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A Case of Air Embolism during Transoral Vestibular Endoscopic Thyroidectomy

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Abstract

Background: Carbon dioxide (CO_2) embolism is a rare but potentially life-threatening complication of endoscopic surgery. While endoscopic thyroidectomy is superior to traditional open thyroidectomy in terms of cosmetic results, it may lead to venous or fatal paradoxical CO_2 embolism. CO_2 embolism involves the inadvertent injection of carbon dioxide into a large vein, artery, or solid organ. The clinical manifestations of CO_2 embolism can vary from asymptomatic to neurological damage, cardiac failure, and even death, depending on the rate and volume of CO_2 entry and the patient's general condition. This case can enhance our understanding of CO_2 embolization during endoscopic surgery.

Case Presentation: This case report describes an incident in which a gas embolism occurred during endoscopic right lobe and isthmus thyroidectomy, resulting in arrhythmia and dramatic fluctuations in circulation and oxygen levels. The operation was halted, and CO_2 injection was stopped. The surgical wound was covered with saline gauze, and the patient inhaled 100% pure oxygen while undergoing aggressive repeated manual pulmonary recruitment maneuvers. Additionally, vasoactive drugs such as m-hydroxyamine and ephedrine were administered to aid in treating the condition. The patient's position was adjusted using the Durant maneuver (partial left lateral and Trendelenburg position). Following the aforementioned treatments, the patient's ventricular arrhythmia transitioned back to a normal and regular sinus rhythm, and both circulation and oxygen levels stabilized.

Conclusions: Carbon dioxide embolism is an uncommon yet potentially severe complication of laparoscopic procedures. We anticipate that this particular case will enhance our comprehension of carbon dioxide embolism during endoscopic surgery.

Keywords

Air Embolism, Pulmonary Embolism, Thyroidectomy, Endoscopy

Background

The safety and effectiveness of transoral thyroid surgery have been confirmed by a large number of studies since the first transoral thyroidectomy was conducted by Wilhelm et al [1] in 2009. Transoral thyroidectomy, performed through the vestibular approach, leaves no visible scar on the body surface, aligning with the minimally invasive concept by

involving dissection in much smaller areas compared to other remote access thyroidectomies like transaxillary, retroauricular, or bilateral axillo-breast approaches. As a result, this procedure gained global popularity.

Similar to endoscopic surgery, transoral thyroid surgery generally involves intra-oral incision, establishment of the subplatysmal space, and thyroidectomy [2]. Currently, the primary methods to maintain the operating space encompass insufflation, suspension, pulling, and a combination of insufflation-suspension techniques [3-7]. Insufflation, the most widely used method, offers the advantage of convenient operation without excessive dependence on suspension or traction equipment. The pressure of CO_2 gas within the cavity can widen the gap of the skin flap and simplify the separation of the skin flap. However, complications such as gas embolism, hypercapnia, and subcutaneous emphysema may arise.

We present this case as a representative instance of CO_2 air embolism, aiming to raise awareness among other anesthesiologists to remain vigilant regarding such complications during transoral vestibular endoscopic thyroidectomy.

Case Presentation

A 39-year-old female, weighing 59.6 kg, standing at 165 cm, and with a BMI of 21.9 kg/m^2, was admitted to the hospital on December 5, 2022, due to a thyroid nodule. Color Doppler ultrasonography of the thyroid gland revealed a weak echogenic nodule measuring about 11×4×7 mm in the inferior right lobe. Preoperative evaluations, including laboratory tests, electrocardiography (ECG), and chest CT, returned normal results.

Upon entering the operating room, routine monitoring was initiated for ECG, blood pressure (BP), and SpO_2. The initial measurements showed a BP of 100/64 mmHg, a heart rate (HR) of 70 beats/min in sinus rhythm on ECG, and SpO_2 at 98%. Anesthesia induction involved the intravenous administration of 2 mg of midazolam, 11 mg of cis-atracurium, 60 mg of propofol, and 17.5 μg of sufentanil. Endotracheal intubation was performed using a 6# nerve monitoring catheter (EMG Endotracheal Tube, Jiang Su Bai Ning), followed by mechanical-assisted ventilation. Anesthesia maintenance was achieved with remifentanil, sevoflurane, and propofol while maintaining a supine head and neck hyperextension position.

During the surgery, the oral cavity was disinfected, and the electrocoagulation hook was inserted diagonally to dissociate the mandibular bone surface. A subcutaneous tunnel was established using a stripper rod and a 12mm trocar was inserted. CO_2 insufflation was initiated, maintaining a pressure of 6 mmHg. Approximately 52 minutes after anesthesia induction, the patient's BP abruptly dropped to 83/52 mmHg, SpO_2 decreased to 92%, and the ECG revealed ventricular tachycardia (**Fig-1**), with an actual effective cardiac fluctuation of 63 bpm. The anesthesia monitor indicated a drop in $PETCO_2$ from 30 cmH_2O to 25 cmH_2O. Concurrently, the surgeon was dissecting the anterior jugular vein (**Fig-2**).

In response to the declining BP and potential malignant arrhythmias, immediate actions were taken. The surgery was suspended, and the patient received pure oxygen inhalation. Additionally, 0.2 mg of methoxamine and 6 mg of ephedrine were administered to elevate BP. Within thirty seconds, BP increased to 123/69 mmHg, HR rose to 75 bpm, but SpO_2 remained between 92-95%. Physical examination revealed diminished breath sounds in the lungs, raising strong suspicion of pulmonary embolism due to the ongoing circulatory and oxygenation fluctuations.

Fig-1: ECG: Continuous Ventricular Premature Beats

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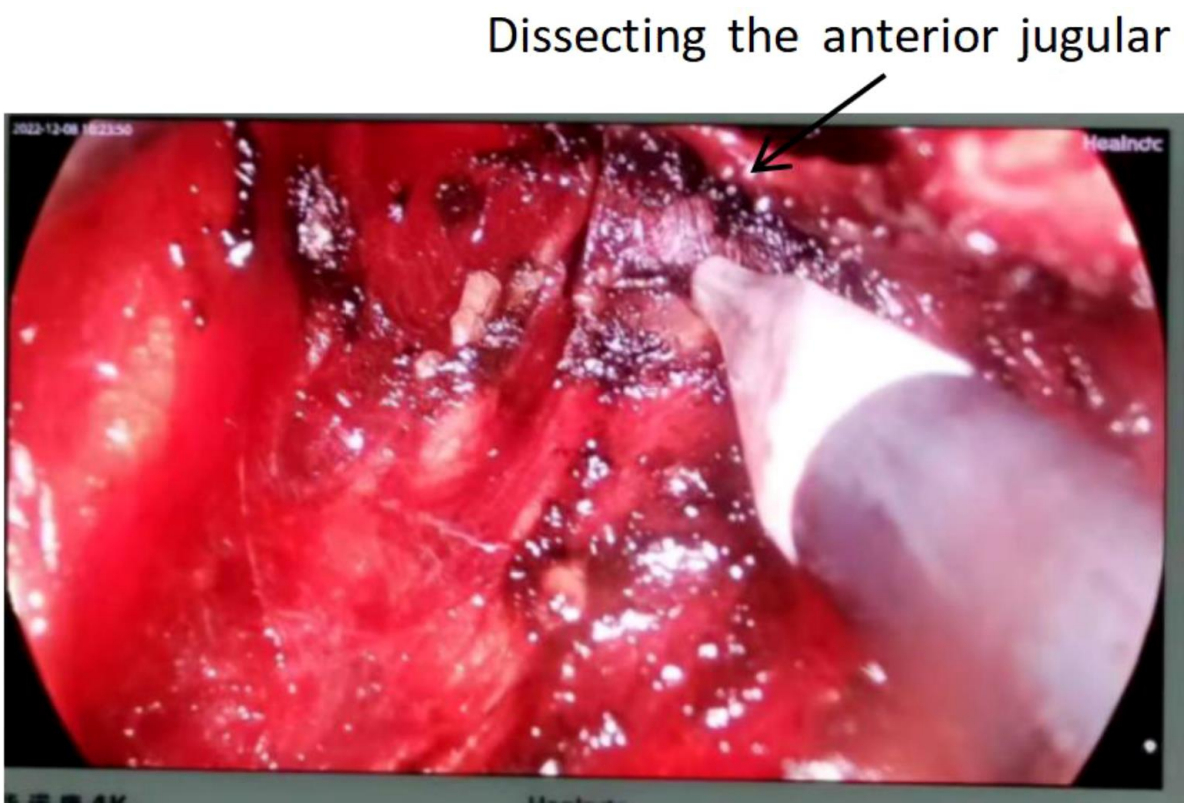

Fig-2:

The patient suddenly dropped the blood pressure and SpO_2, with ECG of ventricular premature beats when the surgeon was dissecting the anterior jugular vein

Fig-3:

The anterior jugular vein ruptured, and the surgeon covered the rupture with salinegauze

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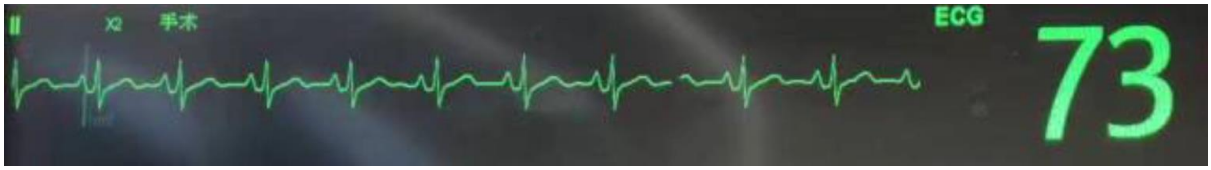

Fig-4: ECG: Restoration of Sinus Rhythm

Upon inspection of the operative field, a rupture in the patient's anterior jugular vein was identified. It was hypothesized that CO_2 had entered the superior vena cava through this rupture, leading to CO_2 embolism through the right heart. The surgical team compressed the vein and covered the operative area with moist gauze to prevent further CO_2 absorption (**Fig-3**). The patient was repositioned into a left lateral Trendelenburg position, and repeated lung recruitment maneuvers were performed. Within 2 minutes, SpO_2 improved to 99%. An arterial blood gas analysis indicated an arterial carbon dioxide partial pressure of 59.6 mmHg and an oxygen partial pressure of 400 mmHg.

After half an hour, the patient's circulatory and oxygenation parameters began to stabilize, and lung auscultation returned to normal. The surgery resumed without significant changes, maintaining normal vital signs. HR ranged between 70-90 bpm with a regular rhythm (**Fig-4**), BP ranged between 95-120/55-70, and SpO_2 reached 100%. The operation lasted a total of 5 hours and 3 minutes, and the patient was successfully extubated with stable vital signs. She was discharged on the 4^{th} day after the surgery.

Discussion

CO_2 embolism is a well-documented complication of laparoscopic procedures [8-10]. Venous air embolism (VAE) occurs when a vein is compromised, and a pressure gradient facilitates the entry of gas into the vein. Consequently, any endoscopic procedure utilizing CO_2 insufflation comes with the potential risk of CO_2 embolism. In our case, patients typically assume an extended neck position during transoral vestibular endoscopic thyroidectomy. Prolonged neck extension can elevate skin tension and impair the flexibility of the operating space, causing undue tightness in the flap, making it challenging to elevate to an adequate height. To achieve clear exposure of the thyroid lobe tissue, CO_2 insufflation was employed to expand the flap, creating a spacious operative field [11].

During the surgery, the anterior jugular vein was inadvertently separated, resulting in venous rupture. Under pressure differentials, CO_2 infiltrated from the ruptured site into the superior vena cava, entered the right heart system, and progressed through the right ventricular ejection, leading to substantial CO_2 entry into the pulmonary artery and subsequently the pulmonary arteriole [12]. CO_2 embolism generally arises from two primary factors: firstly, a confined oral cavity operating space could lead to local vascular tears during expansion, permitting CO_2 entry into the bloodstream through the breached vessels; secondly, injecting CO_2 under excessively high pressure (in this case, 6 mmHg) raises the likelihood of CO_2 introduction into the vascular system. As gas pressure increases, so does the risk of air embolism. We recommend keeping gas pressure below 6 mmHg for enhanced safety [11,13]. In endoscopic thyroidectomy, the established insufflation pressure remains below 6 mmHg, significantly lower than the 12–15 mmHg used in other laparoscopic procedures. This distinction could have contributed to the favorable outcome in our case.

Prior to the widespread adoption of multimonitoring technologies like transesophageal echocardiography (TEE), diagnosing VAE relied heavily on direct observation of air suction in the surgical field, deductions from clinical presentations, or postmortem detection of air within vasculature or heart chambers. Regarding clinical diagnosis, unexplained intraoperative hypotension or reduction in $PETCO_2$, especially in reverse Trendelenburg positioning or when venous vasculature is exposed to atmospheric pressure, or persistent hypotension and/or hypoxia that cannot be attributed solely to hypovolemia, should trigger suspicion of VAE. Notably, a distinct sign of venous air embolism is the classic “water-wheel” or “mill-wheel murmur,” characterized by a splashing auscultatory sound resulting from gas and air churning

in the cardiac chambers [14]. In severe cases or those with delayed onset pulmonary edema, elevated right ventricular afterload and severe hypotension can serve as diagnostic indicators [15].

Transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) remain the most sensitive noninvasive detection methods, capable of identifying not only large vein and microthrombi but also abnormal arterial emboli that could lead to ischemic cerebral complications. While TTE can detect air volumes as small as 0.25 mL (0.05 mL/kg), TEE's sensitivity extends to as little as 0.02 mL/kg of air [16-20].

In our case report, we illustrated successful anesthesia management of air embolism in patients undergoing transoral vestibular endoscopic thyroidectomy. The primary management objectives for strongly suspected or confirmed VAE involve preventing further air entry and offering hemodynamic support when feasible [21]. To halt additional air entry, we employed saline dressings to cover suspected venous lacerations, followed by surgical assessment and closure of any potential entry sites. Additionally, we adjusted the operating table tilt to minimize the air entry source and eliminate negative air pressure gradients. For hemodynamic support, high-flow oxygen inhalation and ephedrine were administered to optimize oxygenation and myocardial perfusion amidst cardiovascular instability [22,23]. Importantly, a partial left lateral position could alleviate increased air accumulation in the right ventricle due to VAE. Recent literature suggests that aggressive, repeated manual pulmonary recruitment maneuvers could serve as an innovative VAE treatment strategy, potentially causing air embolism to fragment into smaller bubbles, facilitating its exit from the pulmonary outflow tract into smaller pulmonary vessels, thus relieving pulmonary obstruction. Additionally, these maneuvers, combined with pure oxygen, reduce pulmonary artery resistance and aid in flushing the embolism distally into the pulmonary artery [24].

Transoral thyroidectomy, involving three incisions in the anterior vestibule for thyroid access, boasts excellent cosmetic outcomes due to the absence of visible surface scars. However, this innovative method of creating a working space presents challenges and carries potential for unconventional yet severe complications. The incidence of venous air embolism following transoral thyroid surgery is approximately 2%, characterized by sudden BP drops, arrhythmias, and reduced oxygen saturation during CO_2 insufflation [25]. While some patients may exhibit mild symptoms like coughing, venous air embolism can remain asymptomatic as small air quantities typically disintegrate and are absorbed in the pulmonary capillaries without clinical manifestations. Yet, an extensive influx of venous air can lead to pulmonary vascular constriction, heightened pulmonary artery pressure, increased right ventricular outflow resistance, consequent right ventricular failure, diminished left ventricular preload, reduced left ventricular output, and eventual systemic cardiovascular collapse [26,27]. Moreover, activated neutrophils within the pulmonary capillaries release thromboxane and leukotrienes, elevating airway resistance and alveolar capillary permeability, culminating in pulmonary edema and alveolar collapse [26]. In extreme scenarios, copious venous air can occupy the right atrium and ventricular outflow tract, entirely blocking right ventricular blood flow, provoking arrhythmias, right ventricular dilation, decreased cardiac output, cardiovascular failure, and even cardiac arrest [28].

Conclusion

In conclusion, we present a case of CO_2 embolism accompanied by ventricular arrhythmia and reduced oxygen saturation observed during transoral vestibular thyroidectomy. For the context of endoscopic thyroid surgery, we propose the following recommendations:

- *Surgeon Proficiency*: Surgeons should possess a thorough familiarity with the floor of the mouth's anatomy. When creating gaps and expanding spaces, a meticulous approach to separating connective tissue should be adopted to prevent inadvertent damage to blood vessels.
- *CO_2 Pressure Regulation*: To mitigate the risk of CO_2 embolism, it is advisable to maintain CO_2 pressure settings below 6 mmHg during insufflation.

- *Positive End Expiratory Pressure* (PEEP): Implementing PEEP serves to lower central venous pressure, contributing to the reduction of embolic events.

Endoscopic thyroid surgery offers distinctive advantages, likely to witness increased adoption in the future. Nevertheless, our vigilance must remain heightened concerning the potential occurrence of CO_2 embolism.

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Availability of Data and Materials

All data generated or analyzed during this study are included in this published article.

Authors' Contributions

XB played a major role in writing the manuscript. WRR, the corresponding author, contributed by critically revising the article for significant intellectual content, giving final approval for the version to be published, and taking responsibility for all aspects of the work. This includes ensuring that questions related to accuracy and integrity are thoroughly investigated and resolved. All authors have reviewed and approved the final manuscript.

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Written informed consent for publishing clinical details and images was obtained from the patient.

Competing Interests

The authors declare that they have no competing interests.

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