Article published online: 2024-05-02

Paradoxical Air Embolism in Spinal Surgery: Case Report and Literature Review

Embolia gasosa paradoxal em cirurgia de coluna: Relato de caso e revisão de literatura

Guilherme José Miotto[1] Artur Eduardo Martio[1] Paulo Moacir Mesquita Filho[1] Octávio Ruschel Karam[1] Wagner Lazaretto Padua[1] Taís Otilia Berres[1] Renan Mathias Ferreira Saltiél[1]

[1] Department of Neurosurgery, Hospital de Clínicas de Passo Fundo, Passo Fundo, RS, Brazil.

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Address for correspondence Renan Mathias Ferreira Saltiél, Department of Neurosurgery, Hospital de Clínicas de Passo Fundo, Marcelino Ramos Street, 355, Cep 99010-160, Passo Fundo, RS, Brazil (e-mail: renanfsaltiel@gmail.com).

Abstract

Air embolism (AE) is a subtype of embolism, caused by the entry of air into the vascular system. It is a predominantly iatrogenic complication, and its symptomatic form is severe, although uncommon. In some cases, a venous thrombi may pass into the arterial system through a venous-arterial shunt, characterizing a paradoxical embolism. Here, we describe the case of a previously healthy 44-year-old female who underwent cauda equina decompression and lumbar epidural abscess drainage. The patient suffered a paradoxical AE intraoperatively and died after 4 days. The occurrence of AE in lumbar spine surgeries in the prone position is rare, but the surgical team must be attentive to its clinical signs and quickly institute initial management when necessary.

Keywords
- air embolism
- paradoxical embolism
- surgery
- spine
- prone position

Resumo

A embolia gasosa (EG) é um subtipo de embolia, causada pela entrada de ar no sistema vascular. É uma complicação predominantemente iatrogênica e sua forma sintomática é grave, embora incomum. Em alguns casos, um trombo venoso pode migrar para o sistema arterial através de um shunt venoso-arterial, caracterizando uma embolia paradoxal. Aqui, descrevemos o caso de uma mulher de 44 anos, previamente saudável, submetida a descompressão da cauda equina e drenagem de abscesso peridural lombar. A paciente sofreu uma EG paradoxal no intraoperatório e morreu 4 dias depois. A ocorrência de EG em cirurgias da coluna lombar em posição prona é rara, mas a equipe cirúrgica deve estar atenta aos seus sinais clínicos e, quando necessário, instituir o manejo inicial rapidamente.

Palavras-chave
- embolia gasosa
- embolia paradoxal
- cirurgia
- coluna
- posição prona

received
February 3, 2023
accepted
August 4, 2023

DOI https://doi.org/10.1055/s-0044-1779439.
ISSN 0103-5355.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

Introduction

Air embolism (AE), a subtype of embolism that occurs when air enters the vascular system, has the potential to generate a severe and deadly clinical scenario.[1,2] It is a predominantly iatrogenic complication, usually secondary to medical procedures, such as central venous catheterization, endoscopy, hysteroscopy, laparoscopy, and hemodialysis, among others.[1–10] The clinical presentation varies according to the final destination of the air embolus, which can happen in a myriad of locations.[2,11,12] Paradoxical AE occurs when air transferred by the vascular system passes through the venous bed and into the arterial bed through a venous-arterial shunt, such as in cases of heart defect (right-to-left shunt) or pulmonary arteriovenous malformation. Patent foramen ovale (PFO) is an important cause of paradoxical embolism, especially due to its high prevalence in the population (up to 25%).[1–3]

Cerebral arterial AE (CAGE) is uncommon, but often has catastrophic results. It is sometimes caused by a paradoxical AE rather than the direct entry of air into the arterial bed. It has been described several times, but rarely associated with lumbar spine surgery or the prone position.[13–16] In this study, we describe the case of a patient undergoing surgical treatment for lumbar discitis who developed pulmonary AE and CAGE during the procedure.

Case Report

A previously healthy 44-year-old woman had persistent lower back pain that irradiated to both lower limbs for 3 months, with the use of common analgesics proving unsuccessful. The pain kept progressing, and about a week prior to admission, she developed walking impairment, fevers, and chills.

On admission, lumbar spine magnetic resonance imaging (MRI) was performed, evidencing lumbar spondylodiscitis at the L5-S1 level (►**Fig. 1**). Furthermore, the patient had sinus tachycardia (HR 120 bpm), increased capillary filling time and fever, in addition to paraparesis. An intensive care unit (ICU) bed was requested due to the diagnosis of systemic inflammatory response syndrome, and broad-spectrum antibiotic therapy (ceftriaxone, vancomycin, and metronidazole) was promptly initiated. A surgical procedure was sequentially indicated for cauda equina decompression and epidural abscess drainage. During the operation, the patient had an abrupt drop in O2 saturation (to 70%), followed by circulatory shock. The anesthesiologist rapidly brought up the possibility of air embolism, which was seen as the most probable cause by the entire team, and management was promptly initiated. The surgical field was immediately covered with compresses and immersed in saline solution to prevent new air entry, the O2 supply was increased to 100%,

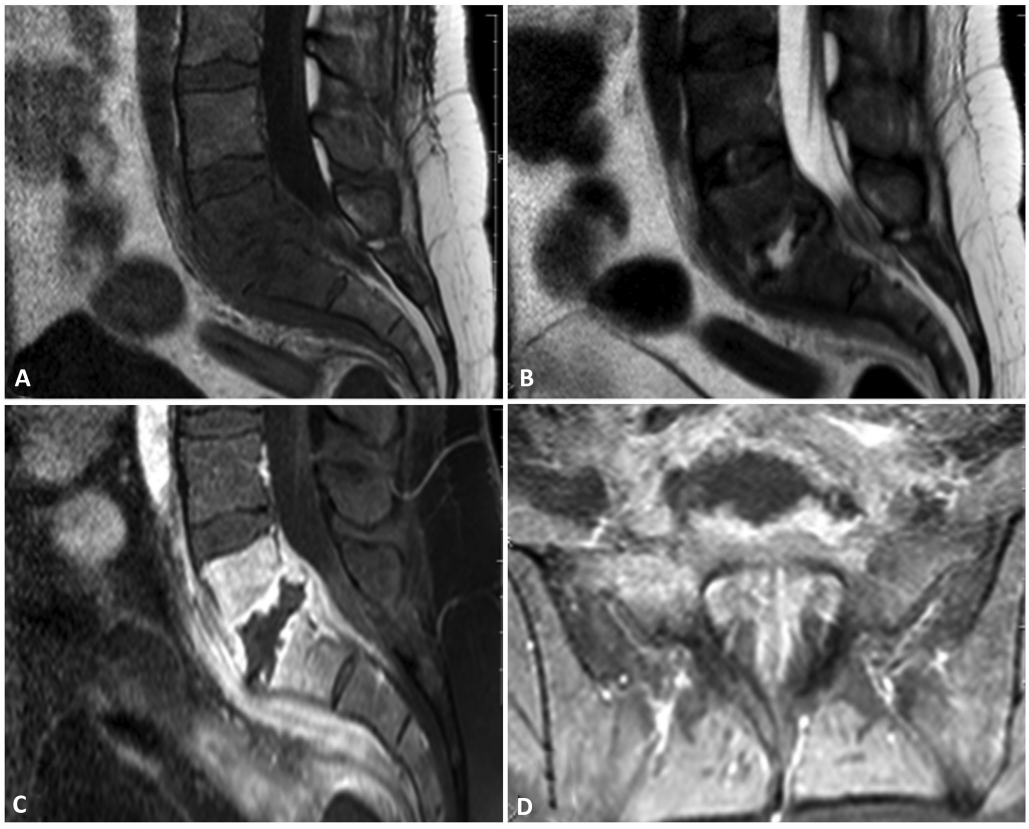

Fig. 1 Preoperative lumbar spine MRI. Spondylodiscitis L5-S1 with infiltration of adjacent soft tissues. The disc component generates compression of the anterior surface of the dural sac. (**A**), (**B**), and (**C**) are sagittal T1, STIR, and contrast enhanced T1 SPIR images, respectively; the involvement of the L5 and S1 vertebrae and the intervertebral disc can be seen, as well as the disc protrusion causing compression of the dural sac. (**D**) is a contrast-enhanced axial T1 SPIR image at the S1 level demonstrating involvement of paravertebral structures. **Abbreviations:** MRI, magnetic resonance imaging; STIR, short T1 inversion recovery; SPIR, spectral pre-saturation with inversion recovery.

and hyperventilation was performed until the condition stabilized. The patient did not have central venous access positioned for aspiration at the time.

In the immediate postoperative period, the patient did not awaken after the cessation of anesthetic medication. Neurological examination showed that she developed right hemiplegia and deviation of conjugated gaze to the left, so she was kept under sedation and mechanical ventilation. An emergency computed tomography (CT) of the head was performed, and multiple air bubbles were spotted within the lumen of the left internal carotid and left posterior cerebral arteries (►**Fig. 2**). Ventilation with 100% O2 was maintained for the management of AE. Hyperbaric therapy is not available at our center, and transfer to another hospital capable of offering this therapy was not feasible. The day after surgery, the patient developed fixed mydriasis and rostrocaudal degeneration. A new CT scan of the head was then performed, demonstrating multiple areas of bilateral ischemia. After further investigation, a transesophageal echocardiogram was performed, which demonstrated a 2 mm PFO. Although small, the PFO was the most probable explanation found for CAGE in this case, since other exams showed no alterations. The patient died after 4 days. Informed consent forms were acquired from the patient's family, as she died before the article was written.

Discussion

For air to enter the vascular system, there must be a direct communication between an air source and a vessel, as well as a pressure gradient that favors its entry.[3,11] The severity of AE depends on some key factors, in particular the amount of air entering the system, the rate of accumulation in the tissues and the patients' position on the surgical bed at the time of the event.[1,2,4,17,18]

Lumbar spine surgeries constitute an atypical clinical scenario for the occurrence of CAGE, which can lead to a delay in management. Nonetheless, this rare association has been described in the past.[13–16] The prone position can create the necessary conditions for the entry of air into the veins of the epidural plexus by generating the necessary gravitational gradient required (believed to be as little as 5 cm height difference between the operative site and the right atrium), as well as a pressure of up to -2.0 cmH2O in the

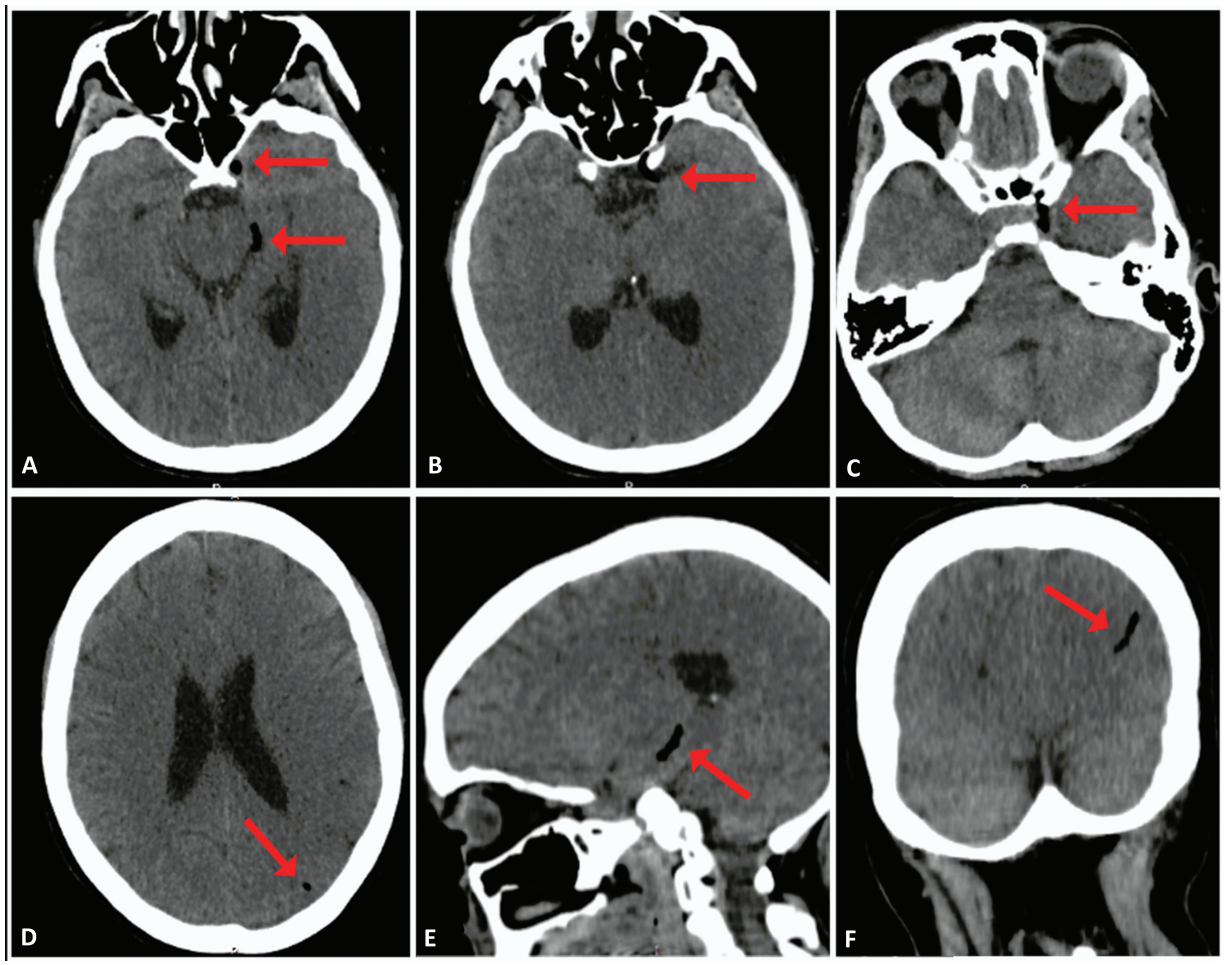

Fig. 2 Immediate post-operative CT scan of the head. Noncontrast CT of the head performed in the immediate postoperative period. In (**A**), density compatible with air is visualized in the left internal carotid and posterior cerebral arteries. (**B**) and (**C**) show air embolus in the left internal carotid artery, in the clinoid and cavernous segments, respectively. (**D**) Demonstrates air embolus in a distal cortical branch of the left posterior cerebral artery. (**E**) and (**F**) demonstrate intraluminal air in the left internal carotid artery and in a distal branch of the left posterior cerebral artery, in the sagittal and coronal sections, respectively. The red arrows point to the air emboli. **Abbreviation:** CT, computed tomography.

inferior vena cava, which creates relative emptying of the epidural veins and a suctioning effect.[12,15,17,19] When happening together, these scenarios can lead to AE. Therefore, despite its rarity, the surgical and anesthesiology teams should be aware that AE is possible and start management immediately after the patient turns symptomatic during surgery.

A high clinical suspicion is necessary to speed up the investigation and diagnosis of AE. The majority of cases are thought to go by unrecognized, as most patients are either asymptomatic or have nonspecific symptoms. The clinical presentation derives from the location of the embolus, which can lodge itself anywhere in the vascular system.[2,12] In CAGE, there is usually a multivessel occlusion, a classic feature of embolic stroke. Focal neurological signs and symptoms, as well as acute-onset decreased level of consciousness in a patient at risk for AE should raise suspicion of CAGE, followed by prompt investigation and treatment.[2,3] Transthoracic or transesophageal (preferred) echocardiography and CT scan of the affected region are the most efficient diagnostic tests in this case, as they can detect air bubbles within the vascular system (►**Fig. 2**). It is noteworthy that a negative CT scan does not completely exclude AE. Some other tests can be performed, but the findings are not specific.[1–3,8,20] Furthermore, the presence of CAGE or other arterial AE should raise the suspicion of a direct connection between the venous and arterial bed. Therefore, investigation is necessary in these cases.[1–3,8]

The treatment of AE must be instituted quickly to decrease ischemic damage. As it has already been described in detail elsewhere,[1–3,8,15,21] we shall briefly summarize it here. When AE is detected during surgery, the surgical site should be covered with compresses soaked in saline solution to prevent the entry of new emboli.[1,15] Then, in addition to hemodynamic support, good ventilation with 100% O2 must be ensured, since high concentrations of O2 help to reduce the nitrogen content of the embolus (thus decreasing its size). Hyperventilation can also be performed for the same purpose.[1–3,8,21] Positioning the patient in left lateral decubitus, and in the Trendelenburg position can also be useful, but not in cases of CAGE.[3] Immediate aspiration through a central venous catheter can be performed.[1,3,8] If available, hyperbaric oxygen therapy is recommended for the more severe cases.[1–3,8,21]

Conclusion

The occurrence of AE, especially CAGE, during lumbar spine surgery in the prone position is very rare, which hampers diagnosis and delays treatment. This clinical scenario has been described a few times in the past, and our case reinforces its existence and importance. Although rare, the surgical team must be attentive to its clinical signs and quickly institute management when necessary. The treatment of AE must be immediate, and even in situations where it is uncommon, the hypothesis must be raised and the initial treatment instituted until this diagnosis can be excluded. Unfortunately, even with the immediate recognition and management of AE in the present case, our patient died, which reinforces the severity of such a scenario.

Ethics Approval and Consent to Participate

Ethical approval was waived by the local Ethics Committee of the Faculdade Meridional - IMED in view of the retrospective nature of the study and all the procedures being performed were part of the routine care. The study was conducted in accordance with the declaration of Helsinki.

Consent for Publication

Informed consent forms were acquired from the patient's family, as the patient died before the article was written.

Availability of Data and Material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

Each author made significant individual contributions to this manuscript. Miotto GJ: Main physician responsible for the patient's care and main surgeon; review of the manuscript's intellectual content; approval of the final version of the manuscript. Martio AE: Development and writing of the article; approval of the final version of the manuscript. Mesquita Filho PM: Development and writing of the article; approval of the final version of the manuscript. Karam OR: Physician responsible for the patient's care, auxiliary surgeon; writing of the article; approval of the final version of the manuscript. Padua WL: Critical review of the intellectual content of the manuscript; approval of the final version of the manuscript. Berres TO: Critical review of the intellectual content of the manuscript; approval of the final version of the manuscript. Ferreira Saltiél RM: Critical review of the intellectual content of the manuscript; approval of the final version of the manuscript.

Funding Statement

No funding was received in any phase of the article's production.

Conflict of Interests

The authors have no conflict of interests to declare.

Acknowledgments

None.

References

1 Mirski MA, Lele AV, Fitzsimmons L, Toung TJ, Warltier David C. Diagnosis and treatment of vascular air embolism. Anesthesiology 2007;106(01):164–177. Doi: 10.1097/00000542-200701000-00026

2 van Hulst RA, Klein J, Lachmann B. Gas embolism: pathophysiology and treatment. Clin Physiol Funct Imaging 2003;23(05): 237–246. Doi: 10.1046/j.1475-097x.2003.00505.x

3 Muth CM, Shank ES. Gas embolism. N Engl J Med 2000;342(07): 476–482. Doi: 10.1056/nejm200002173420706
4 Pronovost PJ, Wu AW, Sexton JB. Acute decompensation after removing a central line: practical approaches to increasing safety in the intensive care unit. Ann Intern Med 2004;140(12):1025-–1033. Doi: 10.7326/0003-4819-140-12-200406150- 00013
5 Spence NZ, Faloba K, Sonabend AM, Bruce JN, Anastasian ZH. Venous air embolus during scalp incision. J Clin Neurosci 2016; 28:170–171. Doi: 10.1016/j.jocn.2015.11.019
6 Cruz AS, Moisi M, Page J, et al. Venous air embolus during prone cervical spine fusion: case report. J Neurosurg Spine 2016;25(06): 681–684. Doi: 10.3171/2016.5.spine16109
7 Ho AM, Ling E. Systemic air embolism after lung trauma. Anesthesiology 1999;90(02):564–575. Doi: 10.1097/00000542-199902000-00033
8 Platz E. Tangential gunshot wound to the chest causing venous air embolism: a case report and review. J Emerg Med 2011;41(02): e25–e29. Doi: 10.1016/j.jemermed.2008.01.023
9 Wong SS-M, Kwaan HC, Ing TS. Venous air embolism related to the use of central catheters revisited: with emphasis on dialysis catheters. Clin Kidney J 2017;10(06):797–803. Doi: 10.1093/ckj/sfx064
10 Mishra R, Reddy P, Khaja M. Fatal Cerebral Air Embolism: A Case Series and Literature Review. Case Rep Crit Care 2016; 2016:3425321. Doi: 10.1155/2016/3425321
11 Durant TM, Long J, Oppenheimer MJ. Pulmonary (venous) air embolism. Am Heart J 1947;33(03):269–281. Doi: 10.1016/0002-8703(47)90656-x
12 Albin MS, Carroll RG, Maroon JC. Clinical considerations concerning detection of venous air embolism. Neurosurgery 1978;3(03): 380–384. Doi: 10.1227/00006123- 197811000–00009
13 Bapteste L, Kamar Z, Mazaud A, Balança B. Air embolism during lumbar surgery in the prone position. Diving Hyperb Med 2021; 51(03):303–305. Doi: 10.28920/dhm51.3.303-305
14 Pham Dang C, Péréon Y, Champin P, Delécrin J, Passuti N. Paradoxical air embolism from patent foramen ovale in scoliosis surgery. Spine 2002;27(11):E291–E295. Doi: 10.1097/00007632-200206010-00025
15 McDouall SF, Shlugman D. Fatal venous air embolism during lumbar surgery: the tip of an iceberg? Eur J Anaesthesiol 2007; 24(09):803–805. Doi: 10.1017/s0265021506002201
16 Miyakoshi N, Hongo M, Kasukawa Y, Ishikawa Y, Kudo D, Shimada Y. Intraoperative Visible Air Bubbling Recorded as a Sign of Massive Venous Air Embolism During Prone Position Surgery for Extensive Ossification of Spinal Ligaments: A Case Report with a Video Clip. World Neurosurg 2019;131:38–42. Doi: 10.1016/j.wneu.2019.07.166
17 Durant TM, Oppenheimer MJ, Webster MR, Long J. Arterial air embolism. Am Heart J 1949;38(04):481–500. Doi: 10.1016/0002-8703(49)90001-0
18 Ho AM-H. Is emergency thoracotomy always the most appropriate immediate intervention for systemic air embolism after lung trauma? Chest 1999;116(01):234–237. Doi: 10.1378/chest.116.1.234
19 DiStefano VJ, Klein KS, Nixon JE, Andrews ET. Intra-operative analysis of the effects of position and body habitus on surgery of the low back. A preliminary report. Clin Orthop Relat Res 1974;(99):51–56. Doi: 10.1097/00003086- 197403000–00005
20 Maddukuri P, Downey BC, Blander JA, Pandian NG, Patel AR. Echocardiographic diagnosis of air embolism associated with central venous catheter placement: case report and review of the literature. Echocardiography 2006;23(04):315–318. Doi: 10.1111/j.1540-8175.2006.00211.x
21 Moon RE. Hyperbaric treatment of air or gas embolism: current recommendations. Undersea Hyperb Med 2019;46(05): 673–683

