Electrocardiogram and X-ray findings associated with iatrogenic pulmonary venous gas embolism

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ABSTRACT

Iatrogenic venous gas embolism (VGE) has been described in cases of patients with hemodialysis catheters and other thoracic central lines. When VGE is present, it may lead to large gas bubbles in the right heart or pulmonary circulation. We reviewed a case of a 52-year-old male hemodialysis patient who inadvertently received an unknown amount of air through a faulty connection in his line during hemodialysis treatment. The patient was symptomatic with chest pain and was found to have an ECG indicative of acute right heart strain and an unusual bulging of his right mediastinum on X-ray. An emergency consult was called for hyperbaric oxygen therapy (HBO₂T) due to the known indications for therapy. The patient had a full recovery after HBO₂T and had complete relief of his chest pain after compression. Repeat decubitus chest X-ray and ECG post-HBO₂T showed resolution of the mediastinal bulge, and ECG had reverted to the patient’s baseline tracing.

Iatrogenic pulmonary VGE may be diagnosed with the aid of ECG and X-ray findings when correlated with historical and other clinical elements. HBO₂ treatment success may be correlated with reversal of ECG and X-ray findings in patients with clinical improvement.

INTRODUCTION

Iatrogenic venous gas embolism (VGE) is known to occur in approximately 2.65 per 100,000 hospitalized patients [1] and has a one-year mortality of over 20% to 50% [1,2]. Significant VGE may lead to ventilation-perfusion mismatch, right heart strain, pulmonary hypertension, myocardial ischemia and arrhythmias [3,4]. The severity of this medical complication is such that, despite its relatively rare occurrence rate, it has garnered the attention of the Centers for Medicare & Medicaid Services [5].

Venous gas embolism is a known – and feared – complication of the placement, use, and removal of central venous catheters [6-11]. In a recently published cohort study from the Raymond Poincare Hospital, University of Versailles in France, central venous lines caused around a quarter of all iatrogenic gas emboli [1]. This complication has been well known for many years [6-9] and can be associated with pulmonary VGE [7] as well as paradoxical cerebral air embolism [8], in cases where venous blood is shunted to the arterial circulation, forming a resultant arterial gas embolism (AGE). Venous gas embolism can lead to significant life-threatening complications [12, 13], even when the condition is known and aggressively managed [1].

Iatrogenic VGE is one of the recognized indications for hyperbaric oxygen therapy (HBO₂T) [13]. A number of case reports describing the successful use of HBO₂T for venous air embolism are present in the literature [6, 14-18]. When a patient presents with an acute venous gas embolism, it is appropriate to obtain emergent consultation for consideration of HBO₂T for treatment of potential complications of VGE, and due to the potential for shunting that could result in a significant AGE.

CASE REPORT

A 52-year-old hemodialysis patient presented to the emergency department (ED) after he was found to have been infused with an unknown amount of air during dialysis. His dual lumen central venous dialysis catheter connection was noted to be leaking and drawing air. The dialysis unit staff noted this when the patient complained of a tightness in his chest. Dialysis was stopped and the patient presented for emergency evaluation via EMS transport to the ED. The patient reported that his chest discomfort had lessened significantly prior to arrival.

The patient was placed in the left lateral decubitus position in an effort to prevent air from entering the right ventricular outflow tract and lessen the potential for...
paradoxical arterial gas embolism (AGE) via occult intracardiac shunt.

Vital signs were found to be in the normal ranges. Physical examination did not reveal a “millwheel murmur” or other findings of significant cardiovascular collapse. Electrocardiogram (Image 2, facing page) and chest X-ray (Image 4, Page 105) were obtained, and an emergent bedside transthoracic echocardiogram was requested. The left decubitus chest X-ray was read by the radiology unit and noted to have atelectasis. However, emergency physicians noted a bulge on the right side of the mediastinum that they deemed as concerning for a possible sign of air embolism.

The ECG was compared to a previous tracing (Image 1, above) and revealed new findings of right-axis deviation and poor r-wave progression when compared to previous ECGs for this patient.

This was considered to correlate with acute right heart strain, presumably secondary to pulmonary venous gas embolism (VGE). Bedside transthoracic echocardiogram (no available images) failed to identify any significant gas embolus but was limited by positioning and body habitus. Both computed tomography and transesophageal echocardiogram were considered as possible additional diagnostic modalities but were not obtained in this case.

The Hyperbaric Medicine service was consulted, and the patient was deemed to have no significant contraindications to hyperbaric oxygen treatment (HBO₂T). The decision was made to proceed to HBO₂T based on clinical history and signs of right heart strain on ECG. The patient was treated in a Sechrist 3200a monoplace chamber for only part of a planned 90-minute treatment due to the patient’s inability to tolerate the confined space. He received a total of 35 minutes of bottom time at 2.8 atmospheres absolute (ATA), without air break, prior to being brought back to surface pressure and removed from the chamber without incident. The patient reported complete resolution of his symptoms.

The patient was returned to the ED after HBO₂T for re-evaluation and disposition. The emergency physicians repeated the decubitus chest X-ray and ECG post-HBO₂T and noted that the mediastinal bulge had resolved (Image 5, Page 105), and the ECG (Image 3, Page 104) had reverted to the patient’s baseline tracing.
The diagnosis of iatrogenic pulmonary VGE was confirmed by the resolution of clinical and diagnostic findings.

**DISCUSSION**

The case described above poses many unique and interesting facets related to the management of patients with iatrogenic VGE. Although the patient did not arrive with significant signs of distress, and there were no significant abnormalities of vital signs or physical examination findings, the patient had ECG and X-ray findings consistent with physiologically important VGE.

In order to attempt to further elucidate the importance of these findings, a literature search was performed utilizing both PubMed (http://www.ncbi.nlm.nih.gov/pubmed) and Google Scholar (http://scholar.google.com). One case was identified in the literature that describes the presence of ECG findings associated with VGE, but the two are not directly comparable, as the case is represented by a 3-lead tracing rather than a 12-lead ECG and relates only to r-wave changes [19]. X-ray findings of air embolism have been described [20-22], but are unlike the mediastinal findings noted in our case. The following discussion includes details relating to ECG and X-ray findings associated with VGE as well as other diagnostic and treatment considerations.

**Electrocardiogram**

Signs of acute right heart strain on a 12-lead electrocardiogram include right-axis deviation, which is noted on the pre-HBO\textsubscript{2}T ECG (Image 2). However, absent from this tracing are any of the other findings classically associated with right heart strain [23]. In review of known ECG findings of pulmonary embolism from
thrombosis, it is notable that the pathologic findings of S1, Q3, T3, right-sided conduction delay and prominent p-waves in the inferior leads, are not present here.

The ECG finding of acute loss of r-wave progression in the precordial leads is noted in the ECG from this case during the symptomatic phase and resolved after treatment. This is consistent with acute right ventricular overload and possible transient right ventricular dilatation from pulmonary VGE [24]. The loss of r-wave progression on ECG can also be attributed to several chronic diagnoses [25]; however, these are not suspected here. Although lead position changes are a possible explanation of the loss of r-wave progression, this is unlikely due to the authors’ own observations of the technique used to obtain the tracings. One other case of r-wave changes was found in the literature [19], in which loss of inferior lead r-waves was noted just prior to decompensation of a patient undergoing femoral hemiarthroplasty with bone cementation. In that case, no complete 12-lead tracing was obtained, and no direct comparison can be made. Other cases of ECG changes in the literature describe infarctions from gas embolism and relate almost exclusively to the documentation of ST segment changes due to coronary artery embolism [26-29], and are not noted in this case.

X-ray

Literature review revealed no other cases of similar mediastinal distortion secondary to VGE. Alternatively, several other findings have been described on chest film relating to the finding of VGE [11,20-22]. These include bell-shaped air collections in the pulmonary arteries, focal oliguria, enlargement of the pulmonary arteries or
Upper mediastinum, and intracardiac air. Other less specific findings may include pulmonary edema and atelectasis. It is also important to note that patients with significant VGE may present with a normal chest X-ray. The right-sided mediastinal distortion noted in this case may be consistent with previously described upper mediastinal widening, in that this patient was in the left lateral decubitus position, whereas others seemed to be described in patients in the upright position. This difference in positioning may account for lack of movement of the pulmonary VGE from the proximal pulmonary arterial truck.

**Echocardiography**

Other diagnostic modalities for the confirmation of cardiac and pulmonary VGE include computed tomography (CT) and echocardiogram. Transthoracic echocardiogram (TTE) is more readily available in the ED setting and does not require sedation. Transesophageal echocardiogram, or TEE, may be more sensitive due to the improved view provided by the transesophageal window. However, TEE requires sedation and possibly more preparation time.
The use of bedside TTE has been described for the diagnosis of VGE [30]. Expected findings include dilation of the pulmonary artery and right ventricle. Air may not be directly visualized depending on positioning and body habitus. The sensitivity of TTE and TEE are not well known for detection of pulmonary VGE. In the reported case, TEE was thought to be inconclusive due to difficulties related to body habitus and the positioning of the patient. Further study to ascertain the sensitivity of this test in iatrogenic VGE is needed.

Computed tomography
Computed tomography (CT) scanning is a potential diagnostic tool available in most settings for the evaluation of a patient for presence of a moderate to large venous gas embolism. CT has been used to diagnose intracardiac air in cases presented in the literature [31,32]. However, it is unknown how sensitive CT is for symptomatic patients with VGE. Air in the right ventricle estimated at 120 mL was noted in one case of a patient who survived and was asymptomatic after combined invasive aspiration of air and hyperbaric oxygen therapy [31]. In the case described above, it was felt that the patient would not benefit from further diagnostics that would also lead to further delays in therapy. As with TEE, further study is needed to illustrate the sensitivity of CT for VGE.

Treatment
Initial management of patients with suspected VGE includes positioning patients in the left lateral decubitus position with the head down and providing 100% oxygen by non-rebreather [12]. These measures are aimed at reduction of gas bubble size and containment of the bubble(s) to the right side of the heart. Invasive removal of gas by insertion of a thoracic central venous catheter is also an option [31] and has the potential to remove a significant volume of gas if accessible at the tip of the catheter. In cases of ventilatory failure, intubation and mechanical ventilation is necessary. Increases in intrathoracic pressure and paO₂ may hasten reduction in VGE size. Circulatory collapse may require pressure support and volume resuscitation.

Hyperbaric oxygen therapy is almost always indicated in cases of significant arterial gas embolism, including cases where paroxysmal cerebral gas embolism from VGE is suspected. However, VGE may not require HBO₂T in patients who are asymptomatic [12]. The exception to this may be in cases where the patient has coexisting pulmonary edema that may be related to the VGE, despite a lack of significant symptoms. Multiple HBO₂T tables are published in the literature for management of gas embolism with seemingly little consensus [1]. The patient described in this case responded well to only a short course of HBO₂T at 2.8 ATA.

Conclusion
Hemodialysis-associated pulmonary venous gas embolism is a potentially life-threatening complication that should be considered an indication for emergency hyperbaric oxygen therapy in patients who are unstable, resistant to other means of resuscitation, or showing signs of right heart strain. The pathologic effects of pulmonary VGE may be subtle, but may manifest as right-axis deviation, poor r-wave progression or other findings of right heart strain on ECG. Left lateral decubitus X-ray films may reveal reversible bulging of the right mediastinum, even when bedside transthoracic echocardiogram is unable to detect air in the right ventricle. If present, these ECG and X-ray findings may be reversed by the elimination of the VGE during HBO₂T.

Despite the uncertainty concerning the sensitivity of ECG and X-ray findings for this diagnosis, in the correct clinical setting, these findings support the diagnosis of venous gas embolism, and treatment success may be correlated with reversal of ECG and X-ray findings in patients with clinical improvement. Further study of these findings is required to confirm their sensitivity as diagnostic markers for VGE. Further study of CT and TEE is also warranted to determine their utility in detection of this potentially life-threatening complication.

REFERENCES


