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CASE REPORT

Asymptomatic carbon dioxide embolism during transoral vestibular thyroidectomy: A case report

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Abstract

BACKGROUND

Endoscopic thyroidectomy has obvious advantages over conventional surgical techniques in terms of postoperative cosmetic outcome. Although the incidence of carbon dioxide embolism (CDE) during endoscopic thyroidectomy is very low, it is potentially fatal. The clinical manifestations of CDE vary, and more attention should be paid to this disorder.

CASE SUMMARY

A 27-year-old man was scheduled for thyroidectomy by the transoral vestibular approach. The patient had no other diseases or surgical history. During the operation, he developed a CDE following inadvertent injury of the anterior jugular vein. The clinical manifestation in this patient was a transient sharp rise in end-tidal carbon dioxide, and his remaining vital signs were stable. In addition, loud coarse systolic and diastolic murmurs were heard over the precordium. The patient was discharged on day 4 after surgery without complications.

CONCLUSION

A transient sharp rise in end-tidal carbon dioxide is considered a helpful early sign of CDE during endoscopic thyroidectomy.

Key Words: Carbon dioxide embolism; Endoscopic thyroidectomy; Transoral vestibular thyroidectomy; End-tidal carbon dioxide; Literature review; Case report

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Core Tip: Carbon dioxide embolism can occur during endoscopic thyroidectomy and is potentially fatal. The clinical manifestations of carbon dioxide embolism vary. Thus, anesthesiologists should pay more attention when diagnosing and managing such patients.

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INTRODUCTION

Endoscopic thyroid surgery, also called remote-access thyroidectomy, has obvious advantages over conventional surgical techniques in terms of postoperative cosmetic outcome[1]. Endoscopic thyroidectomy was first reported in 1997. It has gradually become popular worldwide and consists of the transoral, postauricular, anterior chest, breast and transaxillary approaches[2]. Thyroidectomy by the transoral approach results in no surgical incision scars, less surgical trauma, a broader surgical view of the thyroid gland and a shorter learning curve for surgeons; thus, it is considered to be the ultimate surgical procedure for endoscopic thyroidectomy[3,4].

Endoscopic thyroidectomy can be divided into gasless endoscopic thyroidectomy and carbon dioxide (CO_2) inflatable endoscopic thyroidectomy[5]. CO_2 insufflation improves surgical field exposure but has the potential risk of subcutaneous emphysema, hypercapnia, cerebral edema and carbon dioxide embolism (CDE)[6,7]. We recently encountered a case of CDE during transoral vestibular thyroidectomy. To our knowledge, this is the first report of CDE that manifested as a sudden and dramatic increase in end-tidal carbon dioxide ($ETCO_2$) during endoscopic thyroidectomy.

CASE PRESENTATION

Chief complaints

A 27-year-old man was admitted to our hospital with a thyroid tumor of the middle and lower poles of the right thyroid, which was found 1 wk previously.

History of present illness

The patient was admitted to the hospital for routine physical examination 1 wk ago. Through thyroid color Doppler ultrasound, a thyroid tumor in the middle and lower poles of the right thyroid was found. The patient denied any symptoms such as dyspnea, fear of heat and lethargy.

History of past illness

The patient had no other diseases or surgical history.

Personal and family history

The patient did not smoke or drink and denied a family history of genetic disease.

Physical examination

The patient's trachea was in the center, breath sounds in both lungs were clear and symmetrical, and there was no murmur on heart auscultation.

Laboratory examinations

The results of preoperative blood examinations, blood biochemistry tests, coagulation function tests, thyroid function tests, urinalysis and stool analysis were normal.

Imaging examinations

Preoperative color Doppler ultrasound of the thyroid revealed a 1.9 cm × 2.6 cm nodule in the middle and lower poles of the right thyroid. The results of preoperative chest roentgenogram, electrocardiography and echocardiography were normal.

Surgery and anesthesia procedures

On admission to the operating room, the patient's heart rate, blood pressure, oxygen saturation and electrocardiography were monitored. Propofol, vecuronium and sufentanil were administered intravenously for induction of general anesthesia and sevoflurane, propofol and remifentanil for maintenance anesthesia. $ETCO_2$ and body temperature were continuously monitored throughout general anesthesia.

The patient was placed in the supine position, and the neck was extended with a shoulder pillow. In brief, after sterilization and draping, one 1.2-cm horizontal incision was made from 5 mm anterior the lower oral frenulum, and another two 5-mm horizontal incisions were made on either side of the first incision. Then 20 mL of 0.9% saline solution, containing 0.375% ropivacaine and epinephrine (1:40000), was injected subcutaneously into the submental and anterior neck area. A blunt-tipped 12 mm trocar was inserted into the space for insertion of a 10 mm 30-degree rigid endoscope (KARL STORZ-ENDOSKOPE, STORZ, Indonesia). The pressure of CO_2 insufflation was 6 mmHg, and then two 5 mm trocars were inserted into the oral vestibule on both sides of the endoscope. Under endoscopy, grasping forceps and an ultrasonic knife were used to dissect the skin flap in the plane of the subplatysmal layer. The flap ranged from the level of the sternal notch and the anterior border of the sternocleidomastoid muscle.

During dissection of the anterior cervical area, the anterior jugular vein was inadvertently injured, and obvious bleeding in the surgical area was observed. The ultrasonic scalpel was used to staunch the bleeding (Figure 1). At this time, the patient's $ETCO_2$ had increased from 46 mmHg to 68 mmHg and continued to reach a maximum of 84 mmHg 1 min later (Table 1). His heart rate, blood pressure, oxygen saturation, heart rhythm and airway pressure were similar throughout the procedure. A CDE was initially considered, and CO_2 insufflation was immediately ceased, the sevoflurane vaporizer was turned off, and the patient was placed in the Steep-head down, left-lateral decubitus (Durant's) position. Loud coarse systolic and diastolic murmurs were heard over the precordium using a stethoscope, and breath sounds were normal on both sides. The patient's $ETCO_2$ began to drop to 82 mmHg at the third min, then gradually decreased to the preoperative baseline level of 40 mmHg within approximately 10 min. Surgery was continued using a gasless facelift approach. After the operation, the patient was transferred to the post anesthesia care unit. Bedside chest roentgenogram was immediately performed in the post anesthesia care unit and showed no abnormalities (Figure 2).

Search methods and study selection

To further examine the characteristics of CDE, such as the clinical manifestations, diagnosis, treatment and prognosis, in endoscopic thyroidectomy, we identified similar cases reported in the past decade. We first performed an electronic search of several databases including PubMed, Cochrane Library, EMBASE and Web of Science from January 2010 to November 2020. The search words included "embolism," "hypercapnia," "end-tidal carbon dioxide" and "thyroidectomy" and were adopted for all search strings according to the unique characteristics of each database. After the electronic search, we confirmed the included studies using the following entry criteria: the types of the published articles were case reports, prospective studies or retrospective studies, and the papers that reported hypercapnia or CDE occurring after CO_2 insufflation during endoscopic thyroidectomy were included. Meta-analyses and non-English language studies were excluded.

Finally, 5 cases in four articles were obtained[7-10]. Data on age, weight, tumor size, surgical approach, insufflation pressure, intraoperative anesthesia, embolization time, possible causes, clinical manifestations, diagnostic tools, treatment and prognosis were extracted and are shown in Table 2. Surgical approaches included the bilateral axilla and nipple areola approach, transoral robotic approach, axillo-bilateral-breast approach and the transoral approach. Insufflation pressure was set to 20 mmHg in one study, 8 mmHg in one study and 6 mmHg in two studies. Gas embolism developed in 2 cases when CO_2 was insufflated, and the other cases developed CDE during the process of tissue dissection. Only one report suggested a possible anterior jugular vein tear, and the other three reports did not specify the cause.

Table 1 Intraoperative changes of patient's vital signs during carbon dioxide embolism

Parameter	12:51	12:52	12:53	12:54	12:55	12:56	12:57	12:58	12:59	13:00	13:01
End-tidal CO_2 in mmHg	46	68	84	82	78	73	65	60	55	50	47
Noninvasive systolic blood pressure in mmHg	(-)	99	(-)	(-)	101	(-)	(-)	103	(-)	(-)	101
Noninvasive diastolic blood pressure in mmHg	(-)	57	(-)	(-)	53	(-)	(-)	51	(-)	(-)	57
Heart rate in bpm	68	67	66	66	64	63	64	65	64	64	65
Blood oxygen saturation, %	100	100	100	100	100	100	100	100	100	100	100

Table 2 Characteristics of qualified cases with carbon dioxide embolism in endoscopic thyroidectomy in the last decade

Characteristic	Rajan *et al*[8], 2016	Kim *et al*[7], 2018	Kim *et al*[9], 2010	Fu *et al*[10], 2018[1]
Age in yr	48	59	59	UN
Weight in kg	68	57	54	UN
Size of thyroid nodules in cm	4.0 × 5.0	1.1 × 0.8 × 1.0	UN	UN
Surgical approach	Bilateral axilla and nipple areola	Transoral robotic	Axillo-bilateral-breast approach	Transoral
Insufflation pressure in mmHg	20	6	6	8
Maintenance of anesthesia	UN	O_2–air-sevoflurane	O_2–air-sevoflurane	UN
Time of event	3 h after operation	During skin flap elevation	Beginning of CO_2 insufflation	Beginning of CO_2 insufflation
Possible causes	UN	Anterior jugular vein was lacerated	UN	UN
Clinical manifestations	$ETCO_2$↓, SPO_2↓, hypotension, bradycardia	$ETCO_2$↓, SPO_2↓, hypotension, bradycardia, premature atrial complexes, asystole	$ETCO_2$↓, SPO_2↓, hypotension, tall peaked T-wave	SPO_2↓, hypotension, tachycardia, asystole
Diagnosis tools	$ETCO_2$	$ETCO_2$	$ETCO_2$, TEE	Precardial Doppler sonography
Treatment	Reduced insufflation pressure, Trendelenburg position, glycopyrrolate 0.2 mg, ephedrine 6 mg, 100% O_2 hyperventilation, aggressive intravenous volume expansion, 6 cmH_2O PEEP	Stopped CO_2 gas insufflation, Durant's position, ephedrine 10 mg, atropine 0.5 mg, 100% O_2 hyperventilation, chest compression, epinephrine 1 mg	Stopped CO_2 gas insufflation, Durant's position, 100% O_2 hyperventilation, ephedrine 5 mg	Stopped CO_2 gas insufflation, Left lateral decubitus, dexamethasone, aminophylline, dopamine, high flow O_2, chest compression
Prognosis	Good	Good	Good	Good

[1]This article included 2 cases. CO_2: Carbon dioxide; $ETCO_2$: End-tidal carbon dioxide; O_2: Oxygen; PEEP: Positive end-expiratory pressure; SPO_2: Percutaneous oxygen saturation; TEE: Transesophageal echocardiography; UN: Unknown.

The clinical manifestations after embolism mainly included a sudden and severe drop in $ETCO_2$, a drop in oxygen saturation, hypotension, sinus bradycardia, sinus tachycardia, atrial premature contraction and paradoxical embolism. Three cases developed cardiac arrest. Three reports mentioned $ETCO_2$, one of which used transesophageal echocardiography (TEE) combined with $ETCO_2$, and another reported the use of transthoracic Doppler ultrasound for diagnosis. The treatment methods for CDE included discontinuation of insufflation, adjustment of the patient's position to Durant's position, 100% oxygen hyperventilation, the administration of vasopressors and inotropic agents, aggressive volume expansion, positive end-expiratory pressure for ventilation and cardiopulmonary resuscitation for cardiac arrest.

From the prospective study of a small sample of 81 patients by Fu *et al*[10], 2 patients were identified as having CDE[10]. We calculated that the incidence of CDE in transoral endoscopic thyroidectomy was approximately 2.4%. The prognosis of these 5 patients was good. However, we believe that a long term, high-volume, prospective

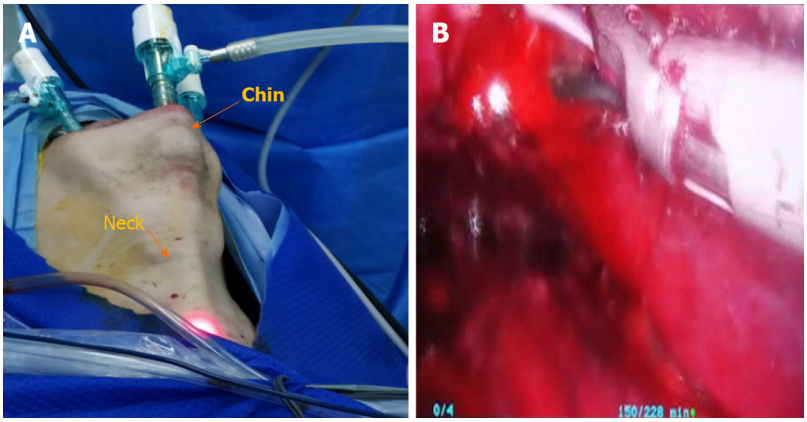

Figure 1 The patient's condition during surgery. A: Three trocars were placed in the oral vestibule; B: The anterior jugular vein was accidentally injured, and bleeding in the operation area was obvious.

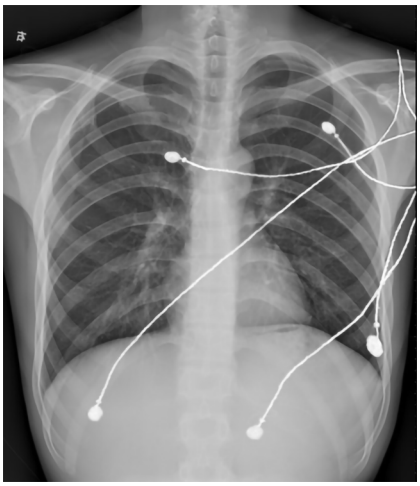

Figure 2 Immediate postoperative chest roentgenogram showed no abnormalities.

study is required to accurately quantify the incidence of CDE in endoscopic thyroidectomy (using reference standard monitoring) and its consequences.

We found that CDE during endoscopic thyroidectomy is rare, and it can develop at any time during surgery. Although CDE may occur under various insufflation pressures, low pressures below 6 mmHg are generally recommended[11]. If necessary, gasless endoscopic thyroidectomy can be considered as an alternative, which can significantly reduce or even avoid the occurrence of CDE[12-14].

FINAL DIAGNOSIS

Carbon dioxide embolism

TREATMENT

We immediately ceased CO_2 insufflation, turned off the sevoflurane vaporizer and placed the patient in the Durant's position.

OUTCOME AND FOLLOW-UP

The patient was extubated 30 min after surgery and discharged on day 4 after surgery without complications related to CDE.

DISCUSSION

Endoscopic surgical techniques, including those that involve insufflation of the tissues with carbon dioxide, are gaining wider acceptance and use worldwide. These advances have introduced the possibility of carbon dioxide embolus (including life-threatening embolus). Such factors introduce challenges in preventing, diagnosing and treating carbon dioxide embolus and determining how the risk of embolus affects the risk-to-benefit profile of any new surgical procedure. These issues have recently been reviewed by Lanier *et al*[15], as related to colorectal surgery[15]. We will discuss some of these same issues as they apply to endoscopic thyroid surgery.

CDE can occur during various laparoscopic surgeries. CO_2 can directly enter veins through the pneumoperitoneum needle, which can be placed into veins or solid organs in error[16]. CO_2 may also enter the right heart system through an opening in damaged vessels during surgery[7]. Due to the lack of a preexisting cavity in the neck, during endoscopic thyroid surgery a tunnel under the skin is necessary to establish a working space for the operation. During this process, blood vessels may be injured. This may be one of the causes of CDE in endoscopic thyroid surgery. The clinical manifestations of CDE range from asymptomatic to neurological impairment, cardiovascular system collapse and even death, depending on the capacity and absorption rate of CO_2[17]. The volume and rate of gas entering the vein are positively related to the size of the damaged vascular cavity and the gas-blood pressure gradient[18].

At present, the most sensitive and specific method for diagnosing CDE is TEE, which can detect CO_2 at 0.1 mL/kg[19]; however, TEE is limited due to its high cost, high invasiveness and complicated technique. $ETCO_2$ is a sensitive and noninvasive method for diagnosing CDE, and sudden or dramatic changes in $ETCO_2$ values, including rapid rise or fall in $ETCO_2$, can help diagnose CDE[20-22]. Animal experiments have shown that a decline in $ETCO_2$ was only seen in air embolism and a large CDE, and in continuous low-dose CDE, $ETCO_2$ did not change significantly[23]. A possible mechanism for this is that a large amount of CO_2 blocks the right ventricular outflow tract and pulmonary artery, which increases the ventilation dead space and leads to a decrease in $ETCO_2$[17]. Deformable emboli smaller than 14-22 μm will be filtered in pulmonary capillaries with a diameter of 3-15 μm[24]. Therefore, if the total volume of the CO_2 emboli is not too large and the speed of entering the right atrium is not too fast, most of the emboli will be filtered by the lungs without the "gas-lock" effect. In addition, the high solubility of CO_2 in the blood and high dispersibility to the lungs increase the excretion of CO_2 through the lungs, thus leading to the increase of $ETCO_2$[17].

The diagnostic sensitivity of CDE by auscultation of "mill-wheel" murmurs through a precardiac or transesophageal stethoscope is low[17]. However, auscultation is simple, noninvasive, inexpensive and may identify abnormalities earlier than other indicators[25]. Even in the absence of clinical signs, typical murmurs of air embolism can also occur, which is a good method for the diagnosis of CDE[22]. In our patient, there were no obvious reasons for simultaneous appearance of a cardiac murmur and transient elevation of $ETCO_2$, other than CDE. Our patient was in good health. The preoperative cardiac examination and thyroid function examination were normal. In addition to the heart murmur and transient and severe $ETCO_2$ rise during the operation, the vital signs including body temperature were normal, the breath sounds of both lungs were normal on auscultation, and the airway pressure was normal during the operation. We did not touch the subcutaneous emphysema. The chest roentgenogram immediately after the operation also showed no abnormalities. (Figure 2). Therefore, we strongly considered the diagnosis of CDE in our patient.

For the treatment of carbon dioxide embolism, we emphasize early diagnosis and timely and correct treatment. Routine monitoring of $ETCO_2$ and auscultation of abnormal heart sounds in the precordial area can detect an early diagnosis of CDE. If necessary, TEE can be used to obtain direct evidence of CDE. Once CDE is suspected, CO_2 insufflation should be discontinued immediately. Hyperventilation with 100% oxygen is important to wash out CO_2 and improve hypoxemia[17]. To facilitate gas bubbles to rise to the top of the right atrium and reduce the "gas-lock" effect, the patient should adopt the Durant's position[26]. If the patient has a central venous catheter, the gas can be aspirated from the central venous catheter[26].

The most important cause of life-threatening CDE is that CO_2 emboli block the right ventricular outflow channel, causing pulmonary hypertension and eventually right heart failure followed by left ventricular failure due to insufficient left ventricular filling. The application of vasopressor drugs and inotropic drugs to maintain heart rate and cardiac output is very important for maintaining hemodynamic stability and

maintaining the oxygenation of vital organs[17]. Chest compression itself is thought to force air out of the pulmonary outflow tract. To improve forward blood flow, cardiopulmonary resuscitation should be initiated if the patient suffers a cardiac arrest[18]. If a patient remains unstable, cardiopulmonary bypass or internal cardiac massage can be considered[27,28].

CONCLUSION

CDE during endoscopic thyroidectomy is rare, and it can develop at any time and under various insufflation pressures during surgery. The clinical manifestations of CDE vary, and more attention should be paid to this disorder. Based on current evidence, we recommend low insufflation pressures below 6 mmHg should be used. If necessary, then gasless endoscopic thyroidectomy can be considered as an alternative. The comprehensive use of multiple diagnostic tools, such as $ETCO_2$, precordial auscultation and TEE, *etc*. should be performed to diagnose CDE to conduct timely intervention and treatment.

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