**Name of journal:** *World Journal of Gastrointestinal Endoscopy*

**ESPS Manuscript NO: 3874**

**Columns: EDITORIAL**

**Air embolism complicating gastrointestinal endoscopy: A systematic review**

**Donepudi S *et al***. Air embolism complicating endoscopy

Suman Donepudi, Disaya Chavalitdhamrong, Li-Ping Pu, Peter V Draganov

**Suman Donepudi, Disaya Chavalitdhamrong, Li-Ping Pu, Peter V Draganov,** Division of Gastroenterology, Hepatology, and Nutrition, Department of Medicine, University of Florida, Gainesville, FL 32610, United States

**Li-Ping Pu,** Department of Medicine and Nursing, Suzhou Health College, Suzhou 215009, Jiangsu Province, China

**Author contributions:** Donepudi S and Chavalitdhamrong D performed the literature review and drafted the manuscript; Pu LP performed the literature review; Draganov PV performed critical revision of the manuscript for all intellectual contents.

**Correspondence to: Peter V Draganov, MD,** Division of Gastroenterology, Hepatology, and Nutrition, Department of Medicine, University of Florida, Room HD 602, PO Box 100214, Gainesville, FL 32610, United States. dragapv@medicine.ufl.edu.

**Telephone:** +1-352-2739474  **Fax:** +1-352-3923618

**Received:** May 29, 2013  **Revised:** July 12, 2013

**Accepted:** July 17, 2013

 **Published online:**

**Abstract**

Gastrointestinal endoscopy has become an important modality for the diagnosis and treatment of various gastrointestinal disorders. One of its major advantages is that it is minimally invasive and has an excellent safety record. Nevertheless, some complications do occur, and endoscopists are well aware and prepared to deal with the commonly recognized ones including bleeding, perforation, infection, and adverse effects from the sedative medications. Air embolism is a very rare endoscopic complication but possesses the potential to be severe and fatal. It can present with cardiopulmonary instability and neurologic symptoms. The diagnosis may be difficult because of its clinical presentation, which can overlap with sedation-related cardiopulmonary problems or neurologic symptoms possibly attributed to an ischemic or hemorrhagic central nervous system event. Increased awareness is essential for prompt recognition of the air embolism, which can allow potentially life-saving therapy to be provided. Therefore, we wanted to review the risk factors, the clinical presentation, and the therapy of an air embolism from the perspective of the practicing endoscopist.

© 2013 Baishideng. All rights reserved.

**Key words:** Air embolism; Endoscopy; Endoscopic Retrograde Cholangiopancreatography; Complications; Therapy

**Core tip:** Air embolism at the time of endoscopy can cause cardiovascular, pulmonary, and neurologi cal symptoms. Symptom onset during the position change from prone to supine is characteristic and should trigger immediate suspicion for air embolism. Potentially lifesaving therapeutic measures should be promptly initiated, including placing the patient in Trendelenburg and left lateral decubitus position, high-flow oxygen, volume expansion and urgent hyperbaric oxygenation therapy.

Donepudi S, Chavalitdhamrong D, Pu LP, Draganov PV. Air embolism complicating gastrointestinal endoscopy: A systematic review. *World J Gastrointest Endosc* 2013*;*

**Available from:** URL: http://www.wjgnet.com/esps/

**DOI:** http://dx.doi.org/10.4253/wjge.v0.i0.0000

**INTRODUCTION**

Air embolism is a consequence of direct communication between a source of air and the vasculature and a pressure gradient favoring the passage of air into the circulation. The effect of an air embolus depends upon both the rate and the volume of air introduced into the circulation. A venous air embolism occurs when air enters the systemic venous circulation. An arterial air embolism results from introduction of air into the arterial system and can produce ischemia of any organ. An air embolism is an uncommon but potentially catastrophic event. Many cases are subclinical with no adverse outcome. However, severe cases are characterized by hemodynamic collapse and/or acute vascular insufficiency of specific organs, such as the brain or the spinal cord. Symptoms may be nonspecific, and therefore, a high index of clinical suspicion for a possible air embolism is required to prompt investigations and initiate appropriate therapy.

**METHODS**

We conducted a systematic review by searching the PubMed database on reported air embolisms complicating all endoscopic procedures. Medical subject headings “endoscopy, complications, air embolism, cerebrovascular accident, cardiovascular abnormalities, esophagogastroduodenoscopy (EGD), enteroscopy, colonoscopy, sigmoidoscopy, endoscopic ultrasound (EUS), and endoscopic retrograde cholangiopancreatography (ERCP)” were used in the title, the abstract, or the index term fields. Manual searches were then conducted using the reference lists from identified articles.

**Risk factors for air embolism**

Air embolism is most commonly associated with an ERCP, but it can result from any endoscopic procedure including an EGD, an enteroscopy, an EUS, a colonoscopy, and a sigmoidoscopy.

Risk factors for an air embolism that have been reported are previous interventions or surgeries of the bile duct system, transhepatic portosystemic shunt[[1-3](#_ENREF_1)], blunt or penetrating trauma to the liver[[4](#_ENREF_4)], inflammation of the digestive system, post-surgical gastrointestinal fistula[[5-7](#_ENREF_5)], and particular interventional techniques.

The inflammatory conditions associated with an increased risk for an air embolism include inflammation of the bile duct or surrounding veins (pylephlebitis), hepatic abscesses, inflammatory bowel diseases, necrotizing enterocolitis, and mesenteric ischemia[[2](#_ENREF_2),[7](#_ENREF_7),[8](#_ENREF_8)]. In addition, gastrointestinal tumors and biliary atresia have been described as risk factors[[9](#_ENREF_9),[10](#_ENREF_10)].

Interventional techniques include cholangioscopy, biliary sphincterotomy, metal stent placement, liver biopsy, insufflation of air with high pressure, excessive amount and/or increased rate of air infusion, procedural site located higher than the level of the heart, and the use of nitrous oxide (N2O)[[3](#_ENREF_3),[11-18](#_ENREF_11)].

**Mechanisms and clinical signs and symptoms**

A number of potential mechanisms for air entry into the venous system have been described. These include intramural dissection of insufflated air into the portal vein, transection of duodenal vein radicles, biliary-venous fistulas/shunts, portocaval collaterals, air flow directly into the hepatic veins or inferior vena cava, retrograde flow into cerebral veins *via* superior vena cava[[7](#_ENREF_7)], inability of the pulmonary circulation to filter out gas emboli[[19](#_ENREF_19),[20](#_ENREF_20)], or entry into the vertebral venous plexus[[21](#_ENREF_21)]. Rapid entry or large volumes of air entering the systemic venous circulation causes a substantial strain on the right ventricle, especially if this results in a significant rise in pulmonary artery pressures. This increase in pulmonary artery pressure can lead to right ventricular outflow obstruction and further compromise pulmonary venous return to the left heart. Consequently, the diminished pulmonary venous return will lead to decreased left ventricular preload with resultant decreased cardiac output, and eventually, systemic cardiovascular collapse.

Importantly, a venous air embolism can be limited to the portal venous system or can evolve into a systemic air embolism through intracardiac shunts, intrapulmonary right to left shunts, retrograde flow into cerebral veins *via* the superior vena cava, or air passage into the left atrium *via* the pulmonary veins[[18](#_ENREF_18),[22](#_ENREF_22)]. The most common cause of an intracardiac shunt is a patent foramen ovale[[11](#_ENREF_11),[23](#_ENREF_23)]. Atrial septal defect, arterio-venous shunts, and intrapulmonary shunts are also reported mechanisms[[24-26](#_ENREF_24)].

The systemic air embolism can cause cardiovascular, pulmonary, and neurological symptoms[[15](#_ENREF_15)]. Cardiovascular signs, symptoms, and findings include arrhythmia, hypotension, myocardial ischemia, right heart failure, cardiovascular collapse, and cardiac arrest. Pulmonary signs, symptoms, and findings include acute dyspnea, tachypnea, breathlessness, rales, wheezing, decrease in end tidal carbon dioxide concentration, hypoxia, cyanosis, and respiratory failure. Neurological signs, symptoms, and findings include eye deviation, dilated pupil(s), failure to regain consciousness after anesthesia, hypertonicity, altered mental status, loss of consciousness, hemiparesis, cerebral hypoperfusion, cerebral edema, and coma.

In the case of an ERCP-related air embolism, typically the symptoms appear or get significantly worse when the patient is repositioned from prone to supine position at the end of the procedure. This patient deterioration with position change should immediately raise a red flag and trigger suspicion for an air embolism as the underlying cause of the patient symptoms.

**Reported cases of air embolism**

We were able to identify 41 cases of air embolism in the published literature following various endoscopic procedures.

***Air embolism cases following EGD and intraoperative small bowel endoscopy***

The first case of air embolism following an EGD was reported by Lowdon *et al*[[18](#_ENREF_18)] in 1988. A 5-wk old infant with biliary atresia status post Kasai procedure (hepatoportojejunostomy) died during endoscopy, and the autopsy revealed air in both the right atrium and right ventricle and in the large hepatic vein in the area of the porta hepatis. The patient was also found to have a patent foramen ovale and air in the coronary arteries. The authors proposed that air under pressure dissected across the diseased hepatic tissue into the large hepatic vein lying just below the denuded liver surface. This combined with her patent foramen ovale resulted in the systemic embolism.

Christl *et al*[[5](#_ENREF_5)] described the first incident of a cerebral air embolism following endoscopy in a patient with a duodenal ulcer and a duodenocaval fistula. It was believed that the air emboli exceeding the absorptive rate of the pulmonary capillary bed might be the cause in this patient, especially with the total amount of air entering the inferior vena cava.

A case report by Katzgraber *et al*[[14](#_ENREF_14)] identified an embolism risk when air insufflation occurs in the presence of damaged vessels. The patient, whom had a history of a perforated gastric ulcer surgically treated 13 years prior, underwent an upper endoscopy for the evaluation of epigastric pain. High-volume air insufflation was noted during the procedure. As the study was continued, the patient suddenly went into cardiac arrest and resuscitation was unsuccessful. On forensics, the right gastric vein was found to be eroded most likely due to his history of multiple ulcerations. The presence of this lesion in combination with the amount of insufflation required allowed air to enter the venous supply, and eventually, enter the heart causing death.

McAree *et al*[[27](#_ENREF_27)] reported a cerebral air embolism in a patient being evaluated for metastatic adenocarcinoma of an unknown origin. Abdominal computed tomography (CT) scan showed ascites and a thickened cecal wall; cytology study of the ascites determined the presence of an adenocarcinoma. Soon after, the patient began vomiting blood and an EGD showed erosive esophagitis. As the procedure was ending, the patient became unresponsive and displayed neurological symptoms. An emergency cerebral CT confirmed air in the brain, specifically the right frontotemporal area. The esophagitis mucosal breakdown is to be considered as the leading cause of the embolism.

Meier *et al*[[28](#_ENREF_28)] reported a patient with an air embolism during an EGD. The patient had a history of a pancreaticoduodenectomy for pancreatic adenocarcinoma and a percutaneous transhepatic cholangiography (PTC) for recent ascending cholangitis. An EGD was done due to the patient developing melena. As the scope was maneuvered towards the hepaticojejunostomy site, the patient’s condition became unstable; unfortunately, the patient was unable to be successfully resuscitated and passed away. The investigators believed the PTC catheter may have created a fistula between the vasculature and the biliary tract. This abnormality allowed the air to enter the venous supply, specifically the hepatic veins and inferior vena cava, upon air insufflation during endoscopy.

In another recent 2010 case, Pandurangadu *et al*[[24](#_ENREF_24)] reported about a cerebral embolism. The patient received an outpatient EGD, which required an esophageal biopsy and ablation of duodenal arteriovenous malformations. Shortly after the EGD procedure, he presented to the emergency room with neurological symptoms of sudden onset lethargy and left-sided weakness. CT scan of the brain showed multiple gas emboli in two areas, the right frontal lobe and frontoparietal region. A transesophageal echocardiogram (TEE) was also done, which ruled out a patent foramen ovale. Therefore, the study proposed the most likely cause of the embolism was the duodenal arteriovenous malformations.

In 2010, a case reported by Park *et al*[[23](#_ENREF_23)] described a paradoxical air embolism during an intraoperative small bowel endoscopy. An adolescent female, with a history of a Kasai operation for biliary atresia, presented with gastrointestinal bleeding. The plan was for an exploratory laparotomy and intraoperative endoscopy for further evaluation. It must also be noted she had a previous exploratory laparotomy three months prior for hematochezia, which was unremarkable with the exception of some bluish edema on the small bowel wall. All preoperative protocols were performed, including an abdominal CT scan; the scan revealed a highly, irregular liver architecture showing massive fibrosis. As the endoscopy procedure ensued, excessive air insufflation was needed to facilitate visualization. An ulcerative lesion was found near the site of the previous Kasai procedure. The patient thereafter became unstable systemically, and immediate stabilization methods were started. TEE confirmed air bubbles entered the heart and the systemic vasculature. In this case, there were multiple risk factors present. The high amount of air insufflation administered and the ulcerative lesion are two of the immediate possibilities. However, two other risk factors can be added. Hopkins *et al*[[29](#_ENREF_29)] found that 47% of patients with chronic liver disease possess an intrapulmonary right to left shunt. The other possibility is the patient’s history of biliary atresia. A previous study showed that 18 of 88 biliary atresia patients, a total of 9.1%, between the ages of 8 mo and 16 years old possessed an intrapulmonary shunt; this shunt can cause fatal complications in previously operated biliary atresia patients[[9](#_ENREF_9)].

***Reported air embolism cases following colonoscopy and sigmoidoscopy***

Chorost *et al*[[21](#_ENREF_21)] reported on a case of a routine screening colonoscopy. Three days after the procedure, the patient presented with severe, lower back pain. After a CT scan of the abdomen, it became evident there was air anterior to the lumbar vertebrae. Batson[[30](#_ENREF_30)], in 1940, suggested that an increase in intraabdominal pressure could allow venous effluent from the pelvis to enter into unimpeded valveless venous channels, such as in this example, the vertebrae. Therefore in this case, it was proposed the combination of the high intraabdominal pressure along with the low intraluminal pressure system of the vertebral venous system provided an optimum pressure gradient for air to seep, causing an air embolism.

Mittnacht *et al*[[31](#_ENREF_31)] reported the only sigmoidoscopy case known to be complicated by an air embolism. The patient had a history of long-standing Crohn’s disease and 2 years status post left partial colectomy with descending colostomy, which was complicated by poor wound healing and fistula formations. The patient required the sigmoidoscopy before a revision of her previous abdominal bowel surgery. During the procedure, the patient went into cardiac arrest as a result of an air embolism. The history of Crohn’s disease, which led to inflamed and deteriorated mucosa, was proposed to allow air entry. Also proposed, there was possible injury to hemorrhoidal veins during the biopsy of the sigmoid. An additional risk was the patient being in Trendelenburg position, allowing for the surgery site to be above the heart.

***Reported air embolism cases following EUS***

Pfaffenbach *et al*[[32](#_ENREF_32)] reported about a patient with severe upper abdominal pain requiring an EUS for evaluation of a pancreatic head lesion. EUS-guided fine needle aspiration was performed. Hepatic portal venous gas was found on a follow up abdominal ultrasonography.

***Reported air embolism cases following ERCP***

Most described cases of endoscopy-related air embolism have been related to an ERCP. We recently reported two air embolism cases following an ERCP, one with an intracranial air embolism and one with a spinal air embolism. To date, a total of 26 cases of systemic air embolism complicating ERCP have been reported (Table 1). Described risk factors for an air embolism following an ERCP are previous interventions or surgeries of the bile duct system, transhepatic portosystemic shunts, percutaneous transhepatic biliary drains, blunt or penetrating trauma to the liver, sphincterotomy, metal stent placement, the inflammation of the bile duct or surrounding veins, hepatic abscesses or tumors, liver biopsy, and insufflation of air with high pressure. Cholangioscopy with air insufflation directly into the bile duct appears to be a particularly strong risk factor for an air embolism. Reported clinical presentations are cardiovascular, pulmonary, and neurological symptoms. Again, we want to emphasize the onset of symptoms or symptom escalation with change of patient position from prone to supine should immediately trigger suspicion for an air embolism.

**Diagnosis**

The diagnosis of an air embolism is often difficult and is complicated by the fact that air may be rapidly absorbed from the circulation while diagnostic tests are being arranged. Exclusion of other life-threatening processes is generally required.

Transthoracic and transesophageal echocardiography have been used to document the presence of air and may show evidence of acute right ventricular dilation and pulmonary artery hypertension consistent with air embolism. An echocardiography also aids in the diagnosis of cardiac anomalies, assessment of volume status, and cardiac contractility; this allows exclusion of other causes of hypotension, dyspnea, and aiding in further patient management. End-tidal CO2 monitoring may show a fall in end-tidal CO2; however, this finding is nonspecific and also occurs with pulmonary embolism, massive blood loss, circulatory arrest, and disconnection from the anesthesia circuit. The pulmonary artery catheter may show a rise in pulmonary artery pressure in venous air embolism, but this is a nonspecific finding. Ventilation-perfusion scan abnormalities may be seen in the setting of a massive air embolism, but this is also a nonspecific finding and the perfusion defects resolve rapidly. The chest CT can detect air with higher sensitivity for massive air emboli. A pulmonary angiography could also be useful but may be normal often times in patients who have suffered an air embolism because of rapid resorption of air.

**Management**

The most crucial step in patient management is to maintain a high index of suspicion for an air embolism. An air embolism should be included in the differential diagnosis of procedural or periprocedural cardiopulmonary instability and neurologic symptoms, particularly in patients with recognized risk factors. Since the clinical presentation of an air embolism can significantly overlap with sedation-related problems and ischemic or hemorrhagic cerebrovascular events, some simple maneuvers to decrease the impact of a potential air embolism should be promptly initiated while the definitive diagnosis is established. These maneuvers include: (1) immediately stop the procedure if at all possible; (2) administer high flow 100% oxygen, which can reduce air bubbles expansion; (3) initiate high volume normal saline infusion; (4) place the patient in Tredelenburg (feet higher than the head) and left lateral decubitus position in order to minimize air migration to the brain and to force-out air from the right ventricular outflow tract[[33](#_ENREF_33)], thereby increasing venous return[[23](#_ENREF_23)]; and (5) if N2O is being used, it must be discontinued because of its ability to rapidly diffuse into the trapped air bubbles, causing an additive effect on the embolism[[23](#_ENREF_23)].

After these initial stabilizing measures are implemented, which should take no more than a few minutes, a decision has to be made regarding the type of evaluation needed to secure the diagnosis. This is a crucial branching point in the management of these patients. Since cerebrovascular accident is most commonly suspected in patients with neurologic symptoms, arrangements for an urgent head CT scan are typically made. If the underlying problem is an air embolism, the patient being sent for a CT scan can have some serious, adverse consequences, because it will delay the diagnosis and the application of specific targeted therapy. Therefore if an air embolism is suspected, a bedside echocardiogram should be promptly performed to quickly secure the diagnosis with visualization of air within the right heart. This can have immediate therapeutic implications. An air aspiration *via* a central venous catheter can be done, and arrangements for urgent hyperbaric oxygenation therapy can be carried out. Hyperbaric oxygenation therapy may reduce air bubble size, accelerate nitrogen reabsorption, and increase the oxygen content of arterial blood; this potentially reduces the ischemia. In the event of circulatory collapse, cardiopulmonary resuscitation (CPR) should be initiated in order to maintain the cardiac output. CPR may also serve to break large air bubbles into smaller ones and force air out of the right ventricle into the pulmonary vessels.

**Prophylactic measures to decrease the risk of air embolism**

Using CO2 for insufflation instead of air can eliminate the risk of an air embolism, because CO2 can be easily absorbed[[34](#_ENREF_34)]. The use of CO2 for insufflation during gastrointestinal endoscopy has been shown superiority than using room air by multiple randomized controlled trials and a meta-analysis[[35](#_ENREF_35),[36](#_ENREF_36)]. It was associated with a decreased postprocedural pain, flatus, and bowel distension. CO2 insufflation also appears to be safe in patients without severe underlying pulmonary disease. This finding supports the use of CO2 in most cases if available. In our unit, we perform all endoscopies with CO2; if CO2 is not available for routine use, we believe it must be used in all cholangioscopy cases or when other risk factors are present.

Another option for patients at risk is to use a precordial Doppler probe monitor during the procedure; it can quickly detect air within the heart and pulmonary vasculature before clinical symptoms may appear[[37](#_ENREF_37)].

**Conclusion**

In summary, endoscopists should be aware of the signs and symptoms of an air embolism. In patients with risk factors, prophylactic measures can be applied. A high index of suspicion for an air embolism should be maintained, because prompt recognition can allow timely administration of specific, potential life-saving therapy.

**REFERENCES**

1 **Maccarone G**, Shakoor T, Ellis B. Air embolism after percutaneous transhepatic biliary drainage and subsequent endoscopic retrograde cholangiopancreatography (ERCP). *Endoscopy* 2011; **43 Suppl 2 UCTN**: E399 [PMID: 22275020 DOI: 10.1055/s-0030-1256943]

2 **Finsterer J**, Stöllberger C, Bastovansky A. Cardiac and cerebral air embolism from endoscopic retrograde cholangio-pancreatography. *Eur J Gastroenterol Hepatol* 2010; **22**: 1157-1162 [PMID: 20555267 DOI: 10.1097/MEG.0b013e32833c5459]

3 **Green BT**, Tendler DA. Cerebral air embolism during upper endoscopy: case report and review. *Gastrointest Endosc* 2005; **61**: 620-623 [PMID: 15812425]

4 **Mohammedi I**, Ber C, Peguet O, Ould-Aoudia T, Duperret S, Petit P. Cardiac air embolism after endoscopic retrograde cholangiopancreatography in a patient with blunt hepatic trauma. *J Trauma* 2002; **53**: 1170-1172 [PMID: 12478046]

5 **Christl SU**, Scheppach W, Peters U, Kirchner T. Cerebral air embolism after gastroduodenoscopy: complication of a duodenocaval fistula. *Gastrointest Endosc* 1994; **40**: 376-378 [PMID: 8056250]

6 **Stabile L**, Cigada M, Stillittano D, Morandi E, Zaffroni M, Rossi G, Lapichino G. Fatal cerebral air embolism after endoscopic retrograde cholangiopancreatography. *Acta Anaesthesiol Scand* 2006; **50**: 648-649 [PMID: 16643257]

7 **Bisceglia M**, Simeone A, Forlano R, Andriulli A, Pilotto A. Fatal systemic venous air embolism during endoscopic retrograde cholangiopancreatography. *Adv Anat Pathol* 2009; **16**: 255-262 [PMID: 19546613 DOI: 10.1097/PAP.0b013e3181aab793]

8 **Kennedy C**, Larvin M, Linsell J. Fatal hepatic air embolism following ERCP. *Gastrointest Endosc* 1997; **45**: 187-188 [PMID: 9041008]

9 **Sasaki T**, Hasegawa T, Kimura T, Okada A, Mushiake S, Matsushita T. Development of intrapulmonary arteriovenous shunting in postoperative biliary atresia: evaluation by contrast-enhanced echocardiography. *J Pediatr Surg* 2000; **35**: 1647-1650 [PMID: 11083444]

10 **Lamparter S**, Goecke W, Koehler HH. Hepatic portal venous gas after upper endoscopy in a patient with a gastrointestinal stromal tumor. *J Clin Ultrasound* 2009; **37**: 401-402 [PMID: 19475552 DOI: 10.1002/jcu.20598]

11 **Efthymiou M**, Raftopoulos S, Antonio Chirinos J, May GR. Air embolism complicated by left hemiparesis after direct cholangioscopy with an intraductal balloon anchoring system. *Gastrointest Endosc* 2012; **75**: 221-223 [PMID: 21470606 DOI: 10.1016/j.gie.2011.01.038]

12 **Rabe C**, Balta Z, Wüllner U, Heller J, Hammerstingl C, Tiemann K, Sommer T, Schepke M, Fischer HP, Sauerbruch T. Biliary metal stents and air embolism: a note of caution. *Endoscopy* 2006; **38**: 648-650 [PMID: 16586241]

13 **Di Pisa M**, Chiaramonte G, Arcadipane A, Burgio G, Traina M. Air embolism during endoscopic retrograde cholangiopancreatography in a pediatric patient. *Minerva Anestesiol* 2011; **77**: 90-92 [PMID: 21150852]

14 **Katzgraber F**, Glenewinkel F, Fischler S, Rittner C. Mechanism of fatal air embolism after gastrointestinal endoscopy. *Int J Legal Med* 1998; **111**: 154-156 [PMID: 9587799]

15 **Mirski MA**, Lele AV, Fitzsimmons L, Toung TJ. Diagnosis and treatment of vascular air embolism. *Anesthesiology* 2007; **106**: 164-177 [PMID: 17197859]

16 **Goins KM**, May JM, Hucklenbruch C, Littlewood KE, Groves DS. Unexpected cardiovascular collapse from massive air embolism during endoscopic retrograde cholangiopancreatography. *Acta Anaesthesiol Scand* 2010; **54**: 385-388 [PMID: 19878099 DOI: 10.1111/j.1399-6576.2009.02144.x]

17 **Mammoto T**, Hayashi Y, Ohnishi Y, Kuro M. Incidence of venous and paradoxical air embolism in neurosurgical patients in the sitting position: detection by transesophageal echocardiography. *Acta Anaesthesiol Scand* 1998; **42**: 643-647 [PMID: 9689268]

18 **Lowdon JD**, Tidmore TL. Fatal air embolism after gastrointestinal endoscopy. *Anesthesiology* 1988; **69**: 622-623 [PMID: 3177925]

19 **Butler BD**, Hills BA. Transpulmonary passage of venous air emboli. *J Appl Physiol* 1985; **59**: 543-547 [PMID: 4030608]

20 **Thackray NM**, Murphy PM, McLean RF, deLacy JL. Venous air embolism accompanied by echocardiographic evidence of transpulmonary air passage. *Crit Care Med* 1996; **24**: 359-361 [PMID: 8605815]

21 **Chorost MI**, Wu JT, Webb H, Ghosh BC. Vertebral venous air embolism: an unusual complication following colonoscopy: report of a case. *Dis Colon Rectum* 2003; **46**: 1138-1140 [PMID: 12907914]

 22 **Desmond PV**, MacMahon RA. Fatal air embolism following endoscopy of a hepatic portoenterostomy. *Endoscopy* 1990; **22**: 236 [PMID: 2242745]

23 **Park YH**, Kim HJ, Kim JT, Kim HS, Kim CS, Kim SD. Prolonged paradoxical air embolism during intraoperative intestinal endoscopy confirmed by transesophageal echocardiography -A case report-. *Korean J Anesthesiol* 2010; **58**: 560-564 [PMID: 20589182 DOI: 10.4097/kjae.2010.58.6.560]

24 **Pandurangadu AV**, Paul JA, Barawi M, Irvin CB. A case report of cerebral air embolism after esophagogastroduodenoscopy: diagnosis and management in the emergency department. *J Emerg Med* 2012; **43**: 976-979 [PMID: 21236613 DOI: 10.1016/j.jemermed.2010.11.031]

25 **Gottdiener JS**, Papademetriou V, Notargiacomo A, Park WY, Cutler DJ. Incidence and cardiac effects of systemic venous air embolism. Echocardiographic evidence of arterial embolization via noncardiac shunt. *Arch Intern Med* 1988; **148**: 795-800 [PMID: 3355298]

26 **Butler BD**, Bryan-Brown C, Hills BA. Paradoxical air embolism: transcapillary route. *Crit Care Med* 1983; **11**: 837 [PMID: 6617227]

27 **McAree BJ**, Gilliland R, Campbell DM, Lucas JW, Dickey W. Cerebral air embolism complicating esophagogastroduodenoscopy (EGD). *Endoscopy* 2008; **40** Suppl 2: E191-E192 [PMID: 18709611 DOI: 10.1055/s-2007-995728]

28 **Meier CB**, Moser AJ, Sanders MK. Fatal venous air embolism during upper endoscopy in a patient with percutaneous transhepatic cholangiography (PTC) catheter. *Endoscopy* 2010; **42 Suppl 2**: E111 [PMID: 20306397 DOI: 10.1055/s-0029-1243942]

29 **Hopkins WE**, Waggoner AD, Barzilai B. Frequency and significance of intrapulmonary right-to-left shunting in end-stage hepatic disease. *Am J Cardiol* 1992; **70**: 516-519 [PMID: 1642191]

30 **Batson OV**. The function of the vertebral veins and their role in the spread of metastases. 1940. *Clin Orthop Relat Res* 1995; (312): 4-9 [PMID: 7634616]

31 **Mittnacht AJ**, Sampson I, Bauer J, Reich DL. Air embolism during sigmoidoscopy confirmed by transesophageal echocardiography. *J Cardiothorac Vasc Anesth* 2006; **20**: 387-389 [PMID: 16750742]

32 **Pfaffenbach B**, Wegener M, Böhmeke T. Hepatic portal venous gas after transgastric EUS-guided fine-needle aspiration of an accessory spleen. *Gastrointest Endosc* 1996; **43**: 515-518 [PMID: 8726771]

33 **Bechi A**, Nucera MP, Olivotto I, Manetti R, Fabbri LP. Complete neurological recovery after systemic air embolism during endoscopic retrograde cholangiopancreatography. *Minerva Anestesiol* 2012; **78**: 622-625 [PMID: 22240610]

34 **Muley SS**, Saini SS, Dash HH, Bithal PK. End tidal carbon dioxide monitoring for detection of venous air embolism. *Indian J Med Res* 1990; **92**: 362-366 [PMID: 2125580]

35 **Wang WL**, Wu ZH, Sun Q, Wei JF, Chen XF, Zhou DK, Zhou L, Xie HY, Zheng SS. Meta-analysis: the use of carbon dioxide insufflation vs. room air insufflation for gastrointestinal endoscopy. *Aliment Pharmacol Ther* 2012; **35**: 1145-1154 [PMID: 22452652 DOI: 10.1111/j.1365-2036.2012.05078.x]

36 **Dellon ES**, Hawk JS, Grimm IS, Shaheen NJ. The use of carbon dioxide for insufflation during GI endoscopy: a systematic review. *Gastrointest Endosc* 2009; **69**: 843-849 [PMID: 19152906 DOI: 10.1016/j.gie.2008.05.067]

37 **Siddiqui J**, Jaffe PE, Aziz K, Forouhar F, Sheppard R, Covault J, Bonkovsky HL. Fatal air and bile embolism after percutaneous liver biopsy and ERCP. *Gastrointest Endosc* 2005; **61**: 153-157 [PMID: 15672079]

38 **Jow AZ**, Wan D. Complication of cardiac air embolism during ERCP and EUS-assisted cyst-gastrostomy for pancreatic pseudocyst. *Gastrointest Endosc* 2012; **75**: 220-221 [PMID: 21492848 DOI: 10.1016/j.gie.2011.01.047]

39 **Nayagam J**, Ho KM, Liang J. Fatal systemic air embolism during endoscopic retrograde cholangio-pancreatography. *Anaesth Intensive Care* 2004; **32**: 260-264 [PMID: 15957727]

40 **Romberg C**. Systemic air embolism after ERCP: a case report and review of the literature (with video). *Gastrointest Endosc* 2009; **70**: 1043-1045 [PMID: 19577747 DOI: 10.1016/j.gie.2009.03.028]

41 **Rangappa P**, Uhde B, Byard RW, Wurm A, Thomas PD. Fatal cerebral arterial gas embolism after endoscopic retrograde cholangiopancreatography. *Indian J Crit Care Med* 2009; **13**: 108-112 [PMID: 19881196 DOI: 10.4103/0972-5229.56061]

42 **Cha ST**, Kwon CI, Seon HG, Ko KH, Hong SP, Hwang SG, Park PW, Rim KS. Fatal biliary-systemic air embolism during endoscopic retrograde cholangiopancreatography: a case with multifocal liver abscesses and choledochoduodenostomy. *Yonsei Med J* 2010; **51**: 287-290 [PMID: 20191026 DOI: 10.3349/ymj.2010.51.2.287]

 43 **Giuly E**, Pesenti C, Pernoud N, Bories E, Francon D. [Air embolism: an unusual complication of endoscopic retrograde cholangiopancreatography]. *Ann Fr Anesth Reanim* 2005; **24**: 1400-1403 [PMID: 16226421]

44 **van Boxel GI**, Hommers CE, Dash I, Goodman AJ, Green J, Orme RM. Myocardial and cerebral infarction due to massive air embolism following endoscopic retrograde cholangiopancreatography (ERCP). *Endoscopy* 2010; **42** Suppl 2: E80-E81 [PMID: 20195976 DOI: 10.1055/s-0029-1243826]

45 **Tan BK**, Saunier CF, Cotton F, Gueugniaud PY, Piriou V. [Thoracoabdominal CT scan: a useful tool for the diagnosis of air embolism during an endoscopic retrograde cholangiopancreatography]. *Ann Fr Anesth Reanim* 2008; **27**: 240-243 [PMID: 18313255 DOI: 10.1016/j.annfar.2007.12.015]

46 **Nern C**, Bellut D, Husain N, Pangalu A, Schwarz U, Valavanis A. Fatal cerebral venous air embolism during endoscopic retrograde cholangiopancreatography-case report and review of the literature. *Clin Neuroradiol* 2012; **22**: 371-374 [PMID: 22689221 DOI: 10.1007/s00062-012-0155-0]

47 **Simmons TC**. Hepatic portal venous gas due to endoscopic sphincterotomy. *Am J Gastroenterol* 1988; **83**: 326-328 [PMID: 3344739]

48 **Merine D**, Fishman EK. Uncomplicated portal venous gas associated with duodenal perforation following ERCP: CT features. *J Comput Assist Tomogr* 1989; **13**: 138-139 [PMID: 2910933]

49 **Barthet M**, Membrini P, Bernard JP, Sahel J. Hepatic portal venous gas after endoscopic biliary sphincterotomy. *Gastrointest Endosc* 1994; **40**: 261-263 [PMID: 8013847]

50 **Chavalitdhamrong D**, Draganov PV. Acute stroke due to air embolism complicating ERCP. *Endoscopy* 2013; **45** Suppl 2 UCTN: E177-E178 [PMID: 23801290]

**P-Reviewers** De Palma GD, Lachter J **S-Editor** Gou SX  **L-Editor E-Editor**

 **Table 1 Reported cases on air embolism complicated endoscopic retrograde cholangiopancreatography**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Case** | **Reference** | **Age/ sex** | **Risk factor(s)** | **Diagnosis** | **Outcome** |
| 1 | Bisceglia *et al*[[7](#_ENREF_7)] | 78/male | Surgical gastroduodenal resection | Pulmonary air embolism | Dead |
| 2 | Rabe *et al*[[12](#_ENREF_12)] | 87/male | Metal stent placement | Cerebral air embolism | Survived |
| 3 | Rabe *et al*[[12](#_ENREF_12)] | 54/male | Billroth II operation, Metal stent placement | Cardiac air embolism | Dead |
| 4 | Jow *et al*[[38](#_ENREF_38)] | 65/male | Biliary duct stones/ inflammation | Cardiac air embolism | Dead |
| 5 | Maccarone *et al*[[1](#_ENREF_1)] | 45/male | Percutaneous transhepatic biliary drainage | Cerebral air embolism | Survived |
| 6 | Siddiqui *et al*[[37](#_ENREF_37)] | 43/female | Biliary sphincterotomy, liver biopsy | Venous air embolism | Dead |
| 7 | Nayagam *et al*[[39](#_ENREF_39)] | 57/male | - | Cerebral air embolism | Dead |
| 8 | Kennedy *et al*[[8](#_ENREF_8)] | 63/female | Biliary sphincterotomy | Venous air embolism | Dead |
| 9 | Stabile *et al*[[6](#_ENREF_6)] | 65/male | Biliary sphincterotomy, PTC | Cerebral air embolism | Dead |
| 10 | Mohammedi *et al*[[4](#_ENREF_4)] | 27/male | Biliary sphincterotomy, blunt hepatic trauma | Cardiac air embolism | Survived |
| 11 | Romberg *et al*[[40](#_ENREF_40)] | 53/male | Biliary duct stones | Cardiac air embolism | Survived |
| 12 | Rangappa *et al*[[41](#_ENREF_41)] | 50/female | Biliary duct stones | Cerebral air embolism | Dead |
| 13 | Bechi *et al*[[33](#_ENREF_33)] | 79/female | Biliary sphincterotomy | Cerebral air embolism | Survived |
| 14 | Goins *et al*[[16](#_ENREF_16)] | 72/female | Cholangiocarcinoma | Cerebral air embolism | Survived |
| 15 | Cha *et al*[[42](#_ENREF_42)] | 50/female | Biliary duct stones,Liver abscesses, choledochoduodenostomy | Cardiac air embolism | Dead |
| 16 | Di Pisa *et al*[[13](#_ENREF_13)] | 8/male | Splenomesenteric portal shunt | Venous air embolism | Survived |
| 17 | Giuly *et al*[[43](#_ENREF_43)] | 60/female | Biliary sphincterotomy, choledochal varices | Venous air embolism | Survived |
| 18 | van Boxel *et al*[[44](#_ENREF_44)] | 82/male | - | Cerebral air embolism | Survived |
| 19 | Tan *et al*[[45](#_ENREF_45)] | 82/female | Metal stent placement | Cerebral air embolism | Dead |
| 20 | Nern *et al*[[46](#_ENREF_46)] | 58/female | Cholangiocarcinoma | Cerebral air embolism | Dead |
| 21 | Simmons *et al*[[47](#_ENREF_47)] | Not available | Biliary sphincterotomy | Venous air embolism | Survived |
| 22 | Merine *et al*[[48](#_ENREF_48)] | 39/female | Biliary sphincterotomy | Venous air embolism | Survived |
| 23 | Barthet *et al*[[49](#_ENREF_49)] | 31/male | Biliary sphincterotomy | Venous air embolism | Survived |
| 24 | Efthymiou *et al*[[11](#_ENREF_11)] | 62/female | Cholangioscopy | Cerebral air embolism | Survived |
| 25 | Our case[50] | 66/male | Metal stent placement | Cerebral air embolism | Dead |
| 26 | Our case[50] | 51/female | Status post Whipple’s operation | Spinal air embolism | Survived |

PTC: Percutaneous transhepatic cholangiography.