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TITLE:
TEE captures right heart gas lock due to massive carbon dioxide embolism in a patient with rare genetic vascular anomaly of absent right superior vena cava with persistent left superior vena cava. A case report:

INTRODUCTION:
We present a case of iatrogenic massive carbon dioxide (CO2) gas embolism in a patient with a rarely encountered genetic vascular anomaly of an absent right superior vena cava with persistent left superior vena cava [figure 1]. This is seen in only 0.09-0.13% of patients with cardiac anomalies [2]. Transesophageal Echocardiography (TEE) imaging confirmed a functional gas lock of the right heart. During this case the veress needle placement and subsequent insufflation occurred within the liver parenchyma. Immediate hemodynamic collapse from gas embolism during insufflation of the abdominal cavity is an extremely rare complication [3].

DESCRIPTION OF CASE:
A 44yo female presented for robotic rectopexy due to recurrent rectal prolapse with bleeding. Significant past medical history of coarctation of the aorta (s/p surgical repair at age 6 years), severe supravalvular aortic stenosis (s/p repair at age 24 years), absent right superior vena cava with persistent left superior vena cava, severe pulmonary hypertension (PA pressures of 81-91 mmHg) and COPD.

After an uncomplicated induction and intubation a right radial a-line was placed. This robotic surgery required steep trendelenburg positioning and abdominal insufflation, both of which can exacerbate pulmonary hypertension. A pulmonary artery (PA) catheter was desired to monitor the degree of pulmonary hypertension and cardiac parameters. The cordis sheath for the PA catheter was placed in the right internal jugular (IJ) vein under ultrasound guidance without difficulty. Unsuccessful blind attempts were made at floating the PA catheter. TEE was then used to aid the placement and again the PA catheter was not able to be floated into the pulmonary artery. PA catheter placement was then aborted and the central venous access was left in place for monitoring central venous pressure (CVP) and medication administration. At this time it was not known that the patient had absence of the right superior vena cava.
The pre-incision TEE (performed at the time of PA catheter placement) showed an enlarged right atrium, no interatrial septal bowing, no atrial septal defect and no gas in the right heart [TEE video 1]. Throughout induction, intubation and line placement the patient remained hemodynamically stable. While in the supine position a veress insufflation needle was placed in the left upper quadrant and insufflation commenced. Within 30-60 seconds the a-line BP decreased from 140/65 to 56/40 mmHg, CVP increased from 16 to 35 mmHg, HR increased from 60 to 80 bpm, EtCO2 decreased from 34 to 24 and SpO2 slowly decreased over minutes to a nadir of 57% [figure 2]. The surgical team was notified of the hemodynamic changes and insufflation was stopped. Vasopressors (phenylephrine, ephedrine, vasopressin), intravenous fluids and milrinone infusion were administered with little effect. TEE was again performed and now showed the right atrium and ventricle entirely filled with gas [TEE video 2]. Immediate attempts were made to aspirate gas from the right IJ central line without success. The patient continued to decline hemodynamically and was then placed in the trendelenburg position with right side up (Durantâ€™s position). After this maneuver small gas bubbles (about 5-10 ml) were able to be aspirated from the central line. The patientâ€™s vital signs subsequently improved over the next minutes and returned to baseline with a subsequent TEE showing no gas in the right heart [TEE video 3].

The surgery team aborted the robotic approach and changed to open laparotomy. Upon gaining intraabdominal access the surgical team encountered ~200ml of blood that was determined to be coming from two small liver lacerations. Hemostasis was achieved and successful open repair of the rectal prolapse was carried out. The patient remained hemodynamically stable for the duration of the procedure and was successfully extubated at the conclusion of surgery.

DISCUSSION:

Clinically significant CO2 embolism is a known but rare complication of laparoscopic surgery. CO2 embolism resulting in serious complications has been reported to occur in 0.0016% of laparoscopic liver biopsies [3]. However small CO2 embolisms with little clinical significance are much more common and have been reported in up to 100% of laparoscopic hysterectomy procedures [3]. The most common cause of massive CO2 embolism is unintentional injection into a large vessel or organ parenchyma during initial insufflation [4].

The lethal amount of CO2 injected into a 70 kg human is estimated to be 600 - 1750 ml based on lethal doses in dogs. Initial veress needle insufflation flow should be started at 1 L/min and then increased to 6 L/min until a pneumoperitoneum of 10-15 mmHg is achieved. At these rates it would take between 6 - 36 seconds to achieve the minimum lethal dose of ~600ml. Due to the rapidity of insufflation the anesthetist needs to be most vigilant during the initial seconds to minutes of insufflation. Gas can gain intravascular access later during surgery and accumulate over time but it is statistically unlikely to reach rapid lethal volumes.

TEE is the most sensitive tool we have for early detection of gas emboli and is capable of detecting volumes of 0.02ml. This volume is typically subclinical but can allow for early detection and notification of the surgeon. Our patientâ€™s TEE showed a large volume of gas filling the right atrium and ventricle [TEE video 2]. Interatrial septal bowing is also noted which was not present in the pre-embolism TEE images. This septal bowing indicates high right atrial pressures from blockage of forward blood flow due to a functional gas lock in the right heart. This correlated with the patientâ€™s systolic BP decreasing from 140 to 56 mmHg and CVP increasing from 16 to 35 mmHg [figure 2].
Early attempts were made to aspirate gas from the central line with no success. However, after placing the patient in Durant’s position we were able to aspirate small air bubbles (about 5-10 ml). The 5-10 ml aspirated does not account for the entirety of the size of the gas embolism and it is thought the remainder of gas was absorbed and possibly diffused into the alveoli for exhalation. Because of the patient’s rare vascular anomaly the location of the tip of the central venous catheter was not known. The catheter would have taken the following path [figure 1]; down the right internal jugular vein â†’ diverted left through the left brachiocephalic vein â†’ down through the persistent left superior vena cava â†’ through the coronary sinus and ended in the right atrium. This anomaly is caused by abnormal embryologic development.

Diligent monitoring by the anesthesiologist allowed for quick recognition and treatment of the embolism. The anesthesiologist needs to be most vigilant during the initial insufflation period to monitor for hemodynamic compromise as this is statistically the most likely time period for adverse events related to insufflation. The use of TEE allows for the evaluation of the severity and size of the embolism, early detection and can guide treatment modalities as well as patient progress.

REFERENCES:

[1]: State University of New York Upstate Medical University, Department of Anesthesiology, Syracuse, New York


Figure Descriptions:

Figure 1: Schematic drawing of the variations of the superior vena cava (SVC); Schematic A = Normal anatomy, Schematic B = Single left SVC (as was seen in our case), Schematic C = Double SVC, the right SVC is either connected to the left by the left brachiocephalic vein or is without any connection. Red line = tracing of the path the right internal jugular central line would have taken.

A = right superior vena cava; B = internal jugular vein; C = left brachiocephalic vein; D = subclavian vein; E = coronary sinus; F = aorta; G = main pulmonary artery; H = left superior vena cava; RV = right ventricle; LV = left ventricle.


Figure 2: Vital signs graph from before, during and after carbon dioxide embolism. Times for TEE images and insufflation are marked on X-axis.
Image Descriptions:

TEE Image 1:
Pre carbon dioxide embolism. Transesophageal echocardiogram four chamber view. Inferiorly are right and left ventricles. Superiorly are right and left atria. Note the interatrial septum is not bowing into the left atrium and no gas is seen.

TEE Image 2: Transesophageal echocardiogram four chamber view during carbon dioxide gas embolism. Gas can is seen filling the right atrium and ventricle. Note interatrial septal bowing into the left atrium.

TEE Image 3:
Post carbon dioxide embolism transesophageal echocardiogram four chamber view. Note the absence of gas and no interatrial septal bowing.