EXPERT REVIEW OF MEDICAL DEVICES
https://doi.org/10.1080/17434440.2022.2142558

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REVIEW

Video laryngeal masks in airway management

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ABSTRACT

Introduction: Video laryngeal masks have become alternatives to classical supraglottic airway devices in recent years. This review provides information on the background of these new medical devices, the most popular and widely used video laryngeal masks, their advantages, disadvantages and their main applications in airway management.

Areas covered: In this review, the physical differences between video laryngeal masks and second-generation laryngeal mask airways, and their properties in specific clinical settings are discussed.

Expert Commentary: To limit airway-related morbidity, an optimal position of supraglottic airway devices must be the primary goal. Extensive research has shown that blindly inserted laryngeal mask can be malpositioned in 50% to 80% of the cases. Therefore, blind insertion should be the exception rather than the rule unlike current practice. Video laryngeal mask airways have clear advantages in routine use and in difficult airway management since they allow a vision-guided technique. Henceforth, the properties perceived in clinical practice must be endorsed with quality clinical evidence.

ARTICLE HISTORY
Received 2 August 2022
Accepted 28 October 2022

KEYWORDS
Airway management; laryngeal masks airways; videolaryngoscopy; endotracheal intubation; optical devices; safety management; economics

1. Introduction

Airway management is a relevant issue for practicing anaesthesiologists, intensivists, and emergency physicians since inability to secure the airway is an important cause of adverse-related outcomes [1]. Technological development and advances in knowledge and training have reduced the frequency of adverse events [2]. However, this medical problem is far from being solved [3]. The enormous scientific production on the subject in recent years is a reflection of this assertion [4].

Failure of one technique to treat the airway increases the risk of failure of successive techniques, increasing the number of attempts and therefore, the risk of trauma and edema in the airway, hypoxia, aspiration, and progression to a 'cannot intubate, cannot oxygenate' situation (CICO) [5]. Thus, the main objective of safe airway management is to limit its instrumentalisation as much as possible [6,7]. For this reason, it is essential to have effective devices for airway management, both in its primary approach and as backup plans in all situations to achieve an atraumatic and timely treatment. Videolaryngoscopy, the fiberoptic bronchoscopy and supraglottic airway devices (SADs) have shown their efficacy, safety and reliability as primary and rescue devices to secure the airway. However, no instrument is perfect in all circumstances, so efforts to develop new devices must continue.

Video laryngeal masks (VLMs) are an evolution of second-generation SADs. These devices incorporate the insertion of a videoscope into a second-generation laryngeal mask. It allows to visualize the previously blind process of insertion and placement of the SAD, correct its position securing optimal gas exchange, and perform a vision-guided tracheal intubation (TI) through the ventilation channel. Despite they shares most of the features of the latest, the inclusion of this improvement has served them to receive the denomination of 'third-generation SADs' [8].

The aim of the present article was to review the background of these medical devices, to describe the most popular and widely used video laryngeal masks, their advantages, and their main applications in airway management.

2. Background. Supraglottic airway devices

When Archie Brain introduced the LMA-Classic in the 1980s, it revolutionized the airway armamentarium of anesthetists. It meant the start of a large group of SADs, which primarily act as a passageway for delivery of oxygen and anesthetic gases, allowing spontaneous and positive pressure ventilation. The aim is to insert the airway device into the hypopharynx, forming an airtight seal enclosing the larynx inlet. The popularity of SADs results from a handsfree approach to airway management that does not involve the insertion of a tracheal tube, while avoiding hand fatigue of the operator holding a facemask. Originally targeted for simple surgical procedures, SADs gradually gained more widespread use and are currently

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Article highlights

- Video laryngeal masks (VLMs) are the latest evolution of supraglottic airways. Their vision-guided insertion could improve their placement and thus avoid the incidence of malposition.
- These devices allow tracheal intubation without fiberoptic assistance; therefore, they could be advantageous as a rescue device in locations where a fiberoptic bronchoscope is not available and in situations where there is not enough time.
- VLMs provide continuous oxygenation-guided intubation which is particularly advantageous in patients with poor preoperative pulmonary reserve.
- Further evaluation is necessary to confirm their precise role in the airway armamentarium.

the most used airway device in the world. Advanced models with specific designs for better performance and higher patient safety were developed by a large group of competitive manufacturers, each producing their own specific SAD, although many 'me-too' devices came on the market.

2.1. Definition and improvements

A large group of devices inserted via the mouth, not penetrating the larynx, used for temporary management of the airway, are most widely referred to as SADs, although other terms as supralaryngeal, extraglottic and periglottic airways are also in use. SADs are categorized by generation and number of lumina (first, second, third), by sealing mechanism (cuffed/non-cuffed) and by scoring sealing (perilaryngeal, pharyngeal, and anatomically preshaped sealers). However, a uniform classification system of SADs that is both easy and helpful for selecting a device, is still not available [9,10]. These devices come in a large range of brands and sizes (for pediatrics and adults), materials (silicone vs PVC), cuffed and non-cuffed devices, whereby some SADs provide additional features (esophageal vents, integral bite blocks, in-built cuff pressure monitor), which may be used in unique settings (for gastroscopy, wire reinforced flexible SADs, self-inflating low-pressure cuffs). Other modifications have been disputed: e.g. mask aperture bars, crossbars over the aperture designed to prevent passive herniation of the epiglottis into the mask opening, may not prevent the epiglottis from obstructing the airway and may even cause airway trauma [11–13]; the presence of a fixation tap or guiding handle may limit the insertion depth of SADs as it may not pass the teeth [14].

2.2. What is an ideal SAD?

An ideal SAD should allow easy insertion of the device, which is a less invasive, less stimulating and less traumatic means of securing the airway than an endotracheal intubation and therefore will be better tolerated by patients and more appreciated by anesthetists as a valuable airway device. Desirable characteristics of SADs include: a) to have a record of a high first-attempt successful insertion rate of the device; b) to provide adequate ventilation of both lungs with minimal or no injury to the pharyngeal mucosa and larynx; c) to allow for easy insertion of a gastric tube with a high first-attempt successful gastric tube insertion rate through a wide gastric channel; d) to protect the airway from aspiration, with early detection of regurgitation during both the insertion and maintenance phases of anesthesia; e) to allow high airway seal pressures during spontaneous and positive pressure ventilation, with low resistance to the gas flow; f) to act as an intubating conduit for tracheal tube insertion via its wider ventilation tract, not obstructed by a non-detachable connector; g) to include features designed to monitor intracuff pressure and prevent overinflation and underinflation of the cuff; h) to adjust correct sizing and allow for dimensional compatibility of all aspects of the SAD, as ventilation and gastric tubes need to avoid to be too narrow, to permit insertion of adequate sizes of endotracheal and gastric tubes; and i) to allow to intubate through the SAD using various techniques and composite assemblies, such as a fiberoptic scope, an Aintree intubation catheter or a flexible exchange airway catheter [15–18]. The fiberoptic scopes used have several incompatibilities in length and diameter [19].

2.3. More and more indications for the use of SADs

Thanks to many improvements, the indications for use of SADs as the principal airway device, have increased significantly since their inception, e.g. in the operating room, for prehospital airway management, the emergency department, obstetrics, ICU, obese population (limited to patients with BMI < 35 kg/m^2), . . . and as a rescue device option in emergency situations [20–24]. The latter issue is outlined by the American Society of Anesthesiologists (ASA) practice guidelines for the management of the difficult airway, following a failed intubation attempt, whereby the SAD can be lifesaving in re-establishing an airway when ventilation by facemask and endotracheal intubation is impossible and where otherwise, a surgical airway (front of neck access) would be required.

2.4. Complications

Although SADs are easy devices to use, troubleshooting can be indicated and requires a flexible and skillful anaesthetist to solve issues related to insertion and maintenance: a) inadequate anasthesia may result in insufficient depth of anesthesia with breath holding, straining, laryngospasm, bronchospasm and airway obstruction; b) the tip of the epiglottis can be downfolded, resulting in air leakage or airway obstruction; c) inappropriate sizing of the device may result in difficulties obtaining an adequate seal; d) patients anatomy can make insertion problematic; e) the distal tip of the cuff can be downfolded backwards or sit across the vocal cords [25–27].

SADs do not provide complete protection against aspiration or regurgitated stomach contents, even if correctly placed [28]. Placement of SADs may even predispose to regurgitation by relaxing the lower esophageal sphincter [29], which results in a decrease in the lower esophageal sphincter barrier pressure. Especially, if the distal tip of the airway device does not sit correctly to block the entrance to the esophagus, acting as a plug to prevent aspiration, there is no protection. Furthermore, vomiting or an increase in intra-abdominal

pressure can overcome the SADs capacity to prevent pharyngeal reflux. Aspiration with SADs occurs more often in patients with risk factors (e.g. full stomach, acute trauma patient, upper gastro-intestinal disease), whereby surgical factors (intra-abdominal pressure, lithotomy/prone position), and anesthesia factors (depth of anesthesia, level of cuff inflation) also play an important role. Failed placement of SADs do occur when the anaesthetist is not well trained or is not used to administer anesthesia with the help of an SAD.

Potential complicates are due to a (forceful) insertion of SADs causing trauma and injury to: a) teeth, lips, tongue; b) mucosa of the oropharynx (blood staining, bleeding); c) glottic structures (vocal cords, epiglottis, arytenoids); d) nerves (recurrent laryngeal, lingual, hypoglossal, inferior alveolar nerves); e) lungs (pulmonary edema may follow vigorous biting on the shaft of the SAD resulting in complete obstruction of the airway); f) laryngospasm and bronchospasm; and g) temporomandibular joint dysfunction [1,30,31]. Sore throat, dysphonia, and dysphagia may result after incorrect insertion of the device or inadequate monitoring of intracuff pressure, avoiding hyperinflation, which results in a decrease in mucosal perfusion. Meticulous attention to the correct insertion process and continuous evaluation of intracuff pressure (during induction and maintenance of anesthesia) is warranted to avoid these traumata.

2.5. Sizing can be problematic

Sizing is a difficult process, with predicting the optimal size most of the time based on manufacturers' specifications, based on weight or height of the patient. Nevertheless, only visual inspection of the device sitting into the hypopharynx is the best technique to guarantee a good match between device and patient anatomy. An ideally positioned and appropriately size fitted SAD should have the tip of the epiglottis aligned with the rim of the proximal cuff, whereby the epiglottis rests on the outside of the device on the inflated cuff. Both an SAD that sits too deep or too superficial, or an SAD whereby the cuff is inadequately inflated (aim at 40 to 60 cmH_20) will result in gas leakage and pollution of the atmosphere in an operating room. Intracuff pressure can be measured using a handheld manometer or a built-in manometer. As intracuff pressures may vary during the maintenance of anesthesia, it is advised to monitor either intermittent or continuously these pressures.

2.6. Oropharyngeal leak pressure

Oropharyngeal leak pressure (OPLP) is considered the golden standard as an indirect measure of successful placement, adequate performance of SADs and as a comparator between devices. A higher OPLP (>25 cmH_20 or >8 cmH_20 above the peak inspiratory airway pressure under positive pressure ventilation) ensures adequate ventilation and protection of the airway to reduce the risk of aspiration [28]. The outcome of OPLP may be affected by changes in the upper airway (anatomical, physiological), patient position and head-neck flexion and extension, depth of anesthesia (whether muscle relaxants are used or not), type of surgery, type of SAD brand and material used and volume of air inflated. However, OPLP is mostly affected by how well the SAD sits in the hypopharynx. Without a correctly placed SAD in the hypopharynx, no conclusions can be drawn about the OPLP. The OPLP measurement is based on the premise that the blindly inserted airway device is sited properly between the base of the tongue and the hypopharynx, producing a close anatomic match between SAD cuff and surroundings. OPLP measurements in an inadequately placed SAD will yield suboptimal results [10,32–34].

2.7. Correct positioning is of prime importance

The correct placement of SADs is of paramount importance to obtain reliable performance of the device and optimal oxygen delivery to the lungs. This requires proper perilaryngeal sealing to stop fluids from entering the airway and protect for pulmonary aspiration (first seal) and esophageal sealing to constitute a barrier to the entry of gastric content into the pharynx and subsequently into the airway (second seal). The SAD does not seal the pharynx. Therefore, the pressure to ventilate the lungs is limited by gas leakage around the device, with potential resultant gastric insufflation and hypoventilation. This implies that pressure-limited ventilation is preferred over volume-control ventilation. However, spontaneous ventilation with an SAD offers several advantages over controlled breathing: a) insufflation of the gastro-esophageal tract is rarely a problem; b) leakage of air is less likely an issue; c) titration of opioids according to the patients respiratory rate is easier; and d) the use of neuromuscular blocking agents is not essential to place the device.

Clinical confirmation of correct positioning of the SAD is established by: a) adequate insertion depth of the device in the patients mouth; b) appropriate chest rise with each breath; c) a normal capnogram trace and adequate oxygen saturation levels; d) low ventilation pressure during positive pressure ventilation; and e) the absence of air leakage with positive ventilation using peak pressures up to 20 mmHg.

2.8. Placement tests to check the position of SADs

Several observational tests are used to determine optimal placement: i.e. suprasternal notch test, bubble test, audible noise detection at the mouth, insertion of an orogastric tube through the gastric channel without resistance and passing a fiberscope or videoscope through the ventilation lumen to view the relationship between the device, the vocal cords, and epiglottis (first seal). However, no information is obtained about the position of the distal cuff and the esophagus (second seal), nor does it yield information whether a correctly-sized SAD has been inserted, while corrective maneuvers are not possible. Ultrasound seems to be as effective as fiberoptic examination of SAD placement, although could not detect suboptimal depth of SADs [35,36].

2.9. Solution – the third generation SAD

If all these subjective tests, including OPLP and intracuff pressure measurements do not provide evidence of an optimal position of the SAD, then perhaps we no longer should use

'blind' insertion techniques, but opt for vision-guided insertion techniques. Videolaryngoscopy may be the answer, but add problems to an already crowded oropharynx [37]. A solution is the new videolaryngeal mask airways whereby a videoscope is inserted into a blind-ended canal [38].

3. Video laryngeal masks

The VLMs are an integral, multifunctional supraglottic airway device consisting of two parts [38]: (1) a second generation disposable SAD with anatomically curved shaped, separate gastric and ventilation channel allowing a functional separation, built-in bite block, silicone cuff, and a reinforced distal tip which allows a more compact seal and therefore a higher oropharyngeal sealing pressure; (2) a reusable flexible videoscope with built-in or stand-alone display. The videoscope is assembled in a closed tip completely sealing channel of the SAD specially designed to harbor it, preventing the reusable part from coming into contact with the patient to avoid contamination. The connection incorporates a click lock, which allows a solid hold of both parts and disconnection after finishing the procedure. This configuration allows easy assembly, usability, and the separation of the components from each other.

The described arrangement of the VLMs allows to combine the advantages of an integrated video laryngoscope incorporated in a 2nd generation SAD. The main VLMs are described below according to the earliest to the latest incorporation into clinical practice.

3.1. LMA CTrach

The LMA CTrach (The Laryngeal Mask Company, Le Rocher, Victoria, Mahe, Seychelles) was incorporated on the market in 2005. It is a variant of the LMA Fastrach especially useful for airway rescue in cases of failed facemask ventilation or TI.

This VLM has 2 fibreoptic channels and a detachable liquid crystal display viewer. One of the fiberoptic channels transmit light from while the other one transmit the image to the viewer. This disposition allows ventilation and TI under direct vision in real time. Likewise, this device has an elevating bar as the LMA Fastrach, which raises the epiglottis during the passage of the ETT into the larynx. It has a rechargeable battery for up to 30 min of continuous use with a charger cradle for recharging the viewer. There are three sizes for patients weighing 30 kg or more (#3 for patients with body weight <50 kg, #4 for patients 50–70 kg and #5 for patients >70 kg).

The insertion of the LMA CTrach can be difficult in patients with a mouth opening of less than 3 cm or prominent incisors [39]. It has a thicker shaft compared to the LMA Fastrach due to the embedded optical fibers of the system. Two maneuvers can be helpful to facilitate the insertion of the LMA CTrach [40]: dorsal and downward pressure over the shaft at the point where it hinges against the incisors while continuing the one handed rotational insertion; and lateral insertion of the device till the cuff is inside the oral cavity and then rotation 90° and complete the insertion.

Successful ventilation could be achieved in up to 100% of patients of general population with the LMA CTrach [41–45]. The overall success rate of TI was 89.7–100% [41–47]; the first attempt success rate was 93.3%, instead of 67.9% for the LMA Fastrach [47]. A 100% success rate of ventilation and intubation has been reported in out-of-hospital emergencies, despite visualization of the laryngeal structures was achieved only in 69% of patients [48].

In another prospective evaluation in 328 patients, view of the vocal cords was only initially achieved in 59% of patients [46]. Poor glottic views indicate a suboptimal position. Some additional maneuvers can improve the glottic visualization and therefore, facilitate TI (up-down maneuver, Chandy maneuver, external larynx manipulation, bimanual mandibular elevation and gentle lateral movements of the device) [46,49,50]. Up-down maneuver can improve the vocal cords view in 80% of the patients in whom there is no initial vision [46]. Chandy maneuver helps to guide the ETT toward the glottis, avoiding its displacement toward the esophagus [49].

There are no prospective studies on difficult airway, although the use of LMA CTrach as a primary approach or rescue device after failed TI has been described in several case series. The rate of success ventilation and TI in these series was 100% and 95.8–100%, respectively [39,49,51,52]. Awake TI in difficult airway was associated with a good tolerance and high success rates [53].

CTrach was the best supraglottic device for unassisted intubation (understood as one that is performed without the help of another device inserted into the larynx or pharynx) along with the LMA Fastrach [18]. Unassisted intubation through the LMA CTrach was significantly faster than fiberoptic-guided intubation through the LMA Fastrach and equally successful [54].

Time to TI was significantly longer in morbidly obese patients than patients with a BMI < 30 $kg.m^{-2}$ [55]. Likewise, LMA CTrach required more optimization maneuvers and time to achieve tracheal intubation than LMA Fastrach [56], Glidescope videolaryngoscope [57] or direct laryngoscopy, although decreased the apnea period, and improved alveolar oxygenation, glottic visualization and overall success TI rate [57–59].

Manual in-line stabilization did not impoverish any variable related to use LMA CTrach [60]. In this setting, it was associated with a longer time to glottic view and TI, and a greater number of optimization maneuvers compared to videolaryngoscopy [61,62], although contradictory results have been obtained [63]. Several studies on elective cervical surgery showed the upper cervical spine mobilization could be less with the LMA Ctrach than with other airway devices [64–66].

Recently, it has been reported that the LMA CTrach was as effective as fiberoptic bronchoscopy for visualization of laryngeal structures after thyroidectomy requiring minor time to optimal laryngeal view [53]. Unfortunately, the distribution of the LMA CTrach has been discontinued [38].

3.2. Totaltrack VLM

The Totaltrack VLM (MedComflow S.A., Barcelona, Spain) is a hybrid device, which combines some features of an endotracheal tube, a supraglottic airway and a videolaryngoscope. The device allows simultaneous ventilation and intubation

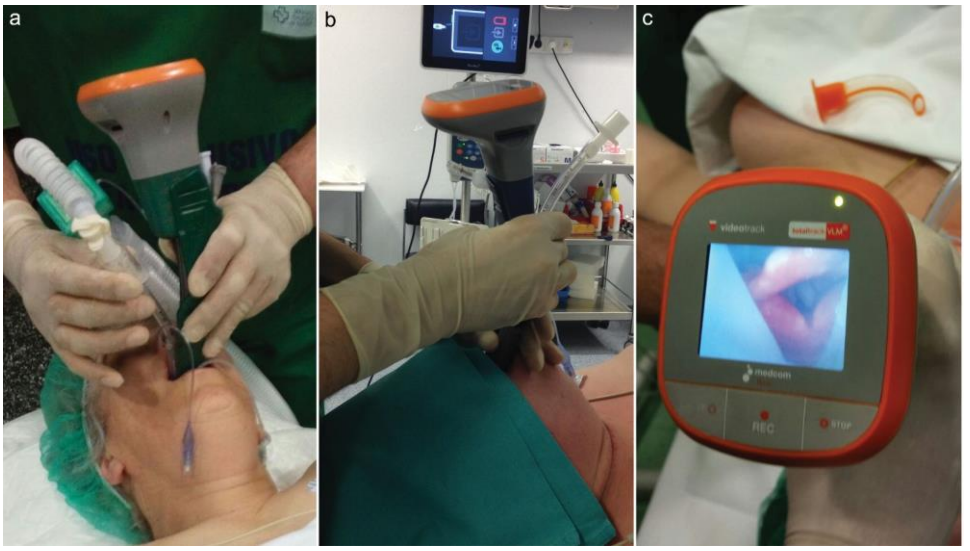

Figure 1. Development of totaltrack in clinical scenarios. Panel A. Tracheal intubation after induction of general anesthesia. Panel B. Awake tracheal intubation with the totaltrack. Panel C. Visualization of the glottic structures using the videotrack.

with continuous visualization of the larynx during both maneuvers (Figure 1). It is made up of several parts: 1) a detachable and reusable system (Videotrack) composed of a 2.5-inch TFT color monitor, a camera with an anti-fogging system and a LED light source, a RCA type connector for transmitting the image to a TV or external monitor and a slot for inserting a SD memory card, 2) a PVC flexible disposable structure that contains the battery, a channel on the left to accommodate the Videotrack optical guide and one on the right for inserting the endotracheal tube, the laryngeal mask and two dedicated channels for aspiration both the stomach and internal mask secretions, 3) a disposable anatomical-shape blade made of a rigid polycarbonate exoskeleton with a 90 degree curve. The device comes in two different sizes: size 3 for patients between 50 and 70 kg, which allows for the passage of standard PVC orotracheal tube from ID 6.5 up to 7.5 and reinforced tubes with a maximum ID of 7.0. Size 4 is recommended for patients between 70 and 100 kg, valid for standard PVC orotracheal tubes from ID 7.0 up to 8.5 and reinforced tubes with a maximum ID of 8.0. It has a relatively slim profile enabling insertion with an interincisors gap of 18 (size 3) and 20 mm (size 4).

The Totaltrack VLM has been used for securing the airway for emergent surgery in uncooperative patients with cervical masses causing airway distortion and trismus [67,68]. It has also been used as a rescue device after failed ventilation and tracheal intubation with other devices, such as Airtraq or LMA Fastrach in emergent difficult airways with satisfactory results [69–71].

The device has been successfully used during simulated conditions of cervical spine immobilization in a manikin model [72]. The efficacy of intubation at first attempt was higher with the Totaltrack VLM device (87.5%) compared to Truview Evo2 and the Macintosh laryngoscope; tracheal intubation was achieved in 100% of patients at the second attempt, even though the device was inserted by novices.

A series of cases showing a better visualization of the larynx and providing effective ventilation and oxygenation during the attempts of intubation with the Totaltrack compared with the standard Macintosh blade laryngoscope in the elective intubation of super obese patients (body mass index >50 $kg.m^{-2}$) [73].

In another prospective evaluation in paralyzed, anesthetized obese patients, the authors obtained a percentage of glottic opening (POGO) of 100% on the 93.7% of patients (86.9–97.7) [74]. Successful intubation at the first attempt was achieved in 81.2% of patients (72–88.5); the net time to achieve intubation (time needed to visualize the glottis + time to insert the tube) was 16s (12–29). The results of this study show that the Totaltrack VLM is easily placed and permits a high rate of successful tracheal intubation at first attempt.

The largest study with this device was conducted by Gómez-Ríos et al. in 300 adult patients [75]; the researchers achieved adequate ventilation and tracheal intubation in all patients. The median time to visualization of vocal cords, to confirmation of ventilation and to successful tracheal intubation was 5 s, 13 s and 24 s, respectively. 6.3% suffered minor complications, such as mucosal lesion or blood staining.

3.3. SaCo VLM™

SaCo Video Laryngeal Mask (SaCoVLM™, UE MedicalR, Zhejiang, China) is a new vision-incorporated third-generation video laryngeal mask. Van Zundert described in detail its features [8,38]. Figure 2 shows the different components of the device. Airway channel is pre-molded based on natural physiological arc and disposes of flexible materials that allow easy insertion and reduce tissue damage. The design of the cuff allows to keep secretions and to avoid aspiration and tissue damage of the soft tissue due to its large contact area and lower mucosal pressure. The SaCo mask is equipped, in addition to the gastric channel (16 Fr gastric tube is the

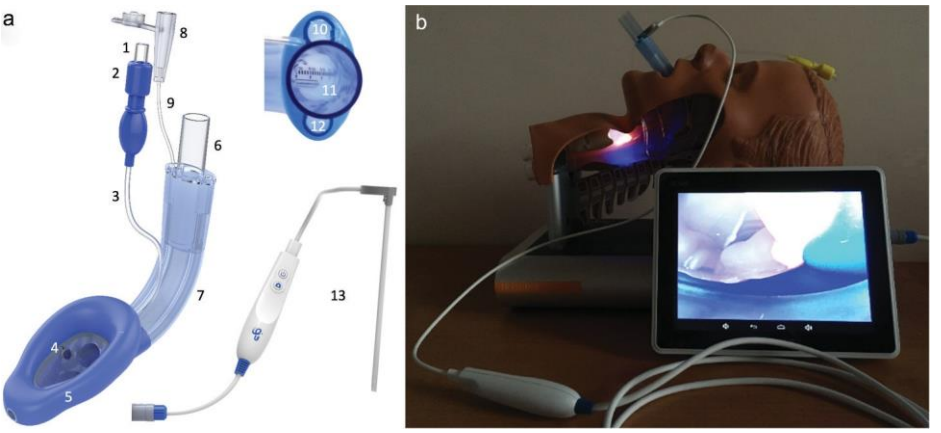

Figure 2. SaCo Video Laryngeal Mask. Panel A. Laryngeal mask and Flexible Visual stylet. 1: Inflation Valve; 2: Pilot Balloon; 3: Inflation Line; 4: Observation Window; 5: Cuff; 6: Connector; 7: Pre-angle airway tube; 8: Cleaning connector; 9: Cleaning tube; 10: visual tube channel; 11: ventilation channel; 12: gastric tube channel; 13: customized flexible videoscope. Panel B. Video laryngeal mask connected to the portable monitor. The device inserted into pharynx of the manikin and visualization of entrance to larynx.

suitable drainage tube) present in 2nd generation supraglottic devices, with a cleaning line. Observation window can be cleaned with saline solution or gas through this cleaning line to get clear image of steam, secretions or blood. SaCoVLM™ can guide tracheal intubation through the ventilation channel under direct vision on separate monitor connected via cable to videoscope (Figure 2, panel B). This monitor allows video or image capture for include into the anesthesia record or for teaching and research purposes.

Once the SaCoVLM™ is correctly positioned and evaluated for correct size, the videoscope can be removed. However, SaCoVLM™ can monitor the conditions of and surroundings of the glottis during the whole operation, which may be advantageous in case of changing ventilation parameters, changing in patient`s positioning or creating pneumoperitoneum. In case of need for tracheal intubation, it may be performed under vision control. The device has three sizes of laryngeal mask. Size 3 is suitable for patients with a body weight between 30 and 50 kg; size 4 for 50 and 70 kg; and size 5 for patients of 70–100 kg. They allow the passage through the ventilation channel of endotracheal tubes of 7.0, 7.5, and 8.0 mm, respectively.

There are so far limited number of papers evaluating SaCo mask in clinical settings. Yan et al. [76] tested SaCoVLM™ in airway management for general anesthesia. They evaluated the device on 100 adult patients scheduled for general anesthesia. The first pass success ratio of insertion was 95%, and the total success ratio 96%. The sealing pressure was 34.1 ± 6.2 cmH_2O and SaCoVLM™ achieved a sealing pressure exceeding 30 cmH_2O in 72% of the patients. The gastric drainage insertions were smooth. The incidence of postoperative sore throat was 13%, without dysphagia and hoarseness. The incidence of blood streams on mask after removal was 7%, and active bleeding occurred in 1% of the cases. The visualization of entrance to larynx was worse than when using fiberoscope (grade 1: 55% vs 1%, grade 2: 23% vs 10%, grade 3: 14% vs 14%, and grade 4: 8% vs 71% for SaCoVLM™ versus fiberoptic evaluation, respectively, [Grade 1 – only small part of entrance of larynx is visualized, grade 4 – full visualization]). However, after adjustment of SaCo mask positioning the grade improved. Yan et al. concluded that the SaCoVLM™ can visualize partial or whole laryngeal inlets during surgery, with a high success rate, a high sealing pressure and smooth gastroesophageal drainage. The poor vision through the SaCoVLM™ is due to the fact that the authors used the first version of the device. The current version has implemented improvements to could optimize the display of glottic structures.

The SaCoVLM™ is a promising device, which can be used for everyday practice or for complex cases. It is inserted in the same technique as standard curved LMA. This new integrated device is easy to set up, assemble, operate, move in and out of the pharynx, and separate components from each other. SaCoVLM™ provides continuous oxygenation-guided intubation which is particularly advantageous in patients with poor preoperative pulmonary reserve. A case report shows that the device might have great efficiency in morbidly obese patients – easy to insert, seal pressure up to 40 cmH2O in most cases, good glottic visualization, and very high intubation success ratio [77] (Figure 3, panel A). Likewise, SaCoVLM™ can be very useful in airway emergencies like unexpected extubation of the patient in the prone position. Its insertion is possible and allows reintubate the trachea without the need for changing the patients position (Figure 3, Panel B). Also, patients can be intubated in the lateral or prone position after so-called 'self-positioning' (Figure 3, Panel C and D). Other SADs can be used on patients in non-standard positions, but this may cause the dislocation of the device and subsequent leakage [78].

The SafeLM® Video Laryngeal Mask System (VLMS) is a similar device, but it comes with a camera angle adjusting handle that allows to see under direct vision up to 140° angle of view of the oropharynx and larynx [38]. Its monitor is embedded in the device.

Figure 3. Clinical performance of the SaCo Video Laryngeal Mask.

4. Role of video laryngeal masks

1. Routine use

1. Vision-guided insertion and placement of the SAD

'Blind' insertion of SADs results in 50–80% aberrant positions in the hypopharynx [26,37,79], which can compromise patient safety. Thus, this can lead to suboptimal control of the airway due to inadequate oropharyngeal airway sealing, air leaks or obstruction, increased risk of further displacement, poor gas exchange, airway trauma, and increased morbidity [8,27,80]. Malpositioned SADs are 26 times more likely to cause gastric insufflation and subsequent aspiration due to poor esophageal sealing [27]. Therefore, selecting the appropriate SAD size and achieving the correct insertion depth and location are priorities [38].

Table 1 shows the requirements of an ideal position of a SAD, the causes malposition [26,27]. Checking the correct size and appropriate position of the SAD has so far been based on subjective observations (suprasternal notch test, bubble test, audible noise detection at the mouth), and indirect clinical tests (resistance to device insertion, dislodgement during cuff insufflation, malalignment of bite block with upper incisors, poor oropharyngeal airway seal, poor esophageal seal, inability to insert a gastric drain, clinically inadequate ventilation as insufficient tidal volume, poor capnography trace, gas leak and/or airway obstruction, and low values for oropharyngeal leak pressure, intracuff pressure and oxygen saturation). The combination of these methods is often inaccurate [8,38].

Van Zundert et al. demonstrated that the vision-guided insertion technique could achieve almost 100% perfect positioning of a SAD [37]. The recent VLMs allow their placement under direct vision facilitated by the view providing through the ventilation channel, and immediate corrective maneuvers; therefore it could improve the placement of the supraglottic airway without the help of an additional device [8], although there is a sparce of evidence in this regard [8,69,70,74,75,81].

4.1.2. Intraoperative diagnosis of malfunction

During the use of the supraglottic airway device, ventilation may become suboptimal and air leaks or airway obstruction may occur. The maintenance of the videoscope on site or its new insertion on your specific channel allows to diagnose the causes of this misplaced or malfunction. Likewise, intraoperative monitoring ensures airway safety and reduces the possibility of aspiration

2. Advanced use in difficult airway management

1. Rescue of a difficult or failed tracheal intubation

SADs play an essential role in the rescue of difficult and failed TI in addition to their use as a primary technique in elective surgical procedures or cardiopulmonary resuscitation [82–84]. They allow ventilation and oxygenation, provide a patent airway with a certain degree of protection against aspiration, and act as conduits to facilitate TI [85–90]. The anatomical and/or technical factors that difficult facemask ventilation and TI do not usually influence the insertion and function of SADs [86]. Therefore, a SAD should be inserted without delay to preserve alveolar oxygenation in the event of a difficult or failed TI.

VLMs are an evolution of the second-generation SAD. Therefore, they probably have most of the ideal characteristics of a SAD: easy insertion, providing effective oxygenation and ventilation with high oropharyngeal sealing pressures, allowing TI through its ventilation lumen and allowing gastric decompression by the gastric channel [34,86,91]. Current airway guidelines recommend the immediate availability of a second-generation SAD, as well as having the necessary competence for its use in all the locations where the airway

Table 1. Requirements of an ideal position of a SAD and causes of malposition.

SAD properly placed (good seal and no leaks)
Requirements of an ideal position
(1) Distal tip of the cuff in the esophagus (2) Epiglottis resting on the outside of the cuff (3) Tip of the epiglottis aligned with the proximal cuff (4) Cuff adequately inflated to produce a seal (pressure 40–60 cm H_2O) (5) No crease in the cuff (silicone is better than PVC)
Avoid: • Cuff overinflation (SDR dislocation) • Cuff hypoinflation (risk of aspiration) • Too deep/too small SAD • Too shallow/too large SAD
Poorly positioned SAD (leaks and airway obstruction)
Causes
(1) Tip of distal cuff a. folding over b. folding backward c. located between the vocal cords (2) Epiglottis in bowl of SAD a. without downfolding b. downfolding epiglottis c. Epiglottis folding double
Treatment Options: • Jaw thrust to open the oropharyngeal space (increase the distance between the epiglottis and the posterior wall of the oropharynx) in order to relocate the SDR • Different size or type of SAD (PVC cuff to silicone cuff or reinforced tip) • Guided technique with an introducer or orogastric tube • Magill forceps

Adapted from *Van Zundert AA, Kumar CM, Van Zundert TC. Malpositioning of supraglottic airway devices: preventive and corrective strategies. Br J Anaesth. 2016; pp57-982.*

is treated. However, VLMs could be more suitable for advanced uses as rescue devices after a failed TI, since they allow vision-guided *'insert-detect-correct-as-you-go'* insertion technique [26,27,37,79]. It can ensure timely insertion and correct placement of the VLM increasing the effectiveness and safety of the devices due to: (1) a high first-attempt ventilation success rates by improving gas exchange and oropharyngeal leak pressure [37,92], (2) accelerating transition between plans (3) preventing gastric aspiration (4) reducing pharyngeal trauma [80]; although all of this requires a formal evaluation comparing VLM with second generation SADs.

The achievement of efficient ventilation and oxygenation gives time to stop and decide how to proceed according to the degree of urgency and type of procedure for which control of the airway is required. VLMs allow TI through ventilation channel under vision. This avoids a blind TI (not recommended since the success rate is low and they can cause greater trauma and impaired oxygenation [93,94]) or the combined use of other devices for fiberoptic-guided tracheal intubation. Therefore, the use of VLM allows TI without fiberoptic bronchoscope assistance, so it could simplify the technique and be especially advantageous in locations where fiberoptic bronchoscope is not available, such as prehospital and emergency care [18]. TI through the ventilation channel of the VLM has several advantages: (1) maintaining the ventilation, continuous oxygenation and the airway patency during the TI procedure, (2) isolating the periglottic structures from possible secretions or blood [66], (3) facilitating the location of the glottis, optimizing the laryngeal view and (4) reducing the difficulty of advancing the ETT by overcoming anatomical obstacles.

These devices eliminate the need for a separate (standalone), expensive (capital cost) and more cumbersome fiberoptic scope.

4.2.2. Baileys manoeuvre

High-risk airway extubation sometimes requires advanced methods when gentle eduction is required to attenuate undesirable cardiovascular or respiratory responses during extubation [95–97]; among them, the administration of pharmacological adjuvants [98–103] such as remifentanil infusion [104] or the 'Bailey maneuver.'

The classic Bailey maneuvers consists of the superimposition of a SAD behind the ETT with the subsequent withdrawal of the ETT. This is a complex technique in a challenging airway, so it should only be performed by experts in SAD insertion [105,106]. The use of a VLM for TI plays a relevant role in performing this technique in a safer and more simplified way, since they allow this modified maneuver to be carried out with the simple partial withdrawal of the ETT within the ventilation lumen of the VLM. This change can be reverse instantly. Video-assisted guided extubation allows monitoring of post-operative airway changes, and smooth awakening.

Table 2 shows the main advantages appreciated by the authors in the clinical performance of these devices, although pending confirming scientific evidence.

Table 2. Potential clinical advantages of video laryngeal masks.

(1)	Uncomplexity vision-guided insertion. This makes the procedure shorter and atraumatic.
(2)	Accurate placement of the SAD without requiring combined use with other devices, such as a video laryngoscope or a fiberoptic bronchoscope. It prevents complications secondary to malposition
(3)	Corrective maneuvers in case of malpositioning of the SAD.
(4)	Ensure optimal gas exchange by direct display rather than indirect parameters
(5)	Tracheal intubation through the ventilation channel of the SAD under direct vision without requiring a fiberoptic bronchoscope for this purpose
(6)	Oxygenation/ventilation during SAD insertion and tracheal intubation
(7)	Recording of the procedure, correct placement of the SAD or anatomical airway and vocal cord aberrations, lesions or disease;
(8)	Continuous intraoperative monitoring of the SAD in situ to detect SAD misalignment or malposition

5. Expert opinion

SADs have become a fundamental tool in modern anaesthesia. They do not provide complete protection against aspiration and regurgitation and does not prevent laryngospasm. Several subjective methods and measurements of OPLP are used as evidence of correct SAD placement in the hypopharynx. However, only visual inspection will help define whether the airway device sits in the correct position, paving the way for future studies with videolaryngeal masks.

VLMs allow vision-guided insertion, corrective maneuvers if necessary, accurate placement in the hypopharynx, gastric tube insertion, and endotracheal intubation under vision. These combined properties of an intubating laryngeal mask and a video laryngoscope allows to establish adequate ventilation and a maintained optimal oxygenation throughout the tracheal intubation process, promoting the shortest apnea period. The seal created by the cuff inflation protects the airway against gastric aspiration and keeps it clear of blood or secretions until tracheal intubation is performed. An adequate view of the glottis leads to a high rate of first-attempt tracheal intubation. Therefore, this device simplifies plan A and plan B of the difficult airway algorithm into one step, facilitating an early transition.

We anticipate that, in the short to medium term, all SAD insertions could be performed under direct vision for the reasons stated. These now requires formal evaluation of efficacy safety and cost-effectiveness. Evidence support will potentially make the use of VLMs the gold standard.

Funding

This paper was not funded.

Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

Reviewers disclosure

Peer reviewers on this manuscript have no relevant financial relationships or otherwise to disclose.

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