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REVIEW

Airway Management During Upper GI Endoscopic Procedures: State of the Art Review

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Abstract With the growing popularity of propofol mediated deep sedation for upper gastrointestinal (GI) endoscopic procedures, challenges are being felt and appreciated. Research suggests that management of the airway is anything but routine in this setting. Although many studies and meta-analyses have demonstrated the safety of propofol sedation administered by registered nurses under the supervision of gastroenterologists (likely related to the lighter degrees of sedation than those provided by anesthesia providers and is under medicolegal controversy in the United States), there is no agreement on the optimum airway management for procedures such as endoscopic retrograde cholangiopancreatography. Failure to rescue an airway at an appropriate time has led to disastrous consequences. Inability to evaluate and appreciate the risk factors for aspiration can ruin the day for both the patient and the health care providers. This review apprises the reader of various aspects of airway management relevant to the practice of sedation during upper GI endoscopy. New devices and modification of existing devices are discussed in detail. Recognizing the fact that appropriate monitoring is important for timely recognition and management of potential airway disasters, these issues are explored thoroughly.

The original version of this article was revised: Figures 6 and 8 incorrectly swapped were corrected in this version.

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Introduction

The growing popularity of deep sedation in patients undergoing gastrointestinal (GI) endoscopy has created immense challenges to anesthesiologists, gastroenterologists, and airway/monitoring device manufacturers. Providing deep sedation for these procedures requires a paradigm shift in the application of the knowledge and resources. From the anesthesia provider's stand point, it is a state of "fish out of water"—moving away from the comfort of the operating room. Apart from the unfamiliarity of the anesthetizing location, absence of a secure airway is a critical concern. Gastroenterologists have clearly benefited from deep sedation. It allows performing complicated procedures with relative ease. However, added cost of anesthesia providers is a major constraint. This could have been one of the reason, Sedasys, the much advertised robot failed [1–3]. From a practical standpoint, securing an airway in a patient with a gastroscope in situ is impossible without endotracheal intubation. More research is needed in the area of airway devices used in GI endoscopy. Finding a reliable respiratory monitor is another area of ongoing research. The present review aims to provide the readers succinct information on the effects of sedative medications on the anatomy and physiology of the airway, followed by a state of the art discussion about the devices available, old and new, to secure an otherwise "insecure" airway in the setting of upper GI endoscopy. Several improvisations in the use of existing devices are also presented. The review is intended as much for anesthesia providers as gastroenterologists.

Anatomy and Physiology of the Upper Airway

An understanding of the upper airway anatomy including many variants of "normal" is crucial for safe administration of sedatives. It should be borne in mind that majority of adverse outcomes including cardio-respiratory arrests are related to challenges in airway management [4–6]. Unlike anesthesia involving an endotracheal intubation, where securing the safe airway is predominantly during induction and extubation, in GI endoscopy, it is an ongoing process and lasts as long as the procedure lasts.

Effects of Sedation on the Upper Airway Physiology

During awake state, negative intraluminal pressure in the pharynx is balanced by the tone of the upper airway musculature [7]. This prevents closure of the upper airway. The velopharyngeal mechanism consists of a muscular valve that extends from the posterior surface of the hard palate to the posterior pharyngeal wall and includes the soft palate (velum), lateral pharyngeal walls (sides of the throat), and the posterior pharyngeal wall (back wall of the throat). The velopharyngeal mechanism creates a tight seal between the velum and pharyngeal walls to separate the oral and nasal cavities for various purposes, including speech. Velopharyngeal closure is accomplished through the contraction of several velopharyngeal muscles and includes levator veli palatini, musculus uvulae, superior pharyngeal constrictor, palatopharyngeus, palatoglossus, and salpingopharyngeus. The mechanism is illustrated in Fig. 1.

Velopharynx is the most common site of collapse during anesthesia, as during natural sleep. Contrary to previous belief, obstruction of the oropharynx due to retrolingual collapse (tongue falling back) is the second commonest cause of collapse [8] (Fig. 2).

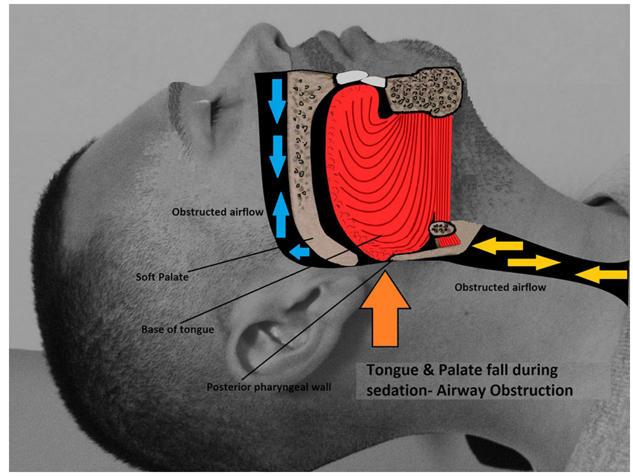

Fig. 2 Figure demonstrating relevant airway anatomy along with situation of airway obstruction. The figure also demonstrates common site of airway collapse in a sedated spontaneously breathing patient

Management of the Upper Airway

Hypoxemia manifesting with low oxygen saturation is common during upper GI endoscopic procedures, especially ERCP. The severity and the frequency of such desaturation depend on the criterion used to define such an event.

Approach to prevention and management of hypoxemia is as varied as the criteria used to define the event. Increasing supplemental oxygen, insertion of a nasal airway, various airway manoeuvers, endoscope withdrawal followed by positive pressure ventilation, insertion of laryngeal mask airway, and rarely endotracheal intubation are some of the approaches employed. It is not uncommon to attempt an aggressive approach such as endotracheal intubation early in the management of hypoxemia. However, such an approach might cause more harm than good, if inappropriately chosen or executed [9]. Attention to more basic tenets of airway management is likely to save more lives than measures such as laryngeal mask airway insertion or endotracheal intubation. To be successful, these

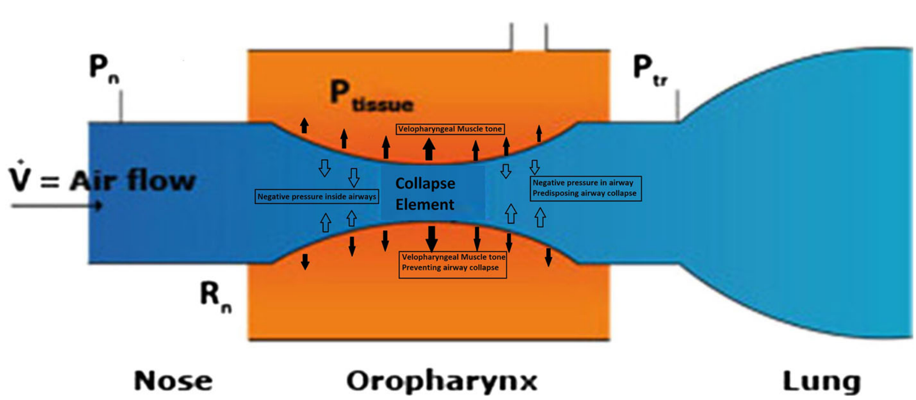

Fig. 1 Velopharyngeal mechanism-demonstrating how the negative pressure inside the airway during spontaneous breathing predisposed to airway collapse and the tone of pharyngeal muscles prevents the same

lifesaving airway maneuvers with appropriate devices need to be employed at pertinent times. It is also essential that sufficient time is allowed for these measures to yield results, if clinically judged to be effective. As an example, if the ventilation is judged to be effective as evidenced by the chest excursions, it is advisable to allow sufficient time for the pulse oximeter derived saturation to return to baseline. Ignoring the lag time inherent in the pulse oximeter, might fool the physician to abandon an effective ongoing approach, in favor of an endotracheal intubation, which is fraught with unexpected consequences in an emergency setting.

Prone and Semi-Prone Positioning

Endoscopic procedures like ERCP are generally performed with the patient in prone/semi-prone position, thereby posing additional challenges, especially in an unintubated patient. Although gravitational forces prevent airway collapse, airway complication rates remain high [6, 10]. Lack of familiarity and absence of a plan in the event of hypoxemia might be the contributing factors. Unexpected technical challenges might increase the risk of losing the airway. One must, however, keep in mind that unlike surgical procedures, endoscopic procedures can be aborted to facilitate airway intervention at almost no notice. To enhance patient safety, continuous oxygen supplementation (preferably via a nasopharyngeal airway) must always be used. Simple manipulations such as assisting ventilation (after turning the patients head or the patient himself to the side) and a firm chin lift could be lifesaving. It goes without saying that it is important to remain vigilant and intervene for any airway compromise with bag-mask ventilation or emergency endotracheal intubation. The airway complication rates are proportional to length of the procedures and constant vigilance is the key.

Maneuver Chin Lift, Jaw Thrust, and Neck Extension

Chin lift is known to cause widening of the entire pharyngeal space, most pronounced between the tip of the epiglottis and posterior pharyngeal [11]. In this study involving children, wherein the measurements were done using magnetic resonance imaging, upper airway dimensions were preserved. In a similar study involving children with adenotonsillar hypertrophy and stridor, chin lift with CPAP (continuous positive airway pressure) relieved stridor under anesthesia [12]. The situation in upper endoscopy may not be exactly comparable due to the presence of endoscope, which can compromise the posterior pharyngeal space. However, the endoscope itself can also act as an upper airway stent (Fig. 3).

A frequent observation during upper GI endoscopy, especially under propofol sedation is thoracoabdominal asynchrony. Commonly caused by airway obstruction, it is possibly due to deeper levels of sedation associated with propofol in comparison to intravenous conscious sedation. Management involves chin lift, jaw thrust, and neck extension. However, rarely these maneuvers may worsen the obstruction instead of relieving it. In the absence of CPAP, chin lift and jaw thrust can reduce the posterior pharyngeal space, potentially worsening upper airway obstruction [13]. Unfortunately, it is not easy to apply CPAP in the absence of an airtight airway. The devices which can possibly allow application of CPAP are discussed later.

The effect of positioning on the airway obstruction is important and supine position is not ideal from this point. Fortunately, most upper GI endoscopic procedures are performed in the lateral position. Lateral position in association with airway maneuvers is known to open the upper airway [14, 15]. Although these studies were done in children, the results are valid in adults in the absence of anatomical abnormality.

Finally, the optimal head positioning during sedation especially deep sedation during upper GI endoscopy is patient dependent. Adults with obstructive sleep apnea (OSA) benefit from a sniffing position [16, 17]. Receding chin, obese neck, and a body mass index (BMI) of over

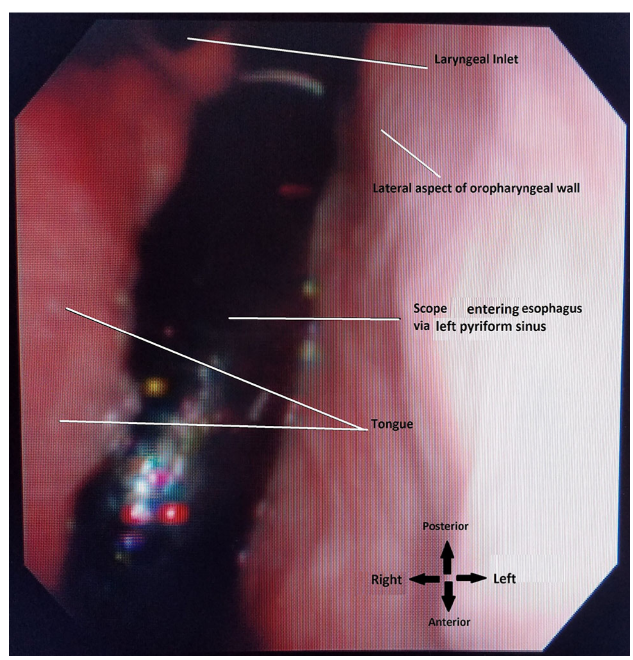

Fig. 3 Mechanism of an endoscope stenting the airway open. The endoscope prevents the collapse of the airway at the pharyngeal level despite negative pressure in the pharynx during spontaneous breathing

30 kg/m^2 in association with OSA can be a cause of both difficult mask ventilation and intubation. Pharyngeal airway collapsibility is increased in this subgroup of patients presenting for endoscopy (Fig. 4). Closing pressure, defined as the pharyngeal pressure at which the posterior pharynx collapses, causing upper airway obstruction is normally sub-atmospheric. However, in patients with OSA it is 2 ± 3 cm H_2O. This can be overcome by adapting a sitting sniffing position (Fig. 5). CPAP is another effective way to overcome such an obstruction. However, it is essential to have means of establishing positive pressure ventilation, if CPAP is ineffective. Jaw thrust helps to pull the tongue forward due to the anatomical link between the two. However, it is not necessarily accompanied by an increase in velopharyngeal space. A combination of maneuvers is probably more important than any single measure and it is important to constantly evaluate their effectiveness and alter the approach depending on the outcome.

It is also important to realize that these maneuvers can only applied after withdrawal of the endoscope. Timely endoscope withdrawal and efficient institution of these measures are critical to their success.

Increasing complexity of GI procedures has set challenges for anesthesia providers to deliver high quality care without compromising safety. Technological advancements in the field of anesthesia have tried to keep pace with

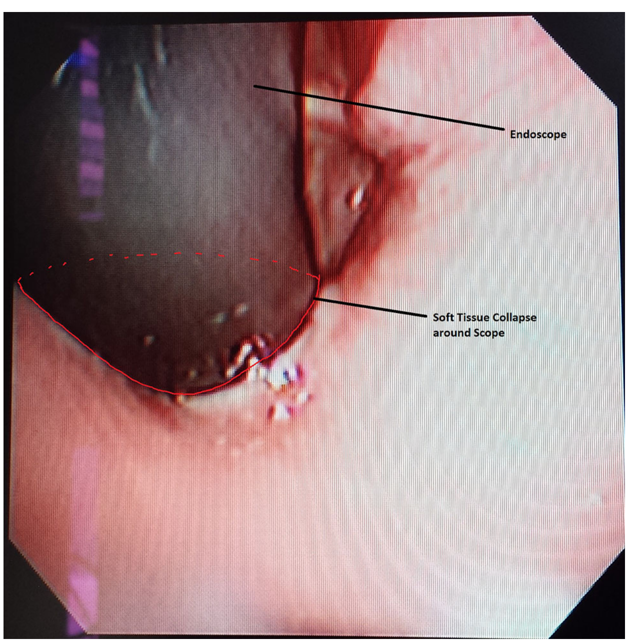

Fig. 4 Pharyngeal collapse in a morbidly obese patient around the endoscope. These patients due to propensity for obstructive sleep apnea generate higher negative airway pressure (to overcome obstruction)—this increased negative pressure further precipitates airway collapse. Also, peri-pharyngeal fat is also increased that enhances airway collapse

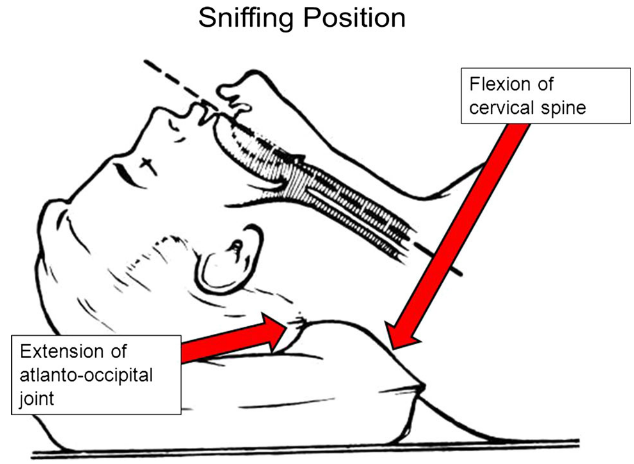

Fig. 5 Figure demonstrating the ideal laryngoscopy position: "Sniffing the morning air"

the required standards. Many airway devices are available/being developed to fill the void that can enhance both patient safety and procedural ease. Airway devices aim to provide supplemental oxygen in many unique ways to prevent procedure related desaturation episodes. We have discussed both contemporary and future devices in the succeeding paragraphs.

Face Masks

These are extra-oral devices that fit along the facial contour to supplement oxygen and/or drive positive pressure ventilation. One of the prerequisite of these masks is to accommodate the upper endoscope while the device is in place.

Panoramic Face Mask

Increasing the concentration of inspired oxygen is a simple, yet effective strategy. It is known to decrease the incidence of hypoxemia in patients undergoing upper GI endoscopy. Panoramic face mask (Fig. 6a) is a modification of the simple face mask and uses a reservoir bag to deliver high inspiratory oxygen. Combination of high volume reservoir and the a one-way valve can provide up to 80–90 % inspired oxygen with negligible rebreathing [18]. The contours of the mask fit the human face closely preventing any leaks around the face. Another unique feature of the mask is a special port that may be used to measure exhaled CO_2 (and derive capnograph waveform). As a result, continuous monitoring of respiration can be achieved. The panoramic mask has two resealable "self healing ports" that can be used to introduce gastroscope (oral port) or the flexible fibreoptic bronchoscope (nasal port). During the upper GI endoscopy, the oral port allows almost

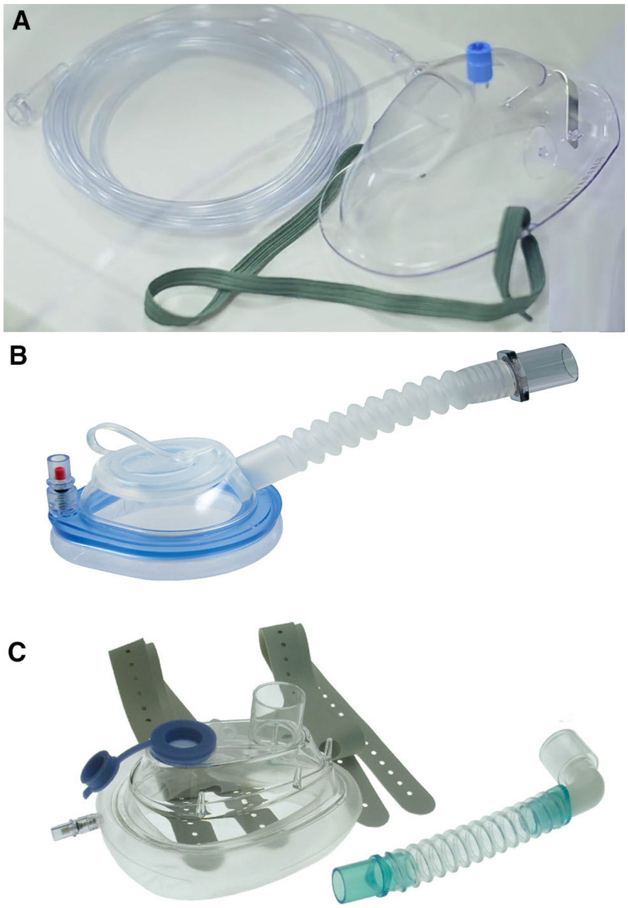

Fig. 6 **a** Panoramic face mask. **b** Endoscopy mask. **c** DEAS mask

frictionless entry of the scope into the mouth and the nasal port remains sealed with a biocompatible glue. The oral port slit allows scopes of various sizes to pass through with minimal leaks around the port, thus a single adult size can be used in patients with variable demographic profiles. Prior to the use of the mask, it must be ensured that the oxygen supply is open and the reservoir bag is inflated. The manufacturer warns that if inflow is missing, it can lead to detrimental hypoxia. Panoramic mask can be used for procedures performed under propofol sedation; however, maintenance of spontaneous breathing is essential is critical for the success of the mask. In addition to the upper GI endoscopy, the manufacturer recommends the use of this mask in flexible fibreoptic bronchoscopy, procedures under sedation, and during monitored anesthesia care.

Endoscopy Mask

An endoscopy mask addresses the limitations of the Panoramic face mask. It has a leak proof cushioned seal along the facial contour that allows positive pressure ventilation in deeply sedated patient (Fig. 6b). Using an endoscopy mask both inspired oxygen concentration and their inspiratory breathing pressure (or ventilatory assistance) can be regulated. An endoscopy mask allows delivery of nearly 100 % oxygen. It may be used in combination with a non-rebreathing circuit (such as a circle system) or a portable breathing system such as Mapleson C. Various minor modifications in these masks increase their practical utility. Endoscopy mask with hooks can be used with a harness. Masks with multiple re-sealable ports can allow the introduction of endoscope orally or nasally (for bronchoscopy). Cushioned edges allow better fit around the anatomical contours of the face and allow leak proof interment positive pressure delivery if needed. When coupled with an anesthesia workstation, inhalational agent based anesthesia can also be provided using these masks. These masks are available in multiple sizes varying from pediatric to adult mask. Despite above advantages these masks are still not the most ideal airway devices for GI endoscopy. Other than logical possibility of facial pressure skin necrosis, they offer no protection against aspiration. Any positive pressure ventilation used with them increases this risk further.

DEAS Endoscopic Mask

DEAS endoscopy mask (Fig. 6c) is a modification of the endoscopy mask. It has all the advantages of the conventional endoscopy mask, but has a separate port for measuring end tidal carbon-dioxide. An additional port for measuring the inspiratory pressure is also present. Both these measurements enhance the safety (CO_2 increases the ability to detect the apnea) and allow better control of patient's ventilation during the upper GI endoscopy. The mask is fitted with an expandable flexible membrane that seals around almost any size of endoscope preventing leaks during the procedure. Similar to a conventional endoscopic mask it has a universal 22 mm port that can be connected to a standard breathing circuit or the closed circuit of an anesthesia workstation. It also suffers similar limitations because of its inability to prevent airway obstruction or aspiration.

Airway Devices

Nasopharyngeal Airway

Nasopharyngeal airway is inserted via the nares and helps to bypass upper airway obstruction (Fig. 7a). Nasopharyngeal airway has a unique role in GI endoscopy as it can be used even in patients undergoing upper GI endoscopy. It is better tolerated by the patient and is less traumatic. In our own retrospective review, use of nasopharyngeal airway during endoscopy to provide CPAP reduces the hypoxemic complications significantly.

Timing of insertion of the nasopharyngeal airway is of profound importance. We typically induce with propofol preceded by fentanyl or a similar short acting opioid. The dose is variable and depends on the patient's age, weight, height, comorbidity, and medication history, all of which influence the pharmacokinetics and pharmacodynamics, the variability of which is 300–400 % [19, 20]. We typically proceed with 1–1.5 mg/kg, although the dose may need to be drastically reduced in elderly patients. Propofol is preceded (1–2 min before) with fentanyl 25–50 mcg for analgesic, propofol sparing, and antitussive effects. Fentanyl is especially important in patients undergoing advanced endoscopic procedures including ERCP. An infusion of propofol at about 120–150 mcg/kg/min follows. Preserving the patency of the upper airway and maintenance of spontaneous ventilation along with suppression of the cough reflex are all of vital importance. At the peak clinical effect of propofol, signaled by loss of eyelash reflex, unresponsiveness, and sometimes apnea, a nasal trumpet is typically inserted and connected to a Mapleson C breathing system (Fig. 7b). At the peak of sedation depth, endoscope is introduced, which also provides sufficient stimulation to initiate (if patient were to be apneic) and sustain spontaneous ventilation. Post procedure discomfort is rare, other than mild throat irritation; therefore, we limit the dose of fentanyl to about 100 mcg, unless the patient is on chronic opioid therapy or other reasons.

It is recognized that the use of nasopharyngeal airway and a Mapleson C breathing system in the manner described above is neither routine nor standard of care. Yet, in the current practice of providing deep sedation by anesthesia providers, it is essential to be prepared for rare events of severe hypoxemia and have a plan to manage them.

Gastrolaryngeal Tube

A gastrolaryngeal tube is a specialized conduit designed to secure airway during the complex gastrointestinal endoscopic procedures in adults. It allows simultaneous use of gastroscope via a separate channel built within the tube (Fig. 8a). The tube has two cuffs, the distal one inflates in the esophagus-preventing the regurgitation of gastric contents (once the pressure increases inside the stomach). The second cuff lies proximally and inflates to block air leak via the naso/oropharynx. In between these cuffs the tube has multiple perforations that lie adjutant to the larynx. These holes are connected to the ventilating channel (extra-oral) and allow the institution of positive pressure ventilation (if required). This tube has a unique advantage for upper GI endoscopy as it not only increases the space for maneuvering the gastroscope, but also can help in the insertion of gastroduodenoscope by guiding it into the esophagus. The ventilating port provides a connection for capnography. As a result, both monitoring and control on ventilation can be achieved reliably. The tube is recommended for use in complex procedures like ERCP, PEG (especially in patients with neurological ailments).

Bite Blocks

Bite blocks are airway devices that assist the endoscopist to introduce the gastroscope into the oral cavity, and they

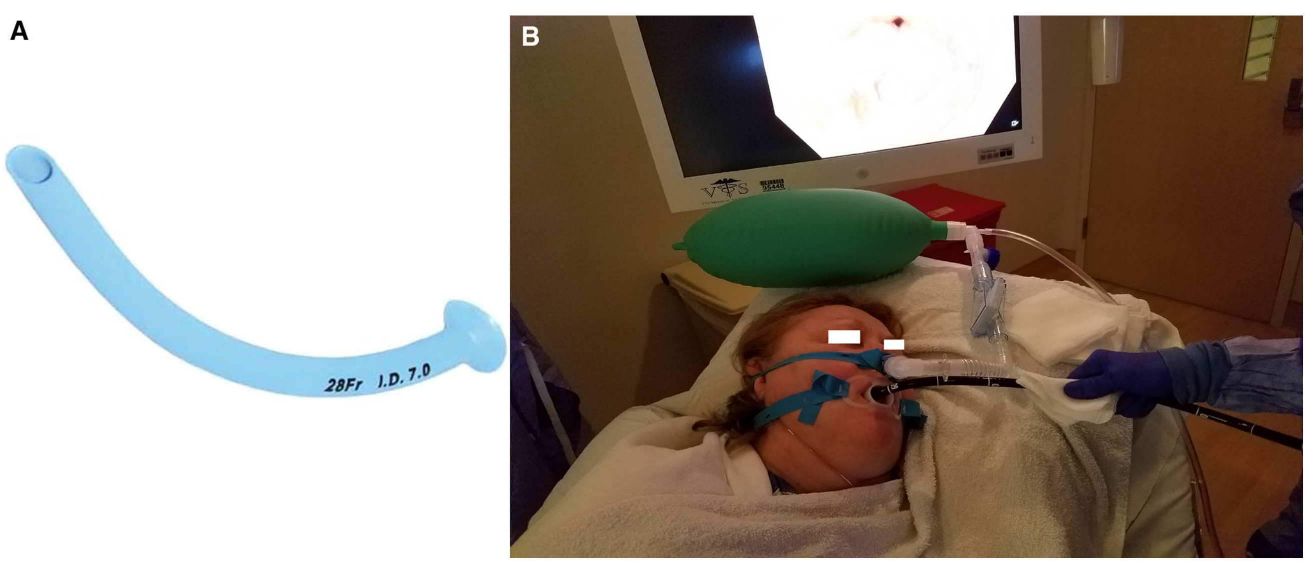

Fig. 7 **a** Nasopharyngeal airway. **b** Mapleson C circuit connected to the nasopharyngeal airway

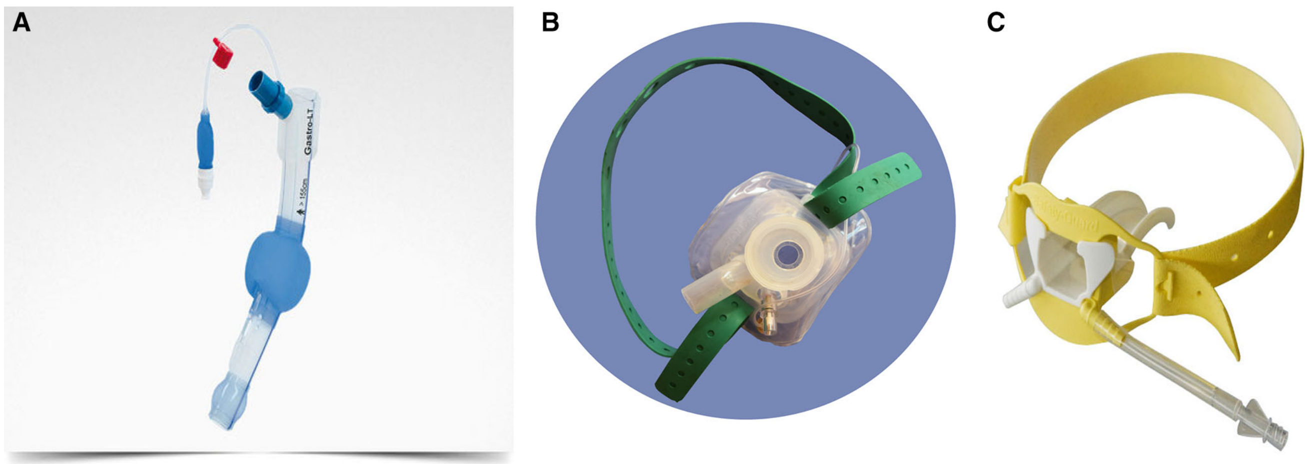

Fig. 8 **a** Gastrolaryngeal tube. **b** Goudra bite block. **c** Safety guard bite block. Written permission/consent to publish the images is obtained from the patients were appropriate (Figs. 8, 9)

simultaneously prevent the patient from biting the scope. Over the years, improvements in the design of the bite blocks have added features that have improved patient safety. Bite blocks now have built-in airway-like features and can prevent airway obstruction during sedation. Various ports within the airways help to supplement oxygen to the patient. Modern bite blocks also incorporate suction ports that clear airway secretions without interrupting the endoscopic procedure.

Goudra's Bite Block

Goudra's bit block is a unique innovation that incorporates all the features of an ideal bite block with an airway. The cushioned external part fits and seals around the oral cavity (Fig. 8b). The anesthesia provider does not need to hold the bite block physically during the procedure, as the hooks allow it to be secured using an atraumatic harness. The intra-oral part of the bite block has an optional soft atraumatic airway flange. This serves a dual purpose: prevents airway obstruction and also helps to guide the gastroscope into the esophagus via the ridges on the airway flange. Taking advantage of a stretchable silicone seal, different size endoscopes can be introduced with minimal leakage. Ports on this bite block allow for positive pressure ventilation (and monitoring ventilation via bag movements) and suction of airway secretions.

Hague Airway

The Hague airway is another modification of the conventional bite block. It has ports for providing high flow oxygen during the procedure and also a port for measurement of $EtCO_2$ (allowing to monitor the patient's breathing). This bite block can also be fitted to patients mouth by virtue of stretchable plastic straps. It is limited in its ability to prevent airway obstruction or to provide assisted positive pressure ventilation in deeply sedated patients.

Safety Guard

The safety guard is a bite block that provides free access to the mouth for endoscopy (Fig. 8c). The guard, like a tongue depressor prevents airway obstruction during the procedure. An oxygenation channel opens intra-orally in close proximity to the vocal cords and thus helps to provide high FiO_2 during the sedation. An integrated connection allows monitoring of $EtCO_2$ for any possible apnea during sedation.

Selection of the Device

Having discussed the available devices and management options, it is helpful to understand the situations in which to employ them. Clearly, any patient with a risk of aspiration (bleeding, emergency, drainage of pesudocyst, gastric outlet obstruction, removal of foreign body, pharyngeal pouch) would necessitate endotracheal intubation. Additionally, patients with anticipated difficult airway, especially difficult mask ventilation might benefit either from intubation or minimal sedation. In the remaining, the large majority of non-advanced endoscopic procedures may be safely performed with an oxygen cannula. We recommend the use of a nasal airway connected to a Mapleson breathing system for all advanced endoscopic procedures, including ERCP. Availability of a portable breathing system and both nasal and oral airways is essential for all procedures and at all times. A panoramic face mask can effectively replace a nasal cannula and assure high inspired oxygen delivery with the convenience of an end tidal carbon dioxide monitor. DEAS mask and endoscopy mask has the added advantage of applying positive pressure ventilation. While a safety guard bite block might displace the tongue, the Goudra bite block allows positive pressure ventilation. However, an awake person might not tolerate the insertion of a bite block with an airway. It should be borne in mind that as demonstrated in Fig. 3, in the majority, the endoscope acts as an oropharyngeal airway, and additional airway is unnecessary. A gastrolaryngeal tube might be a useful device during advanced endoscopic procedures in experienced hands.

Monitoring

It is an understatement to say that adverse event rates during GI endoscopic procedures under deep sedation are at least equal to, if not more than. those of general anesthesia [4–6]. Hypoxemia remains the dominant cause of increased morbidity and mortality. These events are best preempted than treated. As a first step, appropriate monitoring of both ventilation and oxygenation is important. Our own study showed that majority of adverse events during the endoscopy occur as a result of ventilation related issues. Even for the most experienced sedation provider it may be difficult to titrate the depth of sedation and thus prevent over sedation. Further, the ASA standards of basic minimum monitoring applies to patients undergoing procedures under deep sedation. However, continuous monitoring of breathing is one of the most critical aspect of monitoring for which a satisfactory tool is not yet available.

End Tidal Carbon Dioxide Monitoring

End tidal carbon dioxide monitoring or capnography is widely available and easy to use. It relies on the exhaled CO_2 measurement to determine the expiratory phase of the breathing cycle. However, during endoscopy it does have many limitations due to air dilution by the high fresh gas [21]. In fact, the reliability and accuracy was least for capnography, when compared to acoustic respiratory monitor and impedance pneumography. Thus, it is recommended that end tidal CO_2 should not be a sole ventilation monitor during upper GI endoscopy. Furthermore, it should also be kept in mind that it is more of a qualitative monitor (assures patient is breathing), but has poor quantitative value (does not provide information on tidal volume or adequacy of ventilation). Capnography ports are available on many specialized airway devices designed for endoscopy which might improve the reliability. More specialized respiratory monitoring with particularly higher specificity are making way into the endoscopy field.

Impedance Monitoring

This relies on the detection of actual physical movement of the chest/abdominal wall. Impedance technology is incorporated into the ECG electrode system to estimate the breathing rate. With each breath (inspiration) the thoracic cage volume changes, thereby altering alters the electrical properties like capacitance and resistance of the thoracic wall [22]. ECG electrodes sense the small change in electrical conductance resulting from above alterations and report a breathing rate It often is not very reliable due to electrical interference and may be affected by patient movements. Another limitation is seen during upper airway obstruction when the chest walls move without actual inflow of air. Newer impedance monitors (independent of ECG electrodes) have two sensors. They detect whether chest and abdomen move in phase (un-obstructed breathing) or out of phase (obstructed breathing).

Many studies have used pulse oximetry as a substitute for breathing monitoring. We however recommend against its routine use for this purpose. Saturation only begins to fall once apnea has persisted long enough to consume the oxygen stored in functional residual capacity. Thus, the warning for required intervention is delayed. No available monitoring is perfect and vigilance is the key for prevention of respiratory complications during endoscopy.

Acoustic Respiratory Monitoring

The available methods for monitoring respiration during upper GI endoscopy have significant limitations. Pulse oximetry, for example, is found to detect only 50 % of apnea or inadequate ventilation events [23]. Additionally, pulse oximetry (SpO_2) is a lagging indicator of hypoventilation especially in patients receiving supplemental oxygen [24]. Thus, valuable time could be lost in implementing corrective measures, thereby risking severe hypoxemia and possible cardiorespiratory arrest. Impedance pneumography, on the other hand, requires significant chest wall movement to record respiration and continues to show active respiratory activity in patients breathing against a partial or completely closed glottis. Patient movement artifacts (to facilitate the gastroscope insertion, for example) can also adversely affect its accuracy. Acoustic respiratory monitor continuously measures respiratory rate using an adhesive sensor with an integrated acoustic transducer applied on the patient's neck. Although it suffers from many limitations, including signal noise due to pharyngeal muscle movements, in adult patients undergoing advanced GI endoscopic procedures, it was more accurate and provided apnea detection, which was similar or better than $EtCO_2$ or impedance pneumography, two standard of care monitors in the endoscopy suite [21].

Oxygen Reserve Index: A Novel Noninvasive Measure of Oxygen Reserve

The newest and most promising device yet to be released in the USA is the oxygen reserve index monitor [25, 26]. In contrast to pulse oximetry derived oxygen saturation which indicates impaired gas exchange (most commonly due to hypoventilation) after the oxygen blood tension falls below about 100 mm Hg, oxygen reserve index cab detects at levels of about 150 mmHg. An ORI > 0.24 can distinguish $PaO_2 \geq 100$ mm Hg when SpO_2 is over 98 %. Similarly, ORI > 0.55 appears to be a threshold to distinguish $PaO_2 \geq 150$ mm Hg.

Conclusions

Increasing complexity of the procedures coupled with worsening morbidity among the patient population will continue to challenge both gastroenterologists and anesthesia providers. The lack of any financial incentive for shouldering this additional responsibility, sometimes more challenging than the procedure itself is a major practical impediment. It is likely that more research and training will be required to increase the safety of deep sedation during upper GI endoscopy. Intelligent use of existing airway devices along with adaptation of new devices will undoubtedly increase the safety even in most challenging cases.

Compliance with ethical standards

Conflict of interest None.

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