



## Case report

# The effective use of hyperbaric oxygen therapy (HBOT) in the management of air embolism – rare and potentially fatal acute complication of hemodialysis

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## ABSTRACT

**Introduction:** Air embolism is a rare and potentially fatal acute complication. Its causes are mainly iatrogenic. It requires rapid diagnostics and treatment, including hyperbaric oxygen therapy (HBOT).

**Aim:** The main aim was to present the potential causes of air embolism during hemodialysis (HD) and show the importance of quick clinical diagnosis and therapy – on the base of clinical case.

**Case study:** 65-years old male patient with diabetic nephropathy was treated with HD. The permanent dialysis catheters were used as vascular access due to the difficulties with formation of arteriovenous fistula. The massive air embolism occurred during one of the dialysis sessions. The clinical suspicion was confirmed by CT scan which showed the presence of gas bubbles in abdominal arteries. The cause of air embolism was sensor failure. The presence of patent foramen ovale (PFO) with reversed leakage caused the air ingress into arterial system. Patient was qualified for the immediate hyperbaric therapy. The quick improvement in the condition of the patient took place.

**Results and discussion:** The massive air embolism may occur in HD patients, particularly in those who are dialyzed with use of catheters as vascular access. This rare complication should be considered in the case of sudden worsening of patient condition during HD procedure. The use of CT scan to confirm the air embolism suspicion and availability of HBOT are necessary for successful management of this complication.

**Conclusions:** HBOT is a safe and effective method of air embolism treatment in HD patients.

## 1. INTRODUCTION

Air embolism is a rare and potentially fatal acute complication. The quick diagnosis and proper treatment may bring spectacular therapeutic effects.<sup>1</sup> The diagnosis of massive air embolism is usually established on the base of anamnesis and clinical picture. The initial diagnosis is established on the basis of a sudden hemodynamic disorders in patient treated with medical procedures connected with potential risk of ingress of air into arteries and veins. Air embolism may occur in various medical conditions. Its cause is mainly iatrogenic – including the implantation, removal or use central catheters for hemodialysis, other implantable devices, surgical and radiological procedures, biopsy or barotrauma.<sup>2,3</sup> The initial treatment includes the administration of high flow oxygen and placing patient in the proper position. If a venous air embolism is suspected, the patient should be placed in Trendelenburg and left lateral decubitus position (known as Durant's maneuver). However, in cases of arterial gas embolism patients should remain in supine position while Durant's maneuver or Trendelenburg position is not recommended.<sup>3,4</sup> One of the therapeutic options to be used in massive air embolism cases is hyperbaric oxygen therapy (HBOT).

## 2. AIM

The rare case of massive air embolism of abdominal vessels that occurred during hemodialysis and was treated with HBOT is presented in the article. The main aim was to show the crucial importance of quick clinical diagnosis of air embolism, using the adequate medical imaging method to confirm the diagnosis and considering the HBOT.

## 3. CASE STUDY

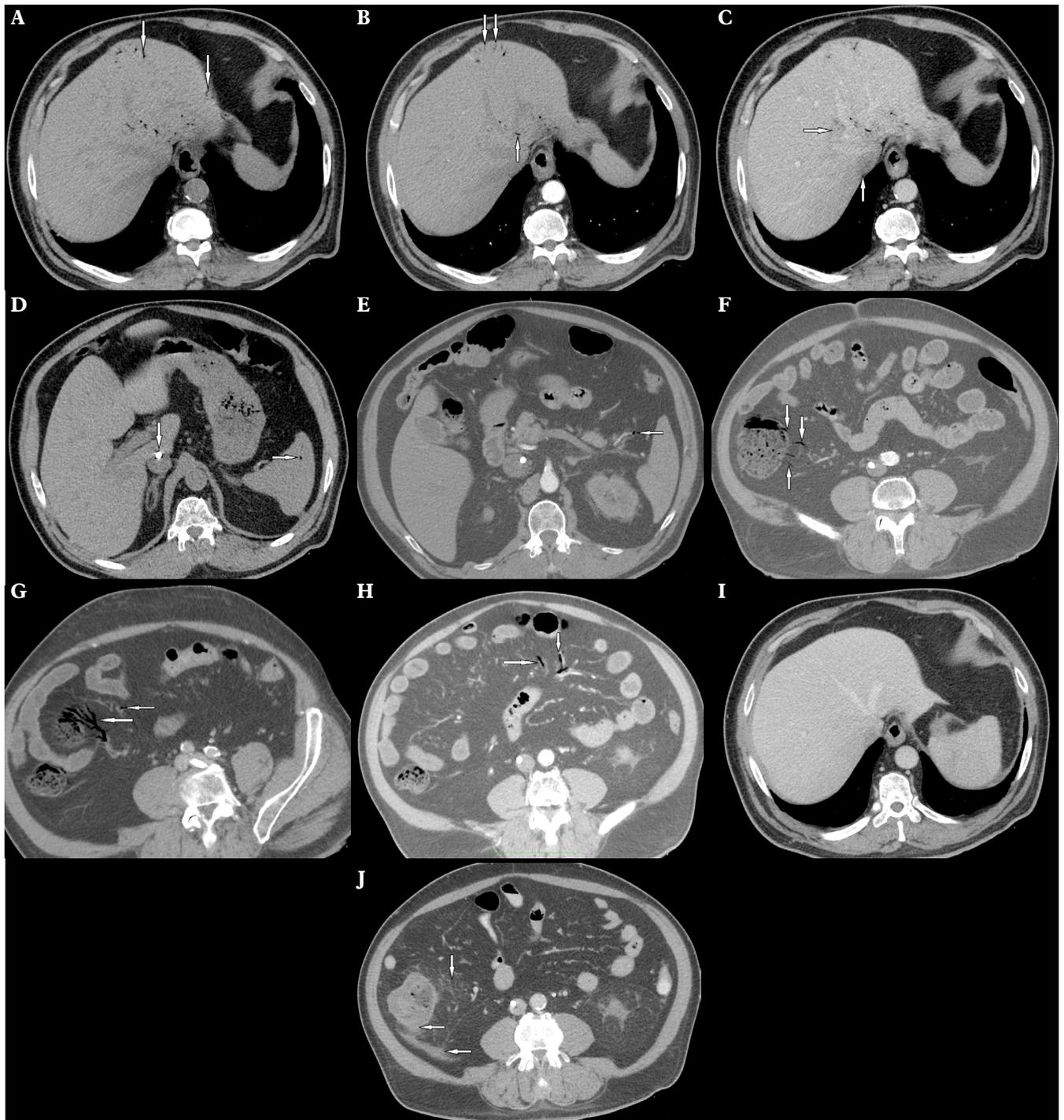
The patient, 65-year old male, with diabetic nephropathy was treated with hemodialysis (HD) for 16 months. The permanent dialysis catheters (inserted into the left femoral vein) were used as vascular access due to the difficulties with formation of arteriovenous fistula.

The sudden severe, diffuse abdominal pain radiating to the lumbar region, accompanied by nausea and retching occurred at the beginning of HD procedure. The decrease of systemic blood pressure (BP) from 123/60 mm Hg to 94/46 mm Hg and low oxygen saturation – 80% were observed. The immediate modification of HD parameters (blood flow reduction, stopping the water removal), oxygen therapy, crystalloids and colloids infusions didn't improve the patient's condition. Therefore, an air embolism was suspected. The thoracic and abdominal computed tomography (CT) scan with contrast was performed immediately and confirmed the clinical suspicion. It showed the presence of gas bubbles in the splenic artery terminal branches, splenic parenchyma, hepatic interlobular vessels and mesenteric vessels of the small intestine and cecum (Figures 1A–1H). The immedi-

ate HBOT performed according to US Navy Profile Table 5 was introduced. The therapeutic protocol included the use of 2.8 atmosphere absolute pressure equal to the 18 m of water column value. The hyperbaric oxygenation was performed in the intensive therapy mode with use of 100% oxygen in inspired mixture. The whole treatment lasted 108 minutes. After 10 minutes patient reported complete resolution of abdominal pain lasting until the end of treatment. The clinical improvement was accompanied by normalization of BP and oxygen saturation. The follow-up CT scan performed 12 h after the HBOT didn't show any air embolism. The hepatic perfusion improved significantly. No abnormalities in the small intestine wall were observed. However, the cecum wall oedema and inflammatory lesions of the visceral fat tissue next to the caecum with a small fluid collection were found (Figures 1I and 1J). The highly probable reversed leakage through patent foramen ovale (PFO) was shown in transthoracic echocardiography and confirmed by transesophageal echocardiography (PFO was diagnosed after gas embolism). The technical inspection of artificial kidney machine revealed sensor failure that was identified as a cause of displacement of residual air from dialyzer into the circulatory system. After leaving hospital patient returned to the regular ambulatory dialysis program.

## 4. DISCUSSION

The dialysis center is very specific medical treatment facility. HDs are usually performed as out-patient procedures. The HD schedule comprise usually three (in some cases two) dialysis sessions per week – each of them lasting normally about 4 h. The transport of patients to the dialysis center and back home – after each dialysis session is also provided as an element of HD care. Throughout the dialysis session patient remains under permanent medical supervision. However, the equipment of dialysis center is designed strictly for renal replacement therapy needs. In all cases of sudden severe and life-threatening complications, the rescue procedures are immediately applied and after the stabilization of medical condition patient is transported to the hospital emergency department to continue advanced diagnostic and therapeutic procedures. The common complications observed throughout HD procedure include: increase or decrease in BP, muscle cramps or bleeding from the access site.<sup>1</sup> Less frequent are: itching, headache, nausea, vomiting, fever or dialyzer first-use syndrome.<sup>1</sup> The air embolism, known also as gas embolism, is potentially fatal acute, non-inflammatory HD complication.<sup>1</sup> The available literature does not contain precise data about the incidence of this complication but we may assume that it is relatively rare.<sup>5</sup> Etiopathogenesis of this complication is connected with the ingress of embolic material (air in this case) into the veins and from veins – dependently on anatomic conditions and physical characteristics of this material – into other parts of the circulatory system. Blocking the right atrium, right ventricle and pulmonary arteries with embolic



**Figure 1.** An abdominal CT. Gas bubbles in the peripheral parts of the liver parenchyma in interlobular veins, marked with arrows in Figures A and B: (A) An abdominal CT, native phase – without contrast enhancement; (B) An abdominal CT with contrast enhancement, early phase (angio); (C) An abdominal CT with contrast enhancement, portal vein phase. Arrows indicate hepatic parenchymal perfusion disorders; (D) A gas bubble in the spleen parenchyma (horizontal arrow). The vertical arrow indicates the dialysis catheter in IVC, native phase; (E) A gas bubble in the small branch of the spleen (arrow). CT of the abdomen after contrast enhancement, arterial phase; (F) A gas embolism in the small arteries of the caecum (arrows). Examination after contrast enhancement, arterial phase; (G) A gas embolism in the venous vessels of the caecum (arrows), portal vein phase. Multiplanar reconstruction; (H) A gas embolism in the small mesentery veins of the jejunum (arrows). Arterial phase, multiplanar reconstruction. Control CT scan of the abdominal cavity 12 h after decompression; (I) No gas bubbles in the liver vessels. Homogeneous enhancement of the liver parenchyma, portal vein phase; (J) No gas embolism in the caecum vessels. Inflammatory lesions of the visceral fat tissue next to the caecum with a small fluid collection.

material causes acute cardiovascular dysfunction – including cardiac arrest.<sup>6</sup>

The modern artificial kidneys element – normally preventing from air embolism – is the air bubble sensor and deaerator. The still existing risk factors of air embolism are: central catheter as HDs vascular access and performing of HD procedures with high speed of blood pump causing high and turbulent blood flow and generating negative pressure in venous system that enables sucking the atmospheric air.<sup>7</sup> Other risk factors include leaky connection of needle and blood tubing, use of outdated HD equipment and unlicensed blood drain lines or malpractice during HD resulting from low level of medical personnel training. Additionally, dehydration, hypervolemia, expansion of blood vessels may contribute to the occurrence of air embolism.<sup>8</sup> The main air embolism risk factor in our patient was the use of permanent catheter as HD vascular access that resulted from the lack of possibility to create arterio-venous fistula due to advanced atherosclerosis connected with the underlying disease. Additionally, the patient was an advanced age male with long history of diabetes type 2 and multi-organ chronic complications, including diabetic nephropathy.<sup>8</sup> However, the real cause of air embolism was sensor failure that took place in the presented case and residual air got from dialyzer into the circulatory system. The presence of PFO with reversed leakage caused the air ingress into arterial system.

The commonly accepted standard diagnostic procedure is CT scan with contrast which is performed to find gas bubbles that may be present mainly intravascularly. It is available, sensitive and specific imaging examination that enables a quick confirmation of the clinical suspicion.<sup>4</sup> In the presented case the presence of gas bubbles was confirmed in the splenic artery, splenic parenchyma, hepatic interlobular vessels and mesenteric vessels. It is a rare location of air embolism which may be found rather in the venous compartment. The entrance of air bubbles into the arteries should raise suspicion of crossed embolism (paradoxical embolism). The cardiac shunt – PFO in most cases, may contribute to the occurrence of paradoxical embolism.<sup>9</sup>

The therapeutic algorithm in air embolism cases occurring during HD includes a couple of important elements. The HD procedure should be stopped immediately and the blood should be left in the extracorporeal circulation lines. It is important to place patient in Trendelenburg position (the body is laid supine, or flat on the back on a 15°–30° incline with the feet elevated above the head) to reduce the risk of entrance of foamed air into heart cavities and brain vessels that may result in blocked blood flow in these areas.<sup>10</sup> The next step is to start passive oxygen therapy using oxygen mask or nasal cannula and to reach hemodynamic stabilization using intravenous fluids and pressor amines.<sup>11</sup> All of the actions listed above were performed in our Dialysis Center and continued in the Hospital Emergency Ward.

In the recent years we may observe the growing importance of the therapy comprising hyperbaric procedures.<sup>12,13</sup> Oxygen therapy with the use of 100% oxygen and adequate-

ly increased pressure is aimed at reducing the size of the air bubble by increasing their solubility and makes vast gradient displacing nitrogen from air bubbles. As a result, it reduces their size and degree of mechanical obstruction. Moreover, high arterial oxygen tension improves its delivery to affected organs and ameliorates tissue ischemia. It also provides the improvement of tissue oxygenation. The HBOT is widely used in cases of diving accidents for many years. It is key element of prophylactics and treatment of caisson disease which is connected with the formation and release of intravascular nitrogen bubbles. The treatment in a hyperbaric chamber is rarely used in the cases of HD patients with air embolism which results from low incidence of this complication as well as low availability of hyperbaric procedures in the rescue system. Taking into account the resolution of clinical symptoms and improvements in radiological findings the presented case should be recognized as a therapeutic success.

## 5. CONCLUSIONS

Air embolism is a rare but potentially fatal complication of extracorporeal renal replacement therapies. The case presented in this article confirms the potential benefits and safety of HBOT as a method used in such situations. The early implementation of HBOT may contribute to the improvement of treatment results and mortality reduction in this group of patients.

### Conflict of interest

We hereby declare that there is no conflict of interest.

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### Ethics

Informed patient consent was obtained.

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