun[53]	200 adults	Glidescope	Good familiarity with Glidescope	100/100 (100)	46	99/100 (99)	30
Xue[83]	57 adults	Glidescope	Good familiarity with Glidescope	30/30 (100)	37.4 ± 9.9	27/27 (100)	28.4 ± 11.7
Walker[84]	120 adults	McGrath	Good familiarity with McGrath	60/60 (100)	47	60/60 (100)	29.5
Hirabayashi[30]	40 adults	Pentax-AWS	Only manikin training	20/20 (100)	33 ± 12	20/20 (100)	59 ± 29
Hirabayashi[43]	520 adults	Pentax-AWS	No previous experience with Pentax-AWS	264/264 (100)	44 ± 19	256/256 (100)	71 ± 44
Malik[55]	75 adults	Pentax-AWS	Good familiarity with Pentax-AWS	25/25 (100)	15 ± 8.31	21/25 (84)	13 ± 8.23
Malik[52]	120 adults with c-spine immobilization	Pentax-AWS	Good familiarity with Pentax-AWS	29/30 (96.7)	16.7 ± 7.6	28/30 (93.3)	11.6 ± 6
Komatsu[59]	96 adults with c-spine immobilization	Pentax-AWS	Over 50 intubations with Pentax-AWS	48/48 (100)	34 ± 13	43/48 (89.6)	49 ± 27
Enomoto[54]	203 adults with restricted neck movement	Pentax-AWS	No previous experience with Pentax-AWS	99/99 (100)	53.8 ± 13.7	93/104 (89.4)	50.5 ± 27
Malik[85]	90 adults with c-spine immobilization	Pentax-AWS	Good familiarity with Pentax-AWS	30/30 (100)	10 ± 8.15	30/30 (100)	11 ± 9.13

c-spine, cervical spine.

Training and teaching

The Storz video-laryngoscope can be a useful adjunct when teaching laryngoscopy and intubation.[18] The high-quality, enlarged image on its monitor allows the instructor to demonstrate the anatomy of the upper airway and the procedures of laryngoscopy and intubation to novices. Moreover, when a novice is attempting intubation, the instructor is able to watch the monitor and provide feedback.[36] Storz is the only video-laryngoscope that is appropriate for intubation teaching, because it has a standard Macintosh blade and, therefore, the intubation procedure is identical to the traditional one. With Storz, the 'peer over my shoulder' teaching method is displaced, considerable is saved and many unnecessary intubation attempts can be avoided.[18] Video-assisted instruction with Storz may shorten the learning curve of direct laryngoscopy and intubation for novices.[36]

Limitations, problems and possible solutions

Difficulty in instrument insertion

Storz V-Mac has a large handle and cables emerging from the top of the handle. Because of these features, the operator may encounter difficulty in inserting the blade the conventional way, especially in obese patients with large chests or breasts. In these cases, the initial insertion of the V-Mac should be performed diagonally, with subsequent positioning of the blade.[17]

Difficulty may also be encountered with the insertion of Glidescope. Because of the 60° angulation, the handle has to be tilted even more than the Macintosh handle, in order for the blade to enter the oral cavity. However, the anterior chest wall of some patients (obese, with short neck or large breasts, etc.) may inhibit the tilting of the handle. Unlike Cobalt and McGrath,[70] the original Glidescope's blade cannot be separated from the handle (which is larger than the Macintosh handle). Thus, the only way to facilitate the insertion of the blade is to further extend the atlanto-occipital joint and to rotate the handle by 90° to the right.[39]

ETT insertion

Difficulty in passing the ETT through the vocal cords, despite the improved visualization of the glottis, has been reported when using angulated video-laryngoscopes.[10,39] A very common problem is that the ETT can be seen posterior to the arytenoids. In this case, several manoeuvres could help; the ETT should be pulled superiorly, rotated over the left arytenoid and gently twisted over the epiglottic aperture. Moreover, external laryngeal pressure and withdrawal of the blade, in order to lessen the tilting of the laryngeal axis and reduce the introduction angle, may be helpful.[71] If the ETT abuts the glottic lip, the operator should turn the ETT while withdrawing the stylet.[20] Sometimes, the ETT's advancement may be impossible, as it may strike the anterior tracheal wall because of the stylet's angle. In this case, the operator should withdraw the stylet by approximately 4 cm, withdraw the video-laryngoscope by 1–2 cm and rotate the ETT slightly, to facilitate its passage into the trachea.[10,70] These problems do not exist with laryngoscopes that incorporate a guiding channel, such as the AWS and the Airtraq, as the ETT is simply pushed along the channel, through the vocal cords.[72]

A possible problem with AWS is the difficulty in inserting the tip of the PBlade into the posterior surface of the epiglottis, with the tip of the blade repeatedly entering the vallecula. In these cases, the epiglottis obstructs the insertion of the ETT. This is corrected by partially withdrawing the device and, with a scooping movement of the PBlade, the intubator lifts the epiglottis and advances the ETT through the vocal cords. A second solution is to insert a gum elastic bougie through the ETT and into the trachea and then railroad the ETT over the bougie via the vocal cords.[73] When the tip of the PBlade is correctly placed behind the epiglottis, it may be impossible to align the target symbol with the laryngeal aperture. Therefore, difficulty in advancing the ETT may be faced, as the ETT tip may swerve from the target and collide with the arytenoids. In this situation, external pressure should be applied on the thyroid cartilage in order to displace the larynx and force the tube's tip to slide into the glottis. Another solution is to use a gum elastic bougie with a smaller diameter and an angulated tip.

Difficulties with ETT insertion do not occur very often with Storz V-Mac, as it displaces soft tissues the same way that Macintosh does, making room for the insertion of the ETT and limiting the need for stylet use, compared with the angulated video-laryngoscopes. As no stylet and pre-shaping of the ETT is required in most of the cases, the intubation process is usually faster with the Storz V-Mac and the potential complications from the stylet use can be avoided.[74] On the other hand, the sharp angle of the angulated video-laryngoscopes may be advantageous in patients with anatomic variations, such as anterior larynx, micrognathia, etc.[63]

Complications

Laryngoscopy with Glidescope requires less upward lifting force (4.9–13.7 N) to expose the glottis, compared with Macintosh (35–47.6 N).[75] Needless to say that less oropharyngeal injuries are caused if less force is applied to the soft tissues. However, some injuries such as perforation of the palatopharyngeal arch,[76] the palatoglossal arch[77] and the soft palate[78] have been reported with the Glidescope. These have an explanation; in video-laryngoscopy, the monitor may attract the operator's visual attention from the mouth, increasing the possibility of injuring the patient. Moreover, as the laryngoscope is inserted, upward force in order to expose the glottis may stretch the palatopharyngeal arch. Advancement of the ETT, which may not be visible until it appears on the monitor, may perforate the trachea. Cooper observed the existence of a potential blind spot during intubation with the Glidescope, at the point where the operator loses direct sight of the ETT tip, until it comes into the camera's visual field.[79] Other possible reasons for the injuries are the use of too large blades, rigid stylets or unnecessary force during the insertion of the ETT. In order to avoid complications, the ETT insertion should be directly observed, until it reaches the uvula and then the operator's attention should be directed to the monitor.[79] Another solution is to insert the ETT into the mouth first and then insert the Glidescope, especially in patients with a narrow oral cavity.[77]

No complications have been reported with the use of Storz V-Mac. On the contrary, recent studies demonstrated that less force is applied to maxillary incisors with V-Mac compared with the Macintosh laryngoscope.[80] Only minor complications have been reported with McGrath, such as a small amount of blood-stained secretion in the oropharynx after the video-laryngoscope's withdrawal.[81] No major complications have been reported with AWS. Its structural features, the lack of a stylet and the continuous observation of the intubation procedure reduce the risk of oral and pharyngeal injury.[27]

Conclusions

Video-laryngoscopes are promising intubation devices, which provide a great visualization of the larynx and have a high intubation success rate. Each particular device has different features, which may constitute advantages or disadvantages, depending on the situation that the anaesthesiologist has to deal with. Their precise role in airway management remains to be established.

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