We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS BOOK CITATION INDEX INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Chapter 8

Air Embolism

Bojan Biocina, Mate Petricevic and Ivica Safradin

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.68649

Abstract

Air embolism is one of the serious causes of morbidity and mortality in medicine and surgery, especially in cardiac surgery. Various medical and surgical procedures have been associated with the risk of air embolism. In the chapter, all procedures and pathologic conditions will be described, paying special attention to the root cause analysis of the events in any given circumstance. Special attention is to be paid to techniques of risk minimization of this serious complication. The chapter will give an in-depth insight to the anatomical, physiological and other preconditions of air embolism, thus helping the reader to implement preventive measures and to increase patient safety

Keywords: embolism, air, gas

1. Introduction

Air embolism is, although uncommon, a potentially catastrophic event that occurs as a consequence of the entry of air into either arteries or veins. Put briefly, air embolism occurs when atmospheric gas is introduced into the systemic vasculature. Here, it would be prudent to clarify that the most appropriate name for this entity would actually be "gas embolism". In most cases, gas embolism is in fact air embolism, although the medical use of other gases such as carbon dioxide, nitrous oxide and nitrogen can also result in the condition [1].

Air embolism in the vasculature is the clinical entity with the great potential for severe morbidity and mortality. Venous air embolism is more prevalent when compared to arterial gas embolism. Even though the etiology of air embolism will be discussed in more detail later on, it is worth to mention that air embolism is actually predominantly an iatrogenic complication of both diagnostic and therapeutic procedures in different medical specialties [1–6].

2. Etiology

As previously mentioned, gas embolism can be either venous or arterial. The most common causes of air embolism are surgery, trauma, vascular interventions and barotrauma from mechanical ventilation and diving [7–10].

Gas embolism most commonly occurs not only in an anterograde venous course, as is most typical, but also may occur via epidural spaces and/or via tissue planes [2]. Medical specialties with documented cases of gas embolism were comprehensively reviewed by Muth et al. [1]. According to the literature, gas embolism may occur in cardiac surgery, cardiology, critical care and pulmonology, diving and hyperbaric medicine, endoscopic and laparoscopic surgery, gastroenterology, nephrology, neurosurgery, obstetrics and gynecology, otolaryngology, orthopedics, urology, vascular surgery, etc. [9–23]. Among these, air embolism occurs more frequently in neurosurgical and otolaryngological procedures when compared to surgical procedures in other specialties. An air embolism incident during neurosurgical procedures ranges from 10 to 80%.

There are numerous surgical or other non-surgical invasive procedures where gas embolism has been reported as a complication: (1) needle biopsy of the lung (bronchoscopic or percutaneous), lung resection [15–17, 24] and radiofrequency ablation of lung cancer [25], (2) arthroscopy and arthroplasty [18, 26], (3) gynecological procedures (hysteroscopy [19, 27, 28], C-section [29]), (4) gastrointestinal procedures (laparoscopy [30], colonoscopy [21], endoscopic retrograde cholangiopancreatography (ERCP) [20]) and (5) cardiac procedures (heart surgeries performed with cardiopulmonary bypass [22], cardiac implantable electronic devices implantation [23, 31], cardiac ablation procedures of cardiac arrhythmias) [32–34]. Gas embolism has also been described in ophthalmological [35] and dental procedures [36]. Mechanisms for gas embolism differ widely among the specialties. For example, in cardiac surgery procedures, possible mechanisms are the entry of air into extracorporeal bypass pump circuit and incomplete removal of air from the heart following weaning from cardiopulmonary bypass [22]. In neurosurgery procedures, the possible mechanism of gas embolism is entry of air through incised veins and calvarial bone, especially during craniotomy with the patient in a sitting position. What remains common for all the surgical procedures is the intraoperative use of hydrogen peroxide which may cause formation of arterial and venous oxygen emboli [1].

Gas embolism may certainly occur when handling intravascular catheters. Gas emboli can occur at the time of catheter insertion, while catheter is in place, or at the time of catheter removal [37]. Handling different types of catheters, be it venous or arterial (i.e., central venous catheters [10, 38], hemodialysis catheters [39, 40], pulmonary artery catheters [41] and angioplasty catheters [42]) may result in gas embolism. When handling intravascular catheters, one should keep in mind the factors that contribute to gas embolism occurrence (fracture or detachment of catheter connections, failure to occlude the needle hub, dysfunction of self-sealing valves in plastic introducer sheaths, the presence of a persistent catheter tract following the catheter removal, deep inspiration during catheter insertion or removal, hypovolemia that reduces central venous pressure and upright positioning of the patient).

3. Detection of gas embolism

In order to diagnose air embolism, a clinician should first set the suspicion and should assess clinical findings. Many cases of gas embolism are subclinical with no adverse outcomes. Usually, even when symptoms are present, they are non-specific, and a high index of clinical suspicion for possible gas embolism is required to prompt investigations and initiate appropriate therapy. A splashing auscultatory sign indicating the presence of gas in cardiac chambers can be auscultated using stethoscope [1]. Doppler ultrasonography is a sensitive and a practical means of detecting intracardiac air [43, 44]. Transesophageal echocardiography remains an even more sensitive and definitive method for detecting intracardiac gas [45].

Transesophageal echocardiography is currently the most sensitive monitoring device for detection of air presence, detecting as little as 0.02 ml/kg of air administered by bolus injection [46, 47]. The major deterrents to transesophageal echocardiography are that it is invasive, is expensive and requires expertise and constant vigilance that may limit its use to just a well-trained cardiac anesthesiologist or cardiologist [2].

Noteworthy, a decrease in the end-tidal carbon dioxide levels, as determined by capnometry, may be suggestive of gas embolism as well.

4. Management

Early diagnosis and treatment before catastrophic cardiovascular collapse are of utmost importance. In general, there are three principle goals in air embolism management: (1) prevention of further air entry, (2) a reduction in the volume of air entrapped and (3) hemodynamic support [2]. In case of gas embolism, clinician should institute high-flow oxygen to maximize patient oxygenation during the period of hemodynamic instability. Nitrous oxide should be discontinued, and the patient should be placed on 100% oxygen. Administration of oxygen is important not only to treat hypoxia and hypoxemia but also to eliminate the gas in the bubbles by establishing a diffusion gradient that favors the egress of gas from bubbles [1, 48]. In certain cases, therapy with catecholamines is required, as well as aggressive cardiopulmonary resuscitation, if needed. Rapid volume expansion is recommended to elevate venous pressure, thus preventing the continued entry of gas into intravascular space. Normovolemia should be achieved to optimize microcirculation. Colloid solutions are preferable to crystalloid solutions for hemodilution as crystalloid solutions may promote cerebral edema.

Hyperbaric oxygen therapy decreases the size of the gas bubble both by rising the ambient pressure and by causing hyperoxia [1]. There is emerging evidence suggesting that all patients with clinical symptoms of arterial gas embolism should receive recompression treatment with hyperbaric oxygen, which is in fact considered the first line treatment of choice for arterial gas embolism [1, 49–51].

As Muth et al. discussed in their paper [1], there is evidence that heparin may be beneficial in the treatment of gas embolism [52]. The possible disadvantage would be the risk of hemorrhage

into the infarcted tissue. Whereas the use of corticosteroid therapy remains controversial and to date is not recommended, the lidocaine therapy has been shown to provide cerebral protection during cardiac surgery [53]. Even with lidocaine, the evidence is controversial [1, 54] and further research is needed to shed a light into its neuroprotective role.

In conclusion, gas embolism is a risk associated with different diagnostic and/or therapeutic procedures in virtually all medical specialties [1]. Arterial gas emboli may be particularly dangerous if they occlude cardiac or cerebral vessels [1]. Whereas hyperbaric oxygen remains the first choice of arteria gas emboli treatment, the mainstays of treatment for venous gas embolism are volume expansion, targeting 12 mm of mercury of central venous pressure, the administration of 100% oxygen, often with ventilatory support [1]. Finally, prevention of air embolism and prevention of further entry of gas in cases of present air embolism remain the Cornerstone Treatment in management of patients at risk for such a clinical entity.

Author details

Bojan Biocina[1]*, Mate Petricevic[2] and Ivica Safradin[2]

*Address all correspondence to: bbiocina@kbc-zagreb.hr

1 Department of Cardiac Surgery, School of Medicine, University of Zagreb, Zagreb, Croatia

2 Department of Cardiac Surgery, UHC Zagreb, Zagreb, Croatia

References

[1] Muth CM, Shank ES. Gas embolism. The New England Journal of Medicine. 2000;**342**: 476-82

[2] Mirski MA, Lele AV, Fitzsimmons L, Toung TJ. Diagnosis and treatment of vascular air embolism. Anesthesiology. 2007;**106**:164-77

[3] Sviri S, Woods WP, van Heerden PV. Air embolism – A case series and review. Critical Care and Resuscitation: Journal of the Australasian Academy of Critical Care Medicine. 2004;**6**:271-276

[4] van Hulst RA, Klein J, Lachmann B. Gas embolism: Pathophysiology and treatment. Clinical Physiology and Functional Imaging. 2003;**23**:237-246

[5] Muth CM, Shank ES. Cerebral arterial gas embolism: Should we hyperventilate these patients? Intensive Care Medicine. 2004;**30**:742-743

[6] Shank ES, Muth CM. Decompression illness, iatrogenic gas embolism, and carbon monoxide poisoning: The role of hyperbaric oxygen therapy. International Anesthesiology Clinics. 2000;**38**:111-138

[7] Dudney TM, Elliott CG. Pulmonary embolism from amniotic fluid, fat, and air. Progress in Cardiovascular Diseases. 1994;**36**:447-474

[8] King MB, Harmon KR. Unusual forms of pulmonary embolism. Clinics in Chest Medicine. 1994;**15**:561-580

[9] Schmitt HJ, Hemmerling TM. Venous air emboli occur during release of positive end-expiratory pressure and repositioning after sitting position surgery. Anesthesia and Analgesia. 2002;**94**:400-403, table of contents

[10] Heckmann JG, Lang CJ, Kindler K, Huk W, Erbguth FJ, Neundorfer B. Neurologic manifestations of cerebral air embolism as a complication of central venous catheterization. Critical Care Medicine. 2000;**28**:1621-1625

[11] Raskin JM, Benjamin E, Iberti TJ. Venous air embolism: Case report and review. The Mount Sinai Journal of Medicine, New York. 1985;**52**:367-370

[12] O'Quin RJ, Lakshminarayan S. Venous air embolism. Archives of Internal Medicine. 1982;**142**:2173-2176

[13] Hybels RL. Venous air embolism in head and neck surgery. The Laryngoscope. 1980;**90**:946-954

[14] Faberowski LW, Black S, Mickle JP. Incidence of venous air embolism during craniectomy for craniosynostosis repair. Anesthesiology. 2000;**92**:20-23

[15] Al-Ali WM, Browne T, Jones R. A case of cranial air embolism after transthoracic lung biopsy. American Journal of Respiratory and Critical Care Medicine 2012;**186**:1193-1195

[16] Ramaswamy R, Narsinh KH, Tuan A, Kinney TB. Systemic air embolism following percutaneous lung biopsy. Seminars in Interventional Radiology. 2014;**31**:375-377

[17] Hemmerling TM, Schmidt J, Bosert C, Klein P. Systemic air embolism during wedge resection of the lung. Anesthesia and Analgesia. 2001;**93**:1135-1136, table of contents

[18] Andersen KH. Air aspirated from the venous system during total hip replacement. Anaesthesia. 1983;**38**:1175-1178

[19] Guillard E, Nancy B, Floch H, Henckes A, Cochard G, Arvieux J, et al. Intracerebral hemorrhage related to systemic gas embolism during hysteroscopy. Undersea & Hyperbaric Medicine: The Journal of the Undersea and Hyperbaric Medical Society, Inc. 2010;**37**:89-93

[20] Chavalitdhamrong D, Donepudi S, Pu L, Draganov PV. Uncommon and rarely reported adverse events of endoscopic retrograde cholangiopancreatography. Journal of Digestive Endoscopy. 2014;**26**:15-22

[21] Sopena-Falco J, Poch-Vall N, Brullet E, Mendez-Reyes H, Martinez-Bauer E, Junquera F, et al. Fatal massive air embolism following diagnostic colonoscopy. Endoscopy 2013;**45 Suppl 2 UCTN**:E91

[22] Schmitz ML, Faulkner SC, Johnson CE, Tucker JL, Imamura M, Greenberg SB, et al. Cardiopulmonary bypass for adults with congenital heart disease: Pitfalls for perfusionists. Perfusion. 2006;**21**:45-53

[23] Xiao PX, Hu ZY, Zhang H, Pan C, Duan BX, Chen SL. Massive pulmonary air embolism during the implantation of pacemaker, case reports and literature analysis. European Review for Medical and Pharmacological Sciences. 2013;**17**:3157-3163

[24] Horan TA, Pinheiro PM, Araujo LM, Santiago FF, Rodrigues MR. Massive gas embolism during pulmonary nodule hook wire localization. The Annals of Thoracic Surgery. 2002;**73**:1647-1649

[25] Hiraki T, Gobara H, Fujiwara H, Ishii H, Tomita K, Uka M, et al. Lung cancer ablation: Complications. Seminars in Interventional Radiology. 2013;**30**:169-175

[26] Peruto CM, Ciccotti MG, Cohen SB. Shoulder arthroscopy positioning: Lateral decubitus versus beach chair. Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2009;**25**:891-896

[27] Sherlock S. Paradoxical gas embolism during hysteroscopy. British Journal of Anaesthesia. 2008;**101**:742; author reply 42-3

[28] Grove JJ, Shinaman RC, Drover DR. Noncardiogenic pulmonary edema and venous air embolus as complications of operative hysteroscopy. Journal of Clinical Anesthesia. 2004;**16**:48-50

[29] Cluver C, Novikova N, Hofmeyr GJ, Hall DR. Maternal position during caesarean section for preventing maternal and neonatal complications. The Cochrane Database of Systematic Reviews. 2013:CD007623

[30] Azevedo JL, Azevedo OC, Miyahira SA, Miguel GP, Becker OM Jr, Hypolito OH, et al. Injuries caused by Veress needle insertion for creation of pneumoperitoneum: A systematic literature review. Surgical Endoscopy. 2009;**23**:1428-1432

[31] Bongiorni MG, Di Cori A, Soldati E, Zucchelli G, Segreti L, Solarino G, et al. Iatrogenic risk of permanent pacemaker and defibrillator implantation. Giornale Italiano di Cardiologia. 2009;**10**:395-406

[32] Doblar DD, Hinkle JC, Fay ML, Condon BF. Air embolism associated with pulmonary artery catheter introducer kit. Anesthesiology. 1982;**56**:389-391

[33] Doblar DD, Hinkle JC, Fay ML, Condon BF. Air embolism associated with pulmonary artery catheter introducer kit. Anesthesiology. 1982;**56**:307-309.

[34] Hinkle DA, Raizen DM, McGarvey ML, Liu GT. Cerebral air embolism complicating cardiac ablation procedures. Neurology. 2001;**56**:792-794

[35] Moon YE. Venous air embolism during vitrectomy: A rare but potentially fatal complication. Korean Journal of Anesthesiology. 2014;**67**:297-298

[36] Davies JM, Campbell LA. Fatal air embolism during dental implant surgery: A report of three cases. Canadian Journal of Anesthesia. 1990;**37**:112-121

[37] Roberts S, Johnson M, Davies S. Near-fatal air embolism: Fibrin sheath as the portal of air entry. Southern Medical Journal. 2003;**96**:1036-1038

[38] Laskey AL, Dyer C, Tobias JD. Venous air embolism during home infusion therapy. Pediatrics 2002;**109**:E15

[39] Levy SD, Oren-Grinberg A, McSparron JI. Paradoxical air embolus after removal of a central venous catheter. Annals of the American Thoracic Society. 2016;**13**:1856-1857

[40] Yu AS, Levy E. Paradoxical cerebral air embolism from a hemodialysis catheter. American Journal of Kidney Diseases: The Official Journal of the National Kidney Foundation. 1997;**29**:453-455

[41] Jastremski MS, Chelluri L. Air embolism and cardiac arrest in a patient with a pulmonary artery catheter: A possible association. Resuscitation. 1986;**14**:113-119

[42] Chang C, Dughi J, Shitabata P, Johnson G, Coel M, McNamara JJ. Air embolism and the radial arterial line. Critical Care Medicine 1988;**16**:141-143

[43] Porter JM, Pidgeon C, Cunningham AJ. The sitting position in neurosurgery: A critical appraisal. British Journal of Anaesthesia. 1999;**82**:117-128

[44] Gildenberg PL, O'Brien RP, Britt WJ, Frost EA. The efficacy of Doppler monitoring for the detection of venous air embolism. Journal of Neurosurgery. 1981;**54**:75-78

[45] 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 Anaesthesiologica Scandinavica. 1998;**42**:643-647

[46] Jaffe RA, Siegel LC, Schnittger I, Propst JW, Brock-Utne JG. Epidural air injection assessed by transesophageal echocardiography. Regional Anesthesia. 1995;**20**:152-155

[47] Furuya H, Suzuki T, Okumura F, Kishi Y, Uefuji T. Detection of air embolism by transesophageal echocardiography. Anesthesiology. 1983;**58**:124-129

[48] Van Liew HD, Conkin J, Burkard ME. The oxygen window and decompression bubbles: Estimates and significance. Aviation, Space, and Environmental Medicine. 1993;**64**: 859-865

[49] Ziser A, Adir Y, Lavon H, Shupak A. Hyperbaric oxygen therapy for massive arterial air embolism during cardiac operations. The Journal of Thoracic and Cardiovascular Surgery. 1999;**117**:818-821

[50] Dutka AJ. A review of the pathophysiology and potential application of experimental therapies for cerebral ischemia to the treatment of cerebral arterial gas embolism. Undersea Biomedical Research. 1985;**12**:403-421

[51] Peirce EC, 2nd. Specific therapy for arterial air embolism. The Annals of Thoracic Surgery. 1980;**29**:300-303

[52] Ryu KH, Hindman BJ, Reasoner DK, Dexter F. Heparin reduces neurological impairment after cerebral arterial air embolism in the rabbit. Stroke. 1996;**27**:303-309, discussion 10

[53] Mitchell SJ, Pellett O, Gorman DF. Cerebral protection by lidocaine during cardiac operations. The Annals of Thoracic Surgery. 1999;**67**:1117-1124

[54] Mitchell SJ, Merry AF, Frampton C, Davies E, Grieve D, Mills BP, et al. Cerebral protection by lidocaine during cardiac operations: A follow-up study. The Annals of Thoracic Surgery. 2009;**87**:820-825