Massive Venous Air Embolism during Orthotopic Liver Transplantation

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Although venous air embolism is cited as a complication of orthotopic liver transplant, there is no documented case reported of air embolism after adequate perfusion (flushing) of the liver. This case is the first such documentation of massive air embolism during liver transplantation.

CASE REPORT

A 40-yr-old 65-kg woman with chronic non-A, non-B hepatitis was admitted for liver transplantation. Four years prior to admission she had an episode of bleeding from esophageal varices, and soon thereafter underwent an end-to-side portocaval shunt. She had no history of significant cardiopulmonary disease.

Immediately prior to surgery her coagulation studies were: PT 14.8 s, FTT 40.7 s, fibrinogen 88 mg/dl, platelets 78,000/mm³. Her hematocrit was 28%. Arterial blood gas while breathing room air was PaO₂ 102 mmHg, PaCO₂ 31 mmHg, pH 7.44. Pulmonary function tests revealed FEV₁ of 2.7 l and FVC of 3.4 l. Electrocardiogram and echocardiography were within normal limits.

In anticipation of large blood requirements because of her coagulopathy and prior portocaval shunt, two 14-G iv catheters, a 20-G radial artery catheter, a pulmonary artery catheter (aia 8.5-Fr introducer), and a right internal jugular 14 Fr USCI® venous cannula were inserted. This last catheter was connected directly to a rapid transfusion device.

Rapid sequence induction of anesthesia using 3 mg d-tubocurare, 275 mg thiopental, and 100 mg succinylcholine was followed with 5 mg midazolam and 15 mg morphine sulfate. Anesthesia was maintained with isoflurane and muscle paralysis was accomplished with pancuronium.

Vital signs were stable throughout the dissection phase of surgery. Veno-venous bypass is not used in our institution, so that at the time the liver vasculature was clamped, there was an expected decrease in systemic blood pressure as well as central filling pressures. The patient required dopamine at 10 μg·kg⁻¹·min⁻¹ to maintain a systolic blood pressure of 90 mmHg during the anhepatic stage, which lasted 50 min. Prior to removing the suprahepatic caval clamp the portal venous clamp was opened, the liver was perfused, and the venous effluent allowed to drain through a small defect in the incomplete infrahepatic anastomosis. Adequacy of hepatic perfusion was assessed visually: the liver was perfused until it reached a uniform color (about 45 s). The portal clamp was then reapplied, closure of the anterior wall of the inferior vena cava was completed, and the portal, suprahepatic, and infrahepatic clamps were removed.

Within 2 min after removal of the vena cava clamps the CVP was noted to increase suddenly from 13-30 mmHg. Pulmonary arterial diastolic pressure rose simultaneously from 9-24 mmHg. The surgeons noted hepatic congestion, consistent with right ventricular failure. Systemic arterial pressure decreased and was treated with two neosynephrine boluses (100 μg each); dopamine was increased to 18 μg·kg⁻¹·min⁻¹. An attempt was made to remove fluid from the central circulation by allowing blood from the internal jugular catheter to drain from the patient into a heparinized collection bag. The patient's systemic blood pressure decreased with this intervention, and so the drained blood was returned to the patient. An arterial blood gas during the acute event showed a PaO₂ 72 mmHg, PaCO₂ 53 mmHg and pH 7.17. At the time hemoglobin saturation was 100% by oximetry. (During the anhepatic phase ABG showed PaO₂ 312 mmHg, PaCO₂ 32 mmHg, pH 7.35 with the same ventilator settings with gas flows of 2 l O₂ and 2 l air.) The patient was treated further with sodium bicarbonate, CaCl₂, and the FIO₂ was increased to 1.0.

The above data were interpreted to be diagnostic of air embolism, and an attempt was made to aspirate air from the CVP and PA ports of the pulmonary arterial catheter. No gas was withdrawn. Over the next 30 min, during which inotropic and metabolic support was maintained, the patient's vital signs improved and the acidosis resolved. The patient ultimately recovered uneventfully from this event.

After the case the computer record of end-tidal gases from the mass spectrometer was retrieved. This record, shown in figure 1, documents a marked and sudden decrease in end-tidal CO₂ and an equally abrupt increase in end-tidal N₂, occurring within 2 min of vena cava unclamping, confirming the diagnosis of massive venous air embolism.

DISCUSSION

Venous air embolism during liver transplantation is cited as a potential complication in many reviews of this procedure.¹ This potential complication is our justification for avoiding nitrous oxide during the procedure. There are no data available, however, on the true incidence of venous air embolism at the time of anastomosis of the donor liver. In addition, although air embolus is a commonly cited problem, there is only one case report of massive air embolus during liver transplant in the anesthesia literature. In that report the diagnosis of air embolism was not considered during the acute event and mass spectrometry data were not reported.²

The cause of the large venous air bolus during our case is not apparent since the surgeons felt their perfusion (flush) of the liver to be adequate. Donor livers are routinely perfused in situ with a preservation solution (usually
UW solution) via the portal vein and hepatic artery. Later, when the liver is placed in the recipient and the portal vein anastomosis is complete, the liver is perfused via the portal vein, such that air plus preservation solution are drained via the open (incomplete) infrahepatic inferior vena cava anastomosis. This maneuver is performed in order to prevent entry of potassium-rich preservation solution and air into the recipient circulation.

In the earlier case report, a clamp from the infrahepatic inferior vena cava was not reapplied after flushing, and this error led to entrainment of venous air. In our case all clamps were appropriately applied. Other external sources of venous air have been reported during liver transplant or resection. These include air entry from a peristaltic pump or air embolism associated with venovenous bypass. In our institution, all tubing used is made of clear materials and was examined for air. No source of air in our peripheral, pulmonary artery, or central transfusion tubing was found. Veno-venous bypass was not used during the case. The patient was completely paralyzed and therefore not entraining air by respiratory efforts. There was no leak in the anesthesia circuit or airway.

A recent case report of fatal pulmonary embolism during liver transplant highlights another rare cause of acute right heart failure during liver transplant. During both venous air embolism and pulmonary thromboembolism, end-tidal CO₂ concentrations would be expected to decrease. Only venous air embolism, however, is associated with the increase in end-tidal N₂ seen in our patient.

Transesophageal echocardiography and precordial Doppler ultrasound are considered the most sensitive monitors of venous air embolism. Neither monitor was used in this patient. We are unwilling to use transesophageal echocardiography in patients with esophageal varices, but will consider its use in transplant patients with documented absence of varices. It is possible that Doppler monitoring could be beneficial in a setting where ongoing entry of air is detected. Since release of the cross-clamp is a one-time event, however, the sensitivity of the Doppler is unlikely to change the clinical course or treatment.

An increase in pulmonary artery pressure, though less sensitive than Doppler in the diagnosis of venous air embolism, has been shown to be proportional to the severity of venous air embolism. End-tidal nitrogen is also a quantitative measure of entrained venous air. Both mass spectrometry and pulmonary artery pressure monitoring were useful in establishing a diagnosis in this case.

Venous air embolism is particularly worrisome in patients with chronic liver disease who may have extensive intrapulmonary arteriovenous shunting. Certainly nitrous oxide is contraindicated during the period of vascular unclamping because of the real potential for venous air release from the donor liver.

This report clearly documents a case of massive venous
air embolism during liver transplantation, despite ade-
quate perfusion of the donor organ prior to unclamping
of the inferior vena cava. The case is presented to alert
anesthesiologists to prepare for this potentially fatal prob-
lem at the time of vascular unclamping.

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Venous Air Embolism during Surgical Manipulation of a Femoral Bone Cyst

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Venous air embolism has been reported as a complica-
tion of many types of surgery, but is perhaps best known
as a complication of the sitting position for posterior fossa
neurosurgery. We report here an unusual case of air em-
bolism in a child occurring as a result of surgical manip-
ulations of a femoral bone cyst.

CASE REPORT

The patient is a 3-year-old male who was in his normal state of good
health until 2 days prior to admission when he jumped from a step of
a bus and subsequently was unable to walk because of left leg pain.
Physical examination on admission to the hospital revealed: BP 92/
50 mmHg, HR 88/min, RR 20/min, T 97.0°F, height 98.1 cm, and
weight 13.4 kg. The remainder of the physical exam and laboratory
tests were normal. X-ray of the left lower extremity revealed lucrency
of the proximal femur with a questionable nondisplaced fracture.

The patient was admitted for the treatment of a proximal left femur
cyst and to rule out a pathological fracture. Plans were made by the
orthopedic service to aspirate the cyst and to inject a steroid into the
cyst, followed by treatment with a hip spica cast.

In the operating room, monitors initially consisted of a pulse ox-
imeter, precordial stethoscope, BP cuff, and ECG. Anesthesia was in-
duced with halothane, nitrous oxide, and oxygen via mask, after which
the trachea was intubated. An iv infusion of D5 in 1/4 normal saline
was administered. End-tidal CO2 (EtCO2), esophageal temperature, and
breath sounds were also monitored. Maintenance of anesthesia consisted
of halothane 1% and N2O (60%) in O2 via a semiclosed circle system,
supplemented with iv atracurium for relaxation. Thirty-five minutes
after surgery began, EtCO2 suddenly decreased from 30 mmHg to 17
mmHg, then to 4 mmHg. Although breath sounds were still equal
bilaterally, auscultation revealed a mill-wheel murmur. Oxyhemoglobin
saturation (Sp02) which had been 100% decreased to 69%. Blood pressure
decreased from 110/52 to 80/40 mmHg and the heart rate decreased
from 148 to 102 per min.

The above changes coincided with the injection of air into an 18-G
spinal needle that had been inserted into the proximal left femur
through a direct lateral approach. A second 18-G needle was also placed
distally to the first. In an effort to collect a fluid specimen from the
cyst, the surgeons had aspirated one needle or the other. At one point,
they injected air of unknown quantity into one needle in an attempt
to aspirate fluid from the other. A total of 3 cc of serosanguinous fluid
was finally aspirated from the cyst.

Venous air embolism from the left femur was suspected and the
surgeons were so informed. Nitrous oxide and halothane were discon-
tinued, and the patient was given atropine 0.2 mg iv. The Sp02 in-
creased from 69 to 95%, then to 100% within 5 min. No additional
air was injected by the surgeons. The EtCO2 increased from 4 to 35
mmHg, the heart rate from 102 to 162 per min, and the blood pressure
from 80/40 to 115/45 mmHg. After the patient regained hemody-
namic stability, anesthesia was changed to isoflurane 0.5–1% in O2,
supplemented with alfentanil totalling 100 µg.