



# Cerebral Air Embolism in Commercial Flights: A Potentially Fatal Complication of Intrathoracic Lesions

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## Abstract

**Background:** Cerebral air embolism (CAE) may exceptionally occur in patients with thoracic lesions during air travelling.

**Methods:** We present 5 new cases of CAE during flights and review precedent cases.

**Results:** Five patients with CAE were admitted to our Emergency Department (A-E). All experienced loss of consciousness (LOC). Chest radiograph showed thoracic bullae. Brain computed tomography (CT) showed subarachnoid bubbles (A), intraparenchymal bubbles (B), global hypoperfusion (C), or no abnormalities (D, E). With supportive treatment, four survived, while B died. Including ours, 18 cases of CAE during commercial flights have been reported. LOC and dyspnea were common. Thoracic cysts (9) and bullae (9) were found. Ten died. Five had experienced episodes suggesting CAE during previous flights. In patients with complete recovery, infarction, edema and intraparenchymal bubbles were absent in basal neuroimaging.

**Conclusions:** CAE may occur in patients with thoracic cysts while air travelling, causing typically neurological and respiratory symptoms early in the flight.

## Keywords

Cerebral air embolism; Air travelling; Hyperbaric oxygen therapy; Thoracic cyst; Bullae

## Abbreviations

CAE: Cerebral Air Embolism; LOC: Loss of Consciousness; CT: Computed Tomography; mRS: modified Rankin Scale; HBO: Hyperbaric Oxygen Therapy; MRI: Magnetic Resonance Image; COPD: Chronic obstructive pulmonary disease; ED: Emergency Department; DVT: Deep Venous

Thrombosis; F: Female; M: Male; CHD: Coronary Heart Disease; AF: Atrial Fibrillation; APS: Antiphospholipid Syndrome; TIA: Transient Ischemic Attack; HTN: Hypertension; OB: Obesity; GCS: Glasgow Coma Scale; ECG: Electrocardiogram; TTE: Transthoracic Echocardiogram; NIHSS: National Institute of Health Stroke Scale; rTPA: Recombinant Tissue Plasminogen Activator

## Introduction

Medical emergencies have been estimated to occur in 1 of every 604 flights. Particularly neurological problems linked to air traffic have been reported to be very frequent, specially strokes and seizures, which account for 2% and 5.8% of in-flight medical emergencies respectively [1,2].

Cerebral air embolism (CAE) is relatively common in diving and invasive procedures, but CAE linked to air traffic is considered exceptional: in the last three decades only thirteen cases have been reported. While flying, thoracic cysts or bullae may expand with the relative decrease in pressure inside the cabin (Boyle-Mariotte's law). Microrupture of these lesions may cause air bubbles to embolize to the systemic circulation [3,4].

Our tertiary university hospital is the reference centre for the international airport of the city. Eighteen per cent of the referrals from the airport are neurological problems [1]. We analyzed our five new cases of CAE during commercial flights as well as previously reported cases (Table 1) [5-17]. Patients' data are anonymously presented, following our institution's research committee's recommendations.

**Table 1:** Clinical features of CAE cases during commercial flights reported in scientific literature.

Year	Sex	Age (y)	Past medical history	Previous problems on board	Known thoracic lesions	Onset after takeoff (min)	Clinical symptoms	Thoracic findings	Neuroimaging	Other embolic phenomena	HBO	mRS
1985 [5]	F	19	No	No	No	10-15	LOC	Bulla	Edema	No	No	6
1998 [6]	F	40	No	No	Yes	10	Dyspnea, chest pain, LOC, seizures	Cyst	Edema, infarctions	Skin, CHD	No	6
2004 [7]	M	43	Tobacco, asthma	No	No	20	Dyspnea, LOC, hemiparesis	Cyst	Normal	CHD	Yes	0
2006 [8]	M	71	CHD, AF, APS, DVT	LOC	Yes	Shortly	Chest pain, headache, LOC	Cyst	Bubbles, edema	CHD	No	6
2007 [9]	F	62	No	No	No	20	LOC, hemiparesis, seizures	Cyst	Bubbles, infarctions	CHD	No	4
2009 [10]	M	68	No	Stroke	Yes	30	LOC	Cyst	Bubbles, edema, infarctions	No	Yes	6
2010 [11]	F	62	No	No	No	30	LOC	Bulla	Bubbles, infarctions	No	No	6
2011 [12]	F	52	No	Seizures	No	?	Dyspnea, seizures, LOC	Cyst	Bubbles	CHD	Yes	6
2013 [13]	F	69	No	No	No	Shortly	Aphasia, seizures	Cyst	Bubbles	CHD	Yes	6
2013 [14]	M	69	COPD	No	No	Shortly	Dyspnea, LOC, seizures	Bulla	Bubbles, infarctions, edema	No	No	6
2013 [15]	M	67	Lung cancer surgery	Syncope	Yes	60	LOC	Bulla	Infarctions	No	Yes	3
2014 [16]	F	61	HTN, Ob, Hypercholesterolemia	No	No	30	LOC, hemiparesis	Cyst	Basal CT bubbles; MRI Infarctions	CHD	No	6
2015 [17]	M	58	No	No	No	20	Hemiparesis, dyspnea, chest pain	Bulla, pneumo thorax	Basal CT bubbles; control MRI left MCA infarction	No	No	2
2015 (A)	F	62	Tobacco, TIA	No	No	60	Dyspnea, LOC, seizures	Bulla	Bubbles	No	No	0
2015 (B)	M	47	Tobacco, HTN, Ob, COPD	No	No	120	Dyspnea, LOC, seizures	Bullae	Bubbles, infarction, edema	No	No	6
2015 (C)	M	33	No	Headache, chest pain, dyspnea	Yes	60	Dyspnea, headache, LOC, vision loss, seizures	Bulla, pneumo thorax	Basal CT normal; control CT diffuse edema, hypoperfusion	No	No	2
2015 (D)	M	45	No	No	Yes	120	LOC, vision loss, hemiparesis	Bulla	Basal CT normal; control MRI multiple infarctions	CHD	No	0
2015 (E)	M	37	No	No	No	Shortly	LOC, seizures, hemiparesis	Cyst	Basal CT normal; MRI left cerebellum infarction	No	No	0

## Cases Presentation

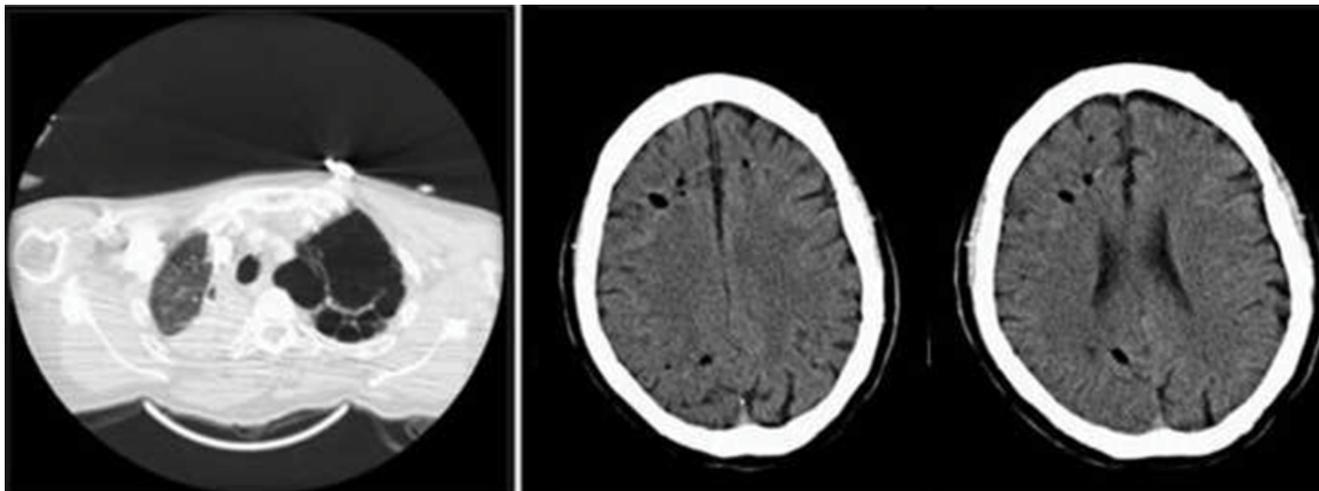
### Case A

A 62-year-old cigarette smoker woman, with history of a transient ischemic attack unrelated to flying, experienced sudden dyspnea and LOC within 60 minutes of a flight. On admission, she was unconscious (Glasgow Coma Scale, GCS, 11), with forced oculocephalic deviation to the right, right central facial palsy, an unintelligible speech, and had a generalized tonic-clonic seizure. Brain CT scan, performed on admission to our Emergency Department (ED), 3 hours after symptoms' onset, showed three subarachnoid bubbles without parenchymal abnormalities, and chest radiograph a

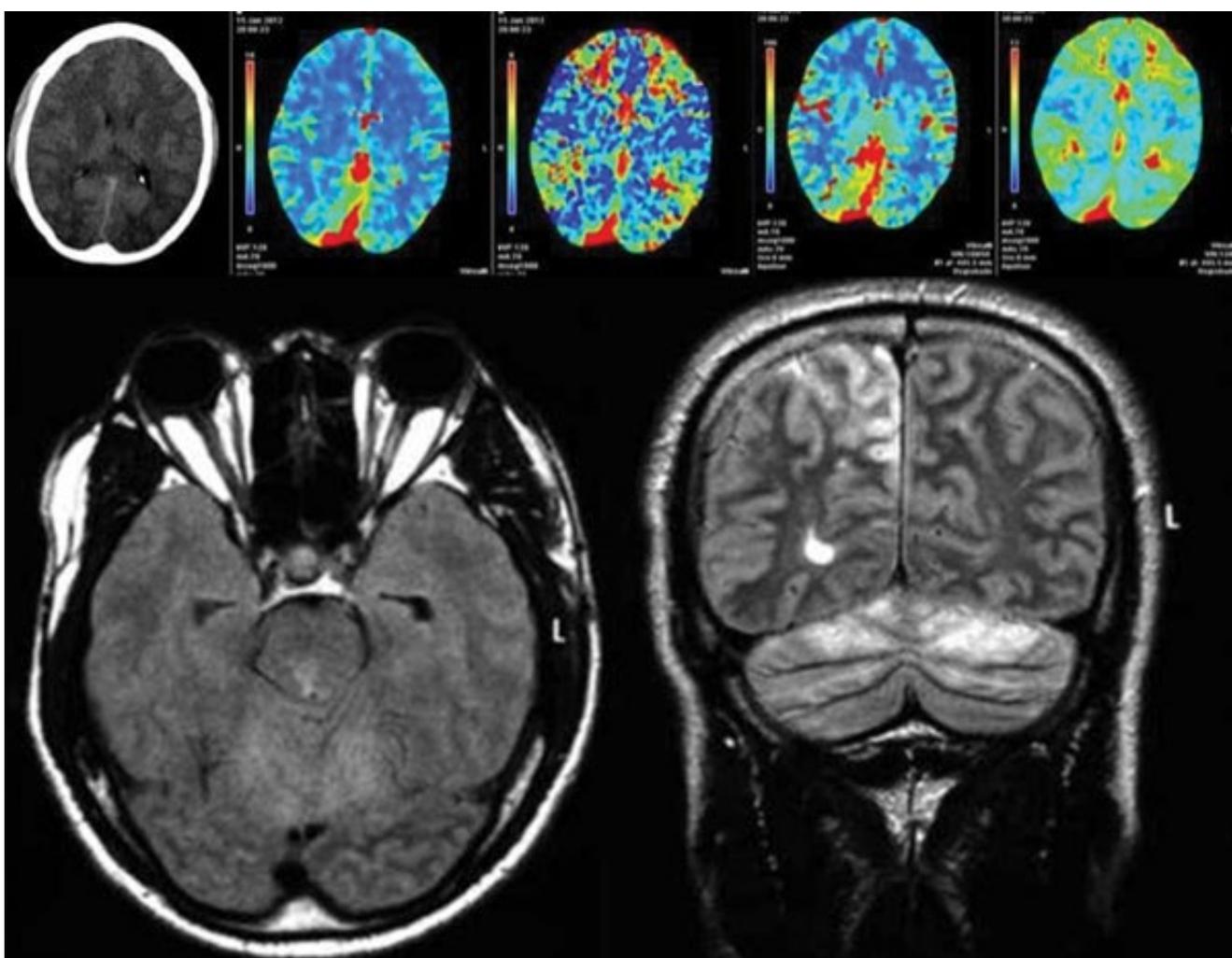
large thoracic bulla of 8 cm. Electrocardiogram (ECG) and transthoracic echocardiogram (TTE, including right to left shunt screening) were normal. A relative contraindication for Hyperbaric Oxygen Therapy (HBO) because of the presence of bullae was considered, and intravenous phenytoin and mechanical ventilation were initiated. A Magnetic Resonance Image (MRI) performed twenty-four hours later was unremarkable. After four days her condition improved; she was discharged without sequelae, with the recommendation of avoiding further air travelling.

### Case B

A 47-year-old man, cigarette smoker with em-



**Figure 1:** Radiologic findings in case B. Plain thoracic CT showing emphysematous bullae on the left lung apex (1a) and plain brain CT showing air bubbles on both cerebral hemispheres (1b,1c).



**Figure 2:** Radiologic findings in case C. Brain CT scan performed 18 hours from the onset showing diffuse edema on both cerebral hemispheres (2a) multimodal CT scan, (2b) cerebral blood volume, (2c) time to peak, (2d) cerebral blood flow, (2e) mean transit time, showed preserved volume with reduced cerebral blood flow and increased transit time, interpreted as global hypoperfusion, FLAIR (2f) and T2 (2g) sequences of initial cranial MRI showing bilateral hyperintensities in right parietal lobe, mesencephalon and cerebellar hemispheres.

physematous chronic obstructive pulmonary disease (COPD), hypertension, hypercholesterolemia, and obesity (OB), experienced sudden dyspnea and progressive LOC in the second hour of a flight. On admis-

sion, he was unconscious (GCS 3), with low oxygen saturation, and had several generalized tonic-clonic seizures. ECG and TTE were normal. Chest CT yielded several apical bullae on the left lung apex and comple-

te atelectasis of the right lung (Figure 1a). Admission brain CT scan, performed three hours after the onset of symptoms, showed multiple intraparenchymal air bubbles in both cerebral hemispheres (Figure 1b and Figure 1c). A relative contraindication for HBO because of the presence of COPD was considered, and supportive treatment with intravenous phenytoin and mechanical ventilation were initiated. Cranial MRI performed twenty-four hours later showed large ischemic areas in both cerebral hemispheres and cerebellum, as well as generalized edema. Progressive deterioration of his neurologic condition and infectious complications led to decease in the sixth week.

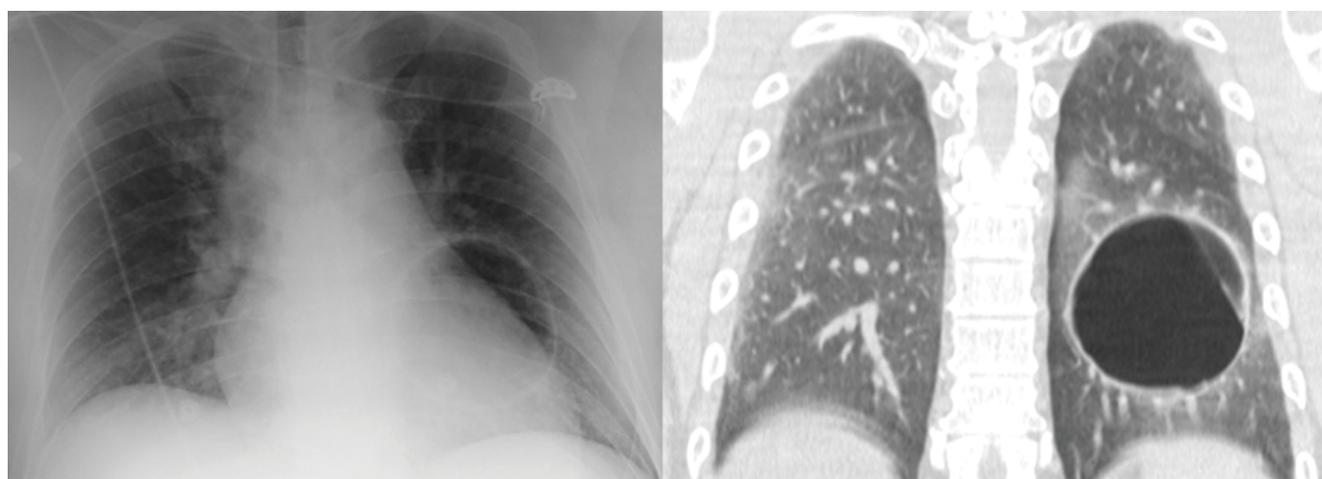
### Case C

A 33-year-old non smoker man had been diagnosed with an emphysematous bulla on the left lung fifteen years ago. Screening for alpha-1antitripsine deficiency was negative and the patient had refused surgery. He had experienced three episodes of dizziness, headache and chest pain early in the course of previous flights. In the current episode, he experienced chest pain, headache, and transient LOC in the first hour of a flight. He was drowsy but responsive, and referred loss of vision in both eyes. On admission, visual examination yielded absence of mirror tracking with preserved response of pupils to light, and temperature was high at 37.5 °C. Chest X ray showed left lung pneumothorax. A plain brain CT scan (six hours after symptoms' onset) was unremarkable. He presented generalized tonic-clonic seizures, followed by severe agitation, which led to sedation, treatment with phenytoin, mechanical ventilation and placement of a thoracic tube. Chest CT scan showed multilobar pneumonia of the right lung and massive left lung pneumothorax. A multimodal CT (eighteen hours after symptom onset) disclosed diffuse brain edema and generalized hypoperfusion, with normal angiography. MRI performed on the 3rd day of admission showed bilateral hyperintense lesions in T2 and FLAIR sequences in parietal and occipital lobes, cerebellum, pons and

medulla (Figure 2). These abnormalities were consistent with endothelial damage due to posterior circulation diffuse cerebral air embolism. HBO was contraindicated because of the presence of pneumothorax. After fifteen days he gradually improved. Control MRI performed one month later showed near resolution of the abnormalities, with two foci of abnormal signal in subcortical right parietal lobe and left cerebellar hemisphere. He was discharged with mild ataxia of the left upper limb, on antiepileptic therapy, and advised not to travel by plane until his left pulmonary bulla was surgically treated.

### Case D

A 45-year-old non smoker man, diagnosed of a small left lung cyst ten years ago, experienced LOC, visual loss and right hemiparesis during a commercial flight two hours after takeoff. On admission, one hour later, he was drowsy but responsive, disorientated, with incoherent speech. He had right hemiparesis (3+1 in the National Institute of Health Stroke Scale -NIHSS-) and referred loss of vision in both eyes. Temperature was 36 °C. Chest radiograph showed a left lung cavity (Figure 3a). Plain brain CT scan and CT angiogram of circle of Willis (3.5 hours after symptoms' onset) were both unremarkable. He received intravenous recombinant tissue plasminogen activator (rTPA) upon the initial diagnosis of posterior territory acute stroke, and was then admitted to the Stroke Unit. Along the following twenty-four hours, level of consciousness, orientation, speech, strength and vision improved. Thoracic CT scan showed a giant bulla on the left lung (Figure 3b). Diffusion-weighted MRI of the brain (twenty-four hours after symptom onset) showed small acute infarctions in multiple locations: left frontal subcortical semioval centre, bilateral cortical parasagittal prerolandic areas and bilateral occipital cortex. Gadolinium-enhanced MRI also showed diffuse patchy frontal, parietal and occipital leptomeningeal enhancement. Troponin T levels were 2.1 ng/ml on admission (normal values < 0.5 ng/ml) and normalized within the following 6 hours.



**Figure 3:** Radiologic findings in case D. Chest radiograph showed a left lung cavity (3a) and plain thoracic CT showed a giant bulla on the left lung (3b).

EKG and TTE were normal and there were no clinical symptoms of heart disease or deep venous thrombosis (DVT). EEG showed unspecific diffuse encephalopathy and CSF analysis was unremarkable. He was discharged four days later, asymptomatic. Thoracic surgery was organized as an outpatient and he was advised not to travel by plane until his bulla was surgically treated.

### Case E

A 37-year-old male experienced LOC and seizures during a commercial flight soon after takeoff. On admission, he was drowsy but able to follow commands, and had left hemiparesis. Temperature was 36 °C. Chest radiograph showed a right lung cavity. Plain brain CT scan (performed four hours after the onset of symptoms) was unremarkable. He was admitted to the Intensive Care Unit due to LOC, where he also suffered several tonic clonic seizures. He received antiepileptic treatment with intravenous valproic acid and phenytoin, with good response. Thoracic CT scan showed a cyst on the right lung. MRI of the brain, performed forty-eight hours after symptom onset, showed an acute infarction on the left cerebellum. EEG and CSF analysis were both unremarkable. On the third day of admission he was transferred to the Department of Neurology where he experienced good recovery. He was discharged eight days later, asymptomatic. Surgery of the cyst was arranged as an outpatient, advising not to travel by plane until his lung lesion was removed.

### Discussion

CAE is increasingly recognized as an infrequent but serious complication of commercial flights. With our five cases, the number of patients reported rises to eighteen [5-17] (Table 1). Middle age travelers (mean age 53.6 years, range 19-71), most of them without known pulmonary disease, were affected.

Onset of symptoms early in the flight was common. There was LOC in all patients, seizures in nine, and focal neurological signs in eight (hemiparesis, aphasia, vision loss), as well as accompanying respiratory symptoms (dyspnea, chest pain) in nine. In 8 cases (6-9, 12, 13, 16, D), patients experienced embolic phenomena in other locations, mainly coronary heart disease.

Except for four cases with normal basal neuroimaging [7, Case C, D, E], CT and MRI scans showed bubbles (either within the parenchyma or the subarachnoid space), edema and/or infarctions. Bubbles were only seen in early performed CT scans, and may be missed in late CT scans, as in our cases C-E and other cases previously reported [5-7,15]. Ten patients died and two remained moderate-severely disabled. Six patients had a complete or near complete recovery: in all of them infarctions, edema and intraparenchymal bubbles were absent on admission CT neuroimaging [Case A, C, D, E, 7, 17]. The presence of these abnormalities in early

performed neuroimaging may thus be an unfavorable prognostic factor. Subarachnoid bubbles seen in early performed CT scans, however, were not related with bad prognosis [Case A, 17]. On the other hand, absence of intraparenchymal bubbles alone did not guarantee a good prognosis [5,6,15], since the presence of bubbles may also be related with the timing of initial neuroimaging.

Interestingly, multimodal CT in one of our patients (Case C), and also in a previously reported patient [12], showed global hypoperfusion without angiographic abnormalities. Furthermore, the MRI of Case D showed small acute strokes in multiple cerebral locations, without any arterial obstruction, as well as diffuse leptomeningeal enhancement. All these findings are probably related to diffuse endothelial damage.

Hyperbaric Oxygen (HBO) therapy was applied only in five cases [7,10,12,13,15]. In our patients, a relative (Cases A, B, D, E) or absolute (Case C) contraindication for HBO, were the reasons for withholding this therapy. In the remaining, the reasons were unavailability [6], worsening of the patient's condition [8,9,14], diagnosis delay [16], and were not reported in four [5,11,17]. HBO is considered beneficial in air embolism. However, its most feared complications include rupture of air-filled cavities due to changes in pressure, pneumothorax and systemic air embolism. HBO may then be rejected in presence of thoracic cysts and severe lung disease. Thus, given CAE in patients with thoracic bullae during air travelling is a rare condition, it lacks evidence of HBO's efficacy and security in this specific setting [18,19].

It is also noteworthy that five patients [Case C, 8, 10, 12, 15] had experienced neurological problems (LOC, stroke, seizures, syncope, headache) in previous flights, and six patients had been previously diagnosed with thoracic lesions [Case C, D, 6, 8, 10, 15]. Three patients did not survive the latter event of CAE [8,10,12] and one remained severely impaired [15].

This underscores the importance of ruling out CAE in passengers with neurological problems on board, especially when the onset is early in the flight and LOC and respiratory symptoms occur.

The demonstration of thoracic cysts or bullae, as well as the presence of bubbles, edema and infarctions in neuroimaging, help confirm diagnosis. Although the outcome is generally poor, the absence of edema and intraparenchymal abnormalities in basal neuroimaging may indicate a better prognosis.

As thoracic cystic lesions bear an uncertain risk for CAE, it may be advisable to discourage individuals with known thoracic cysts or bullae from air traveling, at least until these lesions are surgically treated.

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and take responsibility for the integrity and accuracy of the data. All authors contributed substantially to the work to take responsibility for the content and have read and approved the final version of the manuscript.

## Conflict of Interest

This study was not industry-sponsored. The authors have no conflicts of interest or disclosures to report.

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