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Review

Gastroenterol Res. 2019;12(6):283-287

Clinical Presentation, Diagnosis, and Management of Air Embolism During Endoscopic Retrograde Cholangiopancreatography

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Abstract

Endoscopic retrograde cholangiopancreatography (ERCP) is a minimally invasive procedure that is widely used by endoscopists and has a robust therapeutic profile. It uses endoscopy and imaging for a variety of diagnostic as well as therapeutic purposes. It is used for the management of a lot of pancreaticobiliary diseases such as obstructive jaundice, obstruction related to bile ducts, pancreatic biliary tumors, and traumatic or iatrogenic damage to the bile ducts. Other therapeutic interventions that can be done via ERCP include sphincterotomy, dilation of strictures, removal of biliary stones and placement of stents. Air embolism presents with cardiovascular, pulmonary, and neurologic signs and symptoms. Treatment of air embolism should be started early in suspected cases, and it should be in the differential diagnoses of various complications secondary to high risk of ERCP, especially if a cardiopulmonary compromise is present. Air embolism is rare but a serious complication associated with ERCP. The physicians must keep this in mind while performing ERCP in patients with predisposing risk factors. This review highlights the mechanism, causes, risk factors, pathophysiology, clinical signs, diagnostic modalities, treatment, and preventive measures to deal with this catastrophic complication.

Keywords: Air embolism; Pancreaticobiliary diseases; Endoscopy; Endoscopic retrograde cholangiopancreatography; Complications; Therapeutic procedure; Precordial Doppler ultrasound

Manuscript submitted August 7, 2019, accepted August 22, 2019

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doi: https://doi.org/10.14740/gr1208

Introduction

Endoscopic retrograde cholangiopancreatography (ERCP) is a minimally invasive procedure which uses endoscopy and imaging for diagnostic and therapeutic purposes [1]. Its advantages in the management of pancreaticobiliary diseases are superseded by a higher potential for severe complications than any other standard endoscopic technique due to an extreme degree of expertise, procedural complexity and risk of complications [2]. Since its development in 1968, it has been in use as an excellent diagnostic tool for pancreaticobiliary diseases [3]. However, lately, its diagnostic use has transformed into an almost exclusively therapeutic procedure in support of less invasive techniques such as abdominal ultrasound (AUS) and magnetic resonance cholangiopancreatography (MRCP) [4]. Air embolism after ERCP is an uncommon complication that can be fatal if not recognized and treated early [5]. Air embolism is due to insufflation of high-pressured air to improve visualization. Different methods contributing to air embolism may include intramural dissection due to mucosal damage from high pressures, biliary venous fistulas, and blunt abdominal trauma [6]. According to Afreen et al there is a high incidence of 2.4% for venous air embolism (VAE) during ERCP which calls for the practitioners to be aware of it. Efficient detection can lead to early management, resulting in fewer consequences [7].

Air embolism due to ERCP is because of an abnormal entrance of air that is insufflated during the procedure into the arterial or venous vasculature due to disruption of a mucosal vascular barrier. Its severity is related to both the amount and the velocity with which the air is introduced [8, 9]. The amount of air that causes a circulatory air embolism ranges from 10 to 480 mL, depending on the speed of air entering into circulation and the organ vasculature into which the embolus extends [10]. Air embolism is a serious complication that can occur during an endoscopic procedure, and it can cause significant morbidity and mortality if not diagnosed early [11]. Therefore, it is imperative to keep the possibility of air embolism in mind whenever a patient experiences sudden deterioration of vitals or neurologic compromise, apart from other significant causes. We write this review article to describe the mechanism, causes, risk factors, pathophysiology, clinical signs, diagnostic

modalities, treatment and preventive measures to deal with this catastrophic complication.

Uses and Complications of ERCP

ERCP is an advanced endoscopic technique with a variety of diagnostic as well as therapeutic uses. It is used for the management of a lot of pancreaticobiliary diseases such as obstructive jaundice, obstruction related to bile ducts and pancreaticobiliary tumors, and traumatic or iatrogenic damage to the bile ducts [12]. Other therapeutic interventions that can be done via ERCP include sphincterotomy, dilation of strictures, removal of biliary stones, and placement of stents. Over 500,000 ERCPs are performed annually in the USA [13]. The Center for Medicare and Medicaid Services states that from 2000 to 2010, the number of cases of ERCP performed has risen from 233,378 to 288,715, a 23.7% increase [14, 15]. Gastrointestinal (GI) endoscopy involves insufflation of air at up to 2 L/min [16]. Cholangitis, hemorrhage, pancreatitis and perforation are the most common complications from ERCP [17]. Less common complications of ERCP include cardiac arrest, air in hepatic veins, pulmonary and cerebral air embolism, and paradoxical air embolism [17, 18]. Cardiopulmonary complications of ERCP include arrhythmias, hypoxemia and myocardial ischemia, which is usually transitory [17, 19]. Christensen and colleagues reported that 30% (12/40) patients underwent ST-segment changes suggesting myocardial ischemia. However, none of them had coronary symptoms on exercise stress test [19].

Pathophysiology of ERCP-Induced Air Embolism

Patients who underwent prior endoscopic procedures are at a significantly higher risk for air embolism during ERCP. Placement of metal stents into the biliary tract may be associated with an increased risk of vascular injury, which favors air embolism [20]. The possible explanations of VAE during ERCP include mechanical alteration of the bile duct wall by the endoscope, development of bilio-venous shunts and spontaneous transgression of air from bile ducts [21]. Intramural dissection of air into the portal venous system via injured duodenal vein radicles can also occur following ERCP and sphincterotomy [6]. Other risk factors for air embolism during ERCP are inflammatory processes of the digestive system (pylephlebitis, inflammation of bile duct, inflammatory bowel disease, abscess and mesenteric ischemia), percutaneous biliary drainage, liver abscess, gastrointestinal tumors, transjugular intrahepatic portosystemic shunt (TIPS) and penetrating liver trauma [22]. Portal vein cannulation is also a cause of air embolism during ERCP [23, 24]. Air embolism rate associated with ERCP may be as high as 10% [25]. During ERCP, air from the luminal wall can enter into the venous or arterial system or both depending on where the primary insult began. When the gas enters a venous structure, VAE occurs, and the involvement of the organs depends upon the extension of the embolism. It can travel from the superior vena cava (SVC) through the right heart and end up causing pulmonary air embolism or can also pass through the SVC upwards into the cerebral veins leading to paradoxical air embolism. Also when a venous embolism is large enough, it can pass through the pulmonary veins and the left heart to the arterial circulation and end up lodging into cerebral arteries, one of the mechanisms behind paradoxical air embolism [26-28]. A patent foramen ovale can lead to paradoxical embolism [29]. Other than a patent foramen ovale, air embolus can also pass into the systemic circulation via a transpulmonary shunt [6, 30, 31]. Air-blood interface created due to the air embolus causes platelet activation, which leads to a further decline in blood flow across the pulmonary circulation [30].

Clinical Signs and Symptoms

As most patients are sedated during the procedure, the clinical index of suspicion of air embolism should be kept in mind. Patients often experience severe and rapid clinical deterioration, so many cases often remain undiagnosed and are identified during post mortem [32]. Cardiovascular symptoms and signs include chest pain, dizziness, tachycardia or bradycardia, crackles, acute onset right-sided heart failure, hypotension, elevated jugular venous pressure, mill wheel murmur (loud churning sound likely from mixing of air and blood in the right ventricle that is heard throughout the cardiac cycle), cardiac arrest, arrhythmias like supraventricular tachycardia (SVT), ventricular tachycardia (VT), asystole or pulseless electrical activity [25, 31, 33-35]. Seizures, headache, focal neurological deficits, paraplegia or quadriparesis, altered mental status or failure to regain consciousness after the procedure, hemiparesis, pupillary dilation, skin mottling, and coma are some of the neurological signs and symptoms that may be present if cerebral involvement occurs [36-39]. Pulmonary symptoms and signs include respiratory failure, tachypnea, cyanosis, rales and wheezing [40]. A sudden decrease in end-tidal CO_2 ($EtCO_2$) in intubated patients may be a useful early sign of air embolism during ERCP. Nine out of the 10 reported fatalities from air embolism during ERCP occurred due to systemic embolization, which highlights the importance of early detection [41]. Severe cases of VAE may result in cardiovascular collapse. It was thought to be due to an "air-lock" phenomenon which resulted in large amounts of air entering into the right heart which prevented blood from exiting the ventricle. It now appears more likely that the acute increase in right ventricular pressure and decreased perfusion pressure leads to right ventricular ischemia, right heart failure, arrhythmias, and ultimately, cardiovascular collapse [7].

Diagnosis

Precordial Doppler ultrasound (PDU) is a useful method to detect VAE during ERCP and should especially be considered in high-risk procedures [42]. It is an effective, inexpensive, and noninvasive monitoring device in which heart tone changes, usually called "mill-wheel murmur," are a hallmark of VAE

[8]. VAE may be diagnosed with transesophageal or transthoracic echocardiography [28]. Air can be seen in significant amount in the right heart. Pulmonary artery hypertension and right ventricular strain on electrocardiogram can also be seen. Because of a decrease in cardiac output, capnography demonstrates a decrease in $EtCO_2$. If air is being used for insufflation, nitrogen will be seen among the expired gases [43]. Central venous pressure can be increased by volume expansion, which can prevent further embolization. A computed tomography scan can be done if systemic air embolism is suspected to identify air in the affected organs only after initial stabilization and resuscitation of the patient [44]. Moreover, pulmonary embolism should always be in the differentials of hemodynamic instability [11].

Management

Treatment of air embolism should be started early in suspected cases, and it should be in the differential diagnoses of various complications secondary to high-risk ERCP, especially if a cardiopulmonary compromise is present [8]. Management of VAE is conservative with intravenous (IV) antibiotics and decompression via nasogastric tube [10]. If air embolism becomes evident during the procedure, the procedure should be discontinued, and hemodynamic and respiratory stabilization should be performed [45]. It is also recommended to perform an immediate echocardiogram [28]. If echocardiography confirms air in the right heart, the central catheter is inserted. High-flow 100% oxygen, Trendelenburg, and left lateral decubitus positions are used to prevent air migrating to the brain and to force the air into the outflow tract of the right ventricle [11]. Hyperbaric oxygen therapy is considered first-line treatment as it reduces the size of the air bubbles, increases nitrogen absorption, and increases blood oxygen concentration, which helps reduce cerebral ischemic injury [25]. Hyperbaric oxygen therapy in a chamber with a pressure of 2.5 atm for more than 2 h has shown to improve survival in patients with air embolisms from multiple sources [46]. Athauda et al reported a case where therapeutic hypothermia was used in cerebral air embolism caused by ERCP when hyperbaric oxygen therapy was not available. It is one of the secondary options, but more studies need to be done on this [38]. There is no routine recommendation of anticoagulation as there is a risk of hemorrhagic transformation of ischemic tissue. The only indication of anticoagulation in air embolism is the concomitant development of pulmonary embolism [11].

Mortality and Morbidity of Air Embolism

Shaikh et al mentioned in their review that vascular air embolism has a mortality rate of 48-80% [47]. The lethal dose has been estimated to be 3 - 5 mL/kg and 300 - 500 mL of gas injected at a rate of 100 mL/s has been found to be fatal for humans [48]. Muley et al concluded that 17.2% (41/238) patients undergoing neurosurgery had a fall in $EtCO_2$. Its monitoring is an important parameter to consider early in the course of suspected VAE. Survivors of VAE can have long-term neurological effects [49].

Prophylactic Measures to Decrease the Risk of Air Embolism

Kwan and colleagues used CO_2 instead of air, which reduced the risk of embolism as CO_2 is absorbed more easily. It is also associated with less pain after the procedure and less abdominal distension [50]. The presence of congenital right-to-left shunt should be ruled out in all patients considered for ERCP, possibly via echocardiography before the procedure [5]. Personnel expertise is required to rapidly insert a pulmonary artery catheter into the right heart in order to drain air and should be immediately available [51]. Cotton et al highlighted that for diagnostic purposes, MRCP can now be used and ERCP should be reserved for the procedures that need therapeutic intervention [52].

Conclusions

Air embolism is a rare but serious complication associated with ERCP that must be considered, especially in high-risk cases. The endoscopist must keep this in mind while performing ERCP in patients with predisposing risk factors. Bedside Doppler may be used early to detect air in the right heart. Treatment with high-flow oxygen and resuscitation should be performed early in high-risk cases to prevent the fatal outcomes. After initial stabilization, diagnosis is then confirmed. Aspiration with the help of an expert should be readily available in high-risk cases. All high-risk cases should be intubated with the help of an anesthetist to detect reducing $EtCO_2$ levels to initiate early treatment and reduce the morbidity and mortality associated with this.

Acknowledgments

None to declare.

Financial Disclosure

None to declare.

Conflict of Interest

None to declare.

Author Contributions

All authors made significant contribution to the idea, drafting and revisions of manuscript.

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