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Research Progress on Prevention and Treatment of Hypoxemia in Painless Gastroscopy: A Review Article

Jun Ma[1], Ling Tan[1*]

[1]*Department of Anesthesiology, West China Hospital, Sichuan University, People's Republic of China*

Corresponding Author: **Ling Tan**

Address: Department of Anesthesiology, West China Hospital, Sichuan University, 37# Wainan Guoxue Road, Chengdu 610041, People's Republic of China. Email: 568786730@qq.com

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Abstract

Compared to ordinary gastroscopy, painless gastroscopy has more advantages due to the application of anesthesia techniques such as sedation and analgesia, providing patients with comfort and a quick recovery. However, patients undergoing painless gastroscopy are often at risk of hypoxia, which can result in serious complications. Fortunately, more anesthesia providers have recognized this problem. Therefore, it is essential for anesthesia providers to identify risk factors to prevent hypoxemia. In conclusion, this review highlights the assessment of risk factors for hypoxemia in painless gastroscopy and common airway management methods to prevent and treat hypoxemia in high-risk populations during painless endoscopy.

Keywords

Painless Gastroscopy, Hypoxemia, Risk Factors, Prevention, Treatment

Abbreviations

PG: Painless Gastroscopy; WSIVA: World Society of Intravenous Anesthesia; ASGE: American Society for Gastrointestinal Endoscopy; BPS: Balanced Propofol Sedation; ESGE: European Society of Gastrointestinal Endoscopy; EUS-FNA: Endoscopic Ultrasonography-Guided Fine Needle Aspiration; ERCP: Endoscopic Retrograde CholangioPancreatography; BMI: Body Mass Index; OSAS: Obstructive Sleep Apnea Syndrome; BQ: Berlin Questionnaire; AHI: Apnea-Hypopnea Index; ASA: American Society of Anesthesiologists; HFNC: High-Flow Nasal Cannula

Introduction

With technological advances in diagnosis and treatment in the endoscopic era, gastroscopy has become the preferred approach for examining and treating digestive disorders. It is widely used by medical institutions and health management centers at all levels nationally. According to the results of the 2020 China Digestive Endoscopy Technology Survey, there were 38.73 million patients receiving diagnoses and treatments in 2019, a 34.6% increase from 2012. However, during routine gastroscopy, patients often experience pain, anxiety, hiccups, or even pharyngeal hemorrhage. Sedation and analgesia can aid patient comfort and quick recovery, and painless gastroscopy (PG) is now recommended by several guidelines [1,2]. Recent evidence has shown that patients with PG report feeling significantly more comfortable than those in the routine group. This could increase patient compliance and further increase the rate at which digestive tract disorders are diagnosed early [3]. In addition, PG benefits gastroenterologists, anesthesiologists, and patients' satisfaction by raising the detection rate of gastric polyps from 3.12% to 5.11% [4].

Propofol is the preferred intravenous anesthetic for PG. Furthermore, to relieve discomfort and restrict movement during painless gastroscopy, propofol, low-dose benzodiazepines, and opioids are now regularly used [1]. However, respiratory depression following intravenous anesthesia and gastroscopy of the upper respiratory tract can cause hypoxemia in PG [5-7], considerably increasing the risk of patient morbidity and mortality [8,9].

Therefore, minimizing the risk of hypoxemia is crucial for improving patient safety during PG. To improve patient safety through airway management procedures and provide a guideline for the prevention and treatment of hypoxemia in PG, this study reviews current developments in management techniques in PG.

Hypoxemia in a PG

Hypoxemia is the most common complication during PG, with prevalence varying between 1.8% and 69% [2,6,7,10]. At present, there is no unified standard for the definition of hypoxemia. Some studies have defined hypoxemia in patients undergoing PG as SpO_2 below 90% [6,11-14]. Other studies have also chosen SpO_2 of 92% as the diagnostic threshold for hypoxemia, which reflects the transition from a flat to a steep portion of the oxyhemoglobin dissociation curve [15-20]. The World Society of Intravenous Anesthesia (WSIVA) defines pulse oxygen saturation as an atmospheric pressure SpO_2 <90%. Severe hypoxemia is defined as SpO_2 <75% or SpO_2 <90% lasting for more than 60s [21].

Propofol, benzodiazepines, and opioids are among the frequent intravenous anesthetics used in PG. These drugs have the potential to impair breathing, stiffen the chest wall, and impede the upper airway, which can result in hypoventilation, hypoxemia, and carbon dioxide retention. A study shows that the incidence of hypoxemia without supplemental oxygen was as high as 69% in patients who underwent endoscopic retrograde cholangiopancreatography and ultrasonography gastroscopy [6]. In an effort to reduce the risk of hypoxemia, the sedation and anesthesia guidelines of the American Society for Gastrointestinal Endoscopy (ASGE) recommend supplemental oxygen through a nasal cannula for patients undergoing PG [1]. A randomized controlled study by King et al found that the incidence of hypoxemia remained as high as 40% after sedation on the premise of 4 L/min oxygen flow through nasal catheter inhalation [15]. Accordingly, it is crucial to find a way to address the issue of treating and preventing hypoxemia during PG.

Application of Intravenous Anesthetics in PG

A short-term intravenous anesthetic known as propofol has been used extensively in PG owing to its quick onset, adjustable depth of sedation, rapid drug metabolism, and no accumulation effect [22,23]. Short-acting intravenous anesthetics such as propofol are advised by international sedation and anesthesia guidelines for intravenous sedation or anesthesia [1,2]. However, given its comparatively small analgesic effect, propofol injection alone poses a significant risk for PG, as patients might have withdrawal response to the pain caused by gastroscopy insertion [24]. Insufficient sedation depth will also cause severe coughing and perhaps a laryngeal spasm in the patient [25]. Large doses of propofol can aggravate respiratory and circulatory depression, leading to hypoxemia, hypotension, and other adverse events. Utilizing PG in patients with normal BMI, Shao et al revealed that the incidence of hypoxemia was 14.6% following intravenous sedation with propofol alone at 5 L/min oxygen flow [14]. Prolonged hypoxemia can also potentially result in fatal cardiac and cerebral complications such as myocardial ischemia, permanent neurological damage, and even cardiac arrest. Bhananker et al discovered 25 respiratory depression-related deaths or brain injuries in their review of 8946 sedation-monitoring-related claims, of which 13 were linked to propofol sedation [26]. A retrospective study by Goudra et al covering 73,029 digestive endoscopy patients showed that 20 patients had cardiac arrest due to hypoxemia caused by sedatives during gastroenteroscopy and 14 patients died [27]. Propofol sedation increased the probability of cardiac arrest by more than nine times and increased mortality by more than 11 times compared to non-propofol sedation.

Balanced propofol sedation (BPS), which combines propofol with small doses of benzodiazepines and opioids to reach the appropriate level of sedation and analgesia, was proposed by the American Society of Digestive Endoscopy to increase the clinical safety of medication [1]. Patient safety is increased through the administration of opioids, which can reduce the pain experienced during endoscopic placement and suppress the cough caused by propofol during PG. For PG, benzodiazepines can relieve anxiety.

The European Society of Gastrointestinal Endoscopy (ESGE) recommends moderate sedation for patients undergoing gastroenteroscopy, deep sedation for patients undergoing endoscopic ultrasonography-guided fine needle aspiration (EUS-FNA), and endoscopic retrograde cholangiopancreatography (ERCP) [2]. The degree of target sedation with appropriate drugs and doses usually depends on the type of gastrointestinal endoscopy to ensure safety and comfort.

Risk factors for Hypoxemia in a PG

Elderly Patients:

Numerous studies have demonstrated that hypoxemia and aging are strongly correlated and patients over 60 years old undergoing PG have a significantly greater probability of hypoxemia [28-30]. A 1.1-fold increase in the incidence of hypoxemia was observed in aged patients, according to the analysis of 1016 patients receiving PG conducted by Wani et al [31]. Elderly patients always suffer from functioning pulmonary shunts, diminished diaphragmatic movement, a decreased pulmonary ventilation-to-flow ratio, and respiratory system degeneration [32,33]. With the increased bioavailability of intravenous anesthetics, lower doses of pharmaceutical preparations also have higher biological activity, and the reduced body fat reserve in elderly patients would to a prolonged action time of fat-soluble anesthetics. Elderly individuals have decreased liver and kidney function, lower hepatic protein synthesis capacity, and decreased liver and kidney metabolism of intravenous anesthetics. As a result, it is vulnerable to hypoxemia caused by excessive anesthetics. Elderly patients are more likely to develop hypoxemia as a result of all the aforementioned factors [28].

Obesity Patients:

It has been proven that obesity (body mass index, BMI>30 kg/m^2) is an independent risk factor for sedation-related adverse events [34,35]. Obese patients' respiratory physiology has the following features: first, hypertrophic chest wall hypertrophy, decreased thoracic compliance, high respiratory resistance, and a propensity for respiratory muscle fatigue in obese patients; second, the airway anatomical structure in obese patients is changed, such as short neck, neck activity restriction, and fat deposition in the pharyngeal wall [31,36]; third, baseline oxygen consumption increased as body mass index grew, whereas functional residual gas and oxygen reserve dropped [37]. These pathophysiological alterations often cause upper respiratory tract obstruction, raise the incidence of hypoxemia and increase the frequency of necessitate airway manipulation in obese patients. The risk of hypoxemia is 1.9 times higher in obese patients than in nonobese patients, and the proportion of obese patients requiring emergency airway management was 22.4%, more than twice as much as in nonobese patients in endoscopic procedures [31]. Previous studies also demonstrated that, compared to nonobese patients, patients with morbid obesity (BMI>40 kg/m^2) have a shorter tolerance to hypoxia [38,39]. In addition, in individuals of normal weight, the mean time for SpO_2 to decrease to 90% during apnea after adequate preoxygenation was 6 min compared to only 2.7 min in patients who were morbidly obese [40].

Obstructive Sleep Apnea Syndrome (OSAS):

The upper airway obstruction, apnea, and hypopnea that result in obstructive sleep apnea syndrome (OSAS) reduced airway muscle group tension, which makes the tongue and soft palate increasingly prone to collapse downwards and cause hypoxemia [41]. Polysomnographic(PSG) monitoring is the gold standard for diagnosis, but costly and time-consuming. Thus, during PG, the majority of OSAS patients do not establish a firm diagnosis. With a sensitivity of 86%

and a specificity of 77% for predicting OSAS, the Berlin questionnaire (BQ) can assist in identifying individuals who are at high risk of respiratory disorders [42]. According to research by Liou et al on 614 patients who underwent PG and performed BQ showed that 218 (35.5%) of these patients were considered to have a high risk of OSAS, of whom 54 (24.8%) patients developed hypoxemia, while only 29 (7.3%) patients in the low-risk group developed hypoxemia (OR: 3.37; 95% CI: 2.22-5.13) [43]. The Stop-Bang scale can also be used to identify patients who have a high risk of developing OSAS. The Stop-Bang scale score of 3 has a sensitivity of 83.6% for patients with an apnea-hypopnea index (AHI)>5 and 92.9% in patients with an AHI>15 level of OSAS [44]. The incidence of hypoxemia and frequency of airway manipulation were considerably increased in patients at high risk of OSAS who underwent deep sedation, according to Cote et al's screening on the Stop-Bang scale in patients with PG [44].

American Society of Anesthesiologists (ASA) grades ≥ III:

The ASA classification has been utilized in recent years to assess the probability of cardiorespiratory adverse events in PG, including hypotension and hypoxemia. ASA class III and above is a risk factors for the development of hypoxemia during an indolent digestive endoscopy [29]. Patients with an ASA grade ≥ III typically have comorbidities, limited organ function, or poor cardiopulmonary reserve function. Data from 324737 patients undergoing PG were analysed by Sharma et al showed that the incidence of cardiorespiratory adverse events increased along with higher ASA grade [29]. Hypoxemia were observed in 1.8-fold increase in ASA class III, 3.2-fold increase in ASA class IV and 7.5-fold increase in ASA class V respectively compared to ASA class I and ASA II patients. Consequently, Vargo et al showed that patients with ASA grades ≥ III had a relative risk of hypoxemia that was twice as high as those with class I and II [45].

Prevention and Treatment for Hypoxemia in PG

A major element of the safe performance of PG is the prevention of hypoxemia. In patients with high risk factors of hypoxemia, continuous nasal catheter oxygen intake partly reduces the incidence of hypoxemia [31,46]. While enhancing the inhaled oxygen concentration, inhaled oxygen flow, and tidal volume can essentially guarantee the patient's proper oxygenation and ventilation throughout the endoscopic examination, supraglottic-assisted ventilation equipment may be the dominant method for the hypoxemia issue.

Traditional Nasal Catheter:

Hypoxemia can be effectively avoided with traditional nasal catheter oxygen inhalation during PG. In clinical practice, it is in accordance with the schedule of the oxygen breathing apparatus. The oxygen flow can be regulated from 0 to 10 L/min depending on the conditions. The findings of the research conducted by Bell et al demonstrate that in 150 patients who underwent PG after midazolam injection, the average minimum oxygen saturation in the group of patients without oxygen inhalation was as low as 89% during the examination, whereas in the nasal catheter group it was 96.3%, and the incidence of hypoxemia was significantly lower than in the patients without oxygen inhalation group [47]. In an effort to reduce the risk of hypoxemia during PG under intravenous anesthesia, nasal catheter oxygen is commonly used [1].

Novel Dual-Chamber Nasopharyngeal Catheter:

The novel dual-chamber nasopharyngeal catheter is an invasive oxygen inhalation device that has two 10 Fr oxygen inhalation catheters of 16 cm and attached to the patient's bilateral nasopharynx to enable immediate supraglottic oxygen administration. The device can also monitor end-tidal carbon dioxide during endoscopy to detect hypoventilation early, but its reliability is needed to be verified. The device has several benefits over a standard nasal catheter, including the ability to deliver oxygen directly to the glottis, manage problems with oxygen delivery when the upper airway is obstructed, and maintain constant positive airway pressure while sharing the upper airway with the endoscopist to prevent hypoxemia. As a result, it has been demonstrated that oxygen inhalation in the novel dual-chamber nasopharyngeal catheter is effective in reducing the risk of hypoxemia.

King et al study showed that compared to the traditional nasal catheter group, the incidence of hypoxemia was reduced in the novel dual-chamber nasopharyngeal catheter group (40% vs 11.1%). However, the device should be inserted into the pharynx after the patient loss of consciousness to decrease the risk of bleeding and sore throat [15].

Special Inflatable Mask for Endoscopy:

The endoscopic inflatable mask is a ventilation device with an endoscopic opening which can enable gastroscopy and mask ventilation to be performed simultaneously. In addition, the endoscopic inflatable mask may completely enclose the patient's mouth and nose, thereby increasing the pharyngeal cavity's oxygen absorption area and the patient's tolerance to hypoxia, which effectively reducing the probability of hypoxemia. The mask can be connected to the ventilator via a breathing circuit for artificial assistance or mechanical ventilation. In the situation of hypoxemia, oxygen can be pressured by the mask to enable prompt oxygen supply without withdrawing the endoscope. A study evaluating the effectiveness and safety of an endoscopic inflatable mask for PG in obese patients showed that 12% of patients in the nasal catheter group developed hypoxemia, while the endoscopic inflatable mask group had no cases of hypoxemia [48]. Similarly, Huang et al found that the average SpO_2 during PG was significantly higher than that in the traditional mask group (96% vs 90%) in patients receiving intravenous anesthesia [49]. Notwithstanding the benefits mentioned above, as a breathing device for PG, the endoscopic special inflated mask remains unable to prevent airway obstruction and aspiration.

Nasal Mask:

The silicone inflatable nasal mask cushion's shape fits snugly around the nose, effectively preventing air leakage and significantly improve the oxygen concentration in the nasal cavity. According to a research, mechanical ventilation with a nasal mask has an average tidal volume that is approximately 4 times greater than that of ventilation using an oral-nasal mask, showed that nasal mask ventilation is significantly more effective than oral-nasal mask [50]. During nasal mask ventilation, positive pressure is only produced by the nasopharynx, and the pressure gradient between the nasopharyngeal and oropharyngeal cavities can overcome the effects of gravity on the soft palate and tongue. The mask also can be connected to the ventilator through via a breathing circuit to provide high concentration oxygen and positive pressure ventilation without disturbing the endoscopy. Due to the high price of endoscopic nasal mask, small oral-nasal mask is commonly used as nasal masks in clinical practice [51]. It is worth noting that hyperemia and edema of nasal mucosa caused by high ventilation pressure should be avoided.

High-Flow Nasal Cannula Inhalation Device:

A recently developed technique called high-flow nasal cannula (HFNC) employs a special nasal catheter to provide heated and humidified oxygen to the airway. The oxygen flow rate can be adjusted between 20 and 70 L/min, and HFNC offers oxygen concentrations ranging from 21% to 100% and heated humidified oxygen between 31 and 37°C. High-flow gas can also result in 5-7 cmH_2O PEEP [52,53]. Parke et al demonstrated that the oxygen flow rate was 50 L/min, a positive airway pressure of approximately 1.7 cmH_2O could be achieved [54]. In addition, Lin et al discovered that at an oxygen flow rate of 60 L/min was likely to maintain a positive airway pressure of approximately 2 cmH_2O, significantly raising alveolar oxygen concentrations, decreasing dead space, and increasing end-expiratory lung volume [11]. HFNC can also improve oxygen concentration at the distal end of the airway, resulting in a significant oxygen partial pressure gradient between the alveoli and the respiratory tract, which guarantees that the patients can still maintain efficient gas exchange during respiratory depression. In addition, heating and moisturizing oxygen can also maintain airway mucociliary function, promote sputum drainage, and reduce bronchoconstriction. HFNC can effectively reduce hypoxemia in PG, and various recent studies have discovered that PG with HFNC reduce the incidence of hypoxemia from 71.9% to 36.0% than that with a traditional nasal catheter [18,19]. Moreover, results of a randomized controlled study including 1994 patients undergoing PG showed no cases of hypoxemia during inhalation of pure oxygen at 60 L/min flow through the nasal catheter after intravenous sedation with propofol [11]. There are several limitations of HFNC, which is expensive, requiring special oxygen delivery systems, and may increase the risk of potential adverse events such as hypercapnia.

Nasopharyngeal Ventilatory Tract:

The nasopharyngeal ventilation channel is a transnasal ventilation device with the advantages of simple operation and easy placement. Soft-tissue collapse and posterior tongue drop are important causes of upper respiratory tract obstruction in PG. The nasopharyngeal airway can improve the condition of upper airway obstruction and ensure airway patency without interfering with endoscopy, thus reducing the risk of hypoxemia during PG [55]. Shao et al found that for patients who underwent PG with a BMI of 18-25 kg/m^2, the incidence of hypoxemia in the nasopharyngeal airway group was significantly lower than that in the nasal catheter group at 5 L/min of oxygen flow (2.1% vs 14.6%) [14]. Muller et al also revealed the similar result that the incidence of hypoxemia was significantly lower than that in the nasal catheter group (2% vs 13%) [12]. Xiao et al discovered that oxygen saturation in obese patients was decreased in both nasopharyngeal airway group and nasal catheter group during PG than before examination, but the decrease of SpO_2 in the nasopharyngeal airway group was significantly lower than that in the nasal catheter group (6% vs 10.5%) [7]. The placement of the nasopharyngeal airway would be invasive, the nasal soft tissue may prone to be injured. Therefore, the nasopharyngeal airway should be inserted with lubricant after sedation. For patients with nasal stenosis, operation should be cautiously performed to avoid nasal mucosa injury and nasal bleeding.

Supraglottic Jet Vent Device:

A novel supraglottic airway device which is called the Wei's nasal jet tube can be utilized for supraglottic jet oxygenation and ventilation [13]. As a special nasopharyngeal airway, the device is connected with two catheters in the lumen to the jet ventilation device for oxygen supply and end-tidal carbon dioxide concentration monitoring. Currently, there are two specifications available for adult patients, with internal diameters of 5.0 mm, external diameters of 7.3 mm and lengths of 145 mm, and internal diameters of 7.0 mm, external diameters of 10.0 mm and lengths of 155 mm. The Wei's nasopharyngeal airway can be directly connected to the ventilator machine through the breathing circuit to deliver oxygen to the supraglottic. The effectiveness of supraglottic jet ventilation on the Wei's nasopharyngeal tract during PG were addressed by Qin et al in a multicenter study [13]. Studies have shown that the incidence of hypoxemia in patients treated with supraglottic nasal ventilation has decreased from 9% to 3% and significantly reduced the frequency of jaw support compared with traditional nasal catheter oxygen administration. Attention should be given to potential consequences including airway injury, stomach distension, and dry mouth while using supraglottic jet ventilation.

Conclusion

The use of intravenous anesthetics in PG can result in respiratory depression and upper respiratory tract obstruction, leading to hypoxemia. High-risk factors for hypoxemia in PG include being aged over 60 years, obesity, OSAS, and having ASA grades ≥ III (**Fig-1**). Various supraglottic ventilation devices can effectively reduce the incidence of hypoxemia during PG, although each ventilation device has its own advantages and disadvantages. For high-risk populations, it is crucial to provide continuous positive airway pressure and high flow nasal oxygen systems. During PG, monitoring of end-tidal carbon dioxide concentration should also be recommended. In the future, our research will focus on how to individually choose the ideal ventilation device based on the specific conditions of each patient.

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Authors' Contributions

Jun Ma drafted the manuscript, and Ling Tan revised the article. The author(s) read and approved the final manuscript.

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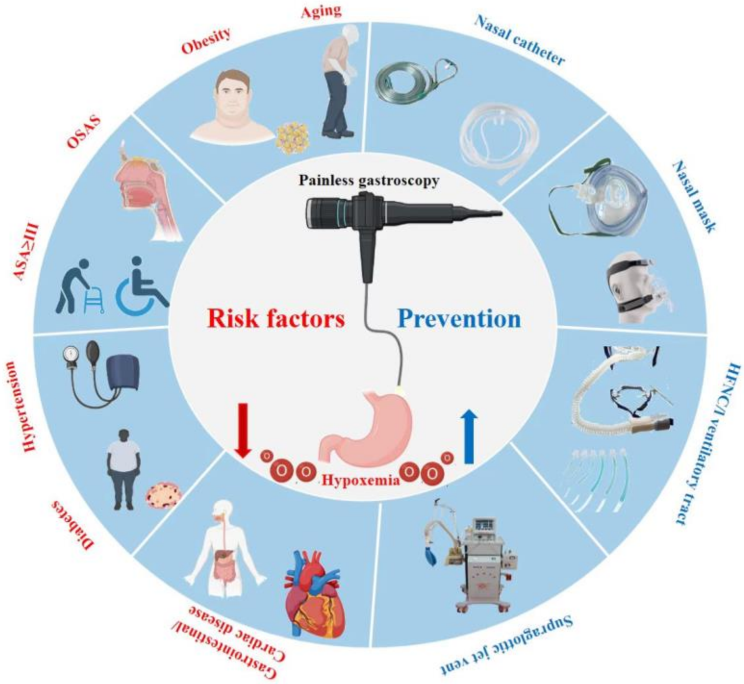

Fig-1: The risk factors and prevention strategy of hypoxemia in patients undergoing painless gastroscopy.

Competing Interests

The authors declare that they have no competing interests.

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