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Patent Foramen Ovale Causing Refractory Hypoxemia after Off-Pump Coronary Artery Bypass: A Case Report

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ABSTRACT

Patent foramen ovale (PFO) is not uncommon in the adult population undergoing cardiac surgery. Although usually innocent, PFO can cause severe hypoxemia, which can be reversed only by surgical or interventional interruption of the interatrial right-to-left shunt. Such a case is presented, and the diagnosis and pathophysiology are discussed.

INTRODUCTION

The increased use of transesophageal echocardiography (TEE) by cardiologists and anesthesiologists has led to an increase in perioperative detection of patent foramen ovale (PFO) [Duff 1977, Chen 1992]. During surgery the impact of cardiac manipulation on the degree of interatrial right-to-left shunting across a PFO usually is negligible. The surgery can be performed without the need to close the PFO. Under certain circumstances, however, the presence of PFO can cause significant arterial desaturation and necessitate surgical or instrumental closure.

CASE REPORT

A well-preserved 87-year-old man was admitted with chest pain and ST changes consistent with subendocardial non–Q-wave myocardial infarction. The total creatine kinase (CK) level was 1387 U/L; CK-MB, 168 U/L (12.2 index); and troponin I, 46 μg/L. The patient had a longstanding history of atherosclerotic heart disease and had been advised to undergo surgery 5 years earlier. The medical history included cancer of the prostate treated with radiation, chronic renal insufficiency, resolved right hemispheric stroke, sleep apnea, and a history of smoking 40 years ago with total tobacco use over 30 pack-years. The patient denied any history of asthma or use of oxygen therapy or inhalers and never complained of shortness of breath, cough, wheezing, congestion, or sputum production. The admission chest x-ray (Figure), however, showed hyperinflation with apical lucency consistent with chronic obstructive pulmonary disease (COPD) as well as central prominence of the pulmonary arteries. Results of arterial blood gas analysis indicated a pH of 7.39, P_{CO_2} of 43.1 mm Hg, and P_{O_2} of 70.8 mm Hg on 6 L of O_2 by nasal cannula. Serum creatinine level was 1.8 mg/dL and blood urea nitrogen (BUN), 36 mg/dL; complete blood cell count and electrolyte values were normal.

Four days later the patient underwent cardiac catheterization and coronary angiography. The results demonstrated total occlusion of the right coronary artery (RCA) and left anterior descending coronary artery (LAD), 90% stenosis of the proximal circumflex coronary artery, diffuse left ventricular hypokinesis with calculated ejection fraction of 33%, and a left ventricular end-diastolic pressure of 23 mm Hg. The serum creatinine and BUN values then rose to 2.2 mg/dL and 40 mg/dL, probably because of the contrast agent. Renal ultrasonography showed a 6-cm mass in the lower pole of the left kidney that was highly suspicious for malignancy. Oxygen saturation on 6 L O_2 was 90% with a P_{O_2} of 62 mm Hg. There was no evidence, however, of pneumonia or major infiltrate on repeated chest x-ray.

Three days later and after renal (creatinine, 1.6 mg/dL; BUN, 31 mg/dL) and pulmonary clearances were obtained, the patient underwent off-pump coronary bypass (OPCAB) surgery. This procedure consisted of left internal mammary bypass to the LAD and its diagonal branch in sequence and saphenous vein grafts to the obtuse marginal branch of the circumflex coronary artery and the posterior descending artery branch of the RCA. Pulmonary artery pressure dropped from 46/28 mm Hg initially to 32/16 mm Hg on completion of the procedure, which was otherwise uneventful and straightforward. Despite a P_{O_2} ranging from 57 to 104 mm Hg only on 100% fraction of inspired gas (F_{IO_2}) throughout the surgery, the patient's condition remained hemodynamically stable, and only minimal administration of vasopressors was required during performance of the lateral and inferior anastomoses. When the patient returned to the intensive care unit, it became evident that we could not raise his arterial P_{O_2} beyond 60 mm Hg on 100% F_{IO_2} despite increasing his tidal volume and positive end-expiratory pressure (PEEP). PEEP

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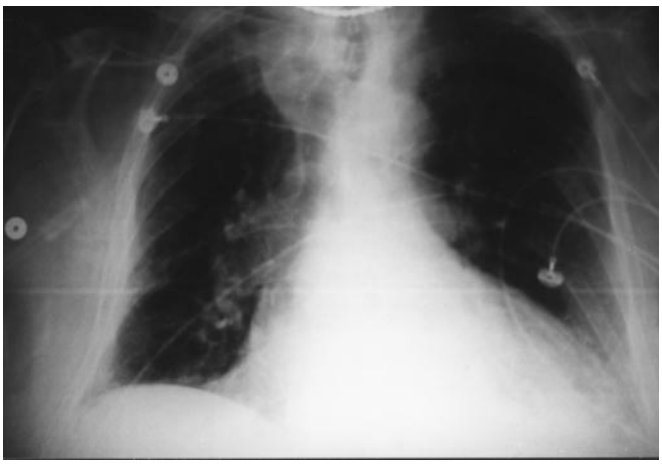

Admission chest x-ray consistent with chronic obstructive pulmonary disease. Central prominence of the pulmonary arteries is noted.

was discontinued, and a TEE study with bubble contrast confirmed the presence of a large PFO with a large right-to-left interatrial shunt (Movie). The patient was returned to the operating room, where primary closure of the PFO was performed during cardiopulmonary bypass (CPB).

Despite partial correction of hypoxemia (P_{O_2} up to 133 mm Hg on 100% F_{IO_2}), the patient's condition deteriorated because of the development of progressive, acute nonoliguric renal failure that necessitated hemodialysis and development of bibasilar atelectasis with effusions, which kept O_2 saturation only approximately 90 mm Hg on 6 L O_2 by nasal cannula. Repeated TEE study showed the PFO to be securely closed (Movie). Results of a ventilation/perfusion lung scan were negative for pulmonary embolism, and results of venous ultrasound examination of the lower extremities were negative for deep venous thrombophlebitis. Computed tomography of the chest confirmed bibasilar atelectasis, which was judged responsible for the persistent significant alveolar-arterial gradient. The patient extubated himself on the fourth postoperative day and progressed fairly well though requiring intensive pulmonary toilet. Anticoagulation was administered for persistent atrial fibrillation, and the patient was transferred to a rehabilitation unit. He then developed an episode of massive hemoptysis (international normalized ratio, 8) and needed reintubation for ventilatory support and frequent therapeutic bronchoscopic procedures. Tracheostomy was performed. Two months after the original surgery, renal function stabilized, and hemodialysis was discontinued. The patient also came off the respirator and continued to progress very well in all respects. Left nephrectomy was planned for the near future.

DISCUSSION

Functional closure of the foramen ovale at birth is frequently incomplete. The result is probe patency in 50% of individuals up to 5 years of age and in more than 25% of persons older than 20 years [Scammon 1918]. PFO thus represents the most common persistent abnormality of fetal origin. Although usually "innocent" and of no hemodynamic significance, PFO has increasingly been implicated in a number of complications because of systematic use of TEE by cardiologists and anesthesiologists. Thus an increased prevalence of PFO has been found in association with paradoxical emboli causing "cryptogenic" strokes [Lamy 2002] and coronary [Meier-Ewert 2003] and peripheral emboli. The association between PFO and refractory hypoxemia secondary to interatrial right-to-left shunting is profusely described in the literature [Fedullo 1985]. PFO and atrial aneurysm have been implicated as possible causes of migraine headaches with aura, particularly in young female patients and within the same family [Sztajzel 2002]. Unexplained decompression sickness in divers as well as high-altitude aviators and astronauts has been attributed to PFO [Sorrentino 1991]. Orthostatic desaturation (platypnea-orthodeoxia syndrome), isolated or occurring after pneumonectomy [Bakris 1997], appears to be the result of PFO.

Simple hypoxemia is a relatively common complication in the period immediately after cardiac surgery whether the operation is performed on pump or off pump. The hypoxia usually is due to pulmonary disease (atelectasis, pneumonitis) or congestive heart failure. This condition responds well to oxygen administration, increase in tidal volume, administration of PEEP, or diuretics. Less well recognized is transient right-to-left shunting through a PFO. The shunting usually does not improve with oxygen therapy and worsens with PEEP administration. Such shunting also has been reported in patients with pulmonary embolism, COPD [Liu 1999], right ventricular infarction, positive-pressure ventilation with PEEP, heart failure with left ventricular assist devices, cardiac tamponade, and unilateral diaphragmatic paralysis; after pneumonectomy; and in patients with obstructive sleep apnea syndrome [Beelke 2000]. In all these cases the primary driving force is reduction in compliance of the pulmonary bed or right ventricle. The result is increased central venous and pulmonary artery diastolic pressures and subsequent right-to-left shunting. Significant hypoxemia, however, has been described, albeit rarely, even in the absence of these hemodynamic changes [Godart 2000], and is thought to be caused by the anatomic position of a large eustachian valve in association with a PFO [Bashour 1983].

This report describes the case of an elderly patient with persistent PFO and significant right-to-left shunting who developed refractory hypoxemia after OPCAB surgery. During OPCAB, manipulation of the heart causes significant fluctuations in the patient's hemodynamics with increased mean pulmonary artery pressures, increased right ventricular end-diastolic pressures, and drop in cardiac index, all of which are easily controlled with fluids and inotropics but may uncover a PFO [Akhter 1999, Do 2002, Schoevaerdts 2002, Sukernik 2002]. Mechanical ventilation with PEEP enhances intraatrial right-to-left shunting and causes further desaturation of left atrial blood [Cujec 1993]. Recognition of a PFO should cause immediate discontinuation of ineffective PEEP, because continuing PEEP can aggravate the situation by increasing pulmonary vascular resistance.

In the care of our patient we failed to recognize the presence of a hemodynamically significant PFO intraoperatively

because of unavailability of the TEE probe then. The PFO was suspected only when the P_{O_2} failed to improve after tidal volume was increased and F_{IO_2} was increased to 100%, especially after an increase in PEEP, which made the hypoxemia worse. Despite secure surgical closure of the PFO, the patient continued to be hypoxemic, probably as a result of underlying COPD, sleep apnea, institution of CPB, and persistent atelectasis that necessitated frequent therapeutic bronchoscopic procedures. All these factors were aggravated by the occurrence of acute-on-chronic renal failure, which necessitated hemodialysis. Although the patient needed tracheostomy, he eventually recovered completely.

CONCLUSION

Because 25% of the population may have a PFO, interatrial right-to-left shunting may occur more frequently than had previously been recognized and should be considered in the differential diagnosis of hypoxemia. This possibility is particularly important in OPCAB surgery, in which manipulation of the heart causes disturbed diastolic filling of the right ventricle by direct compression. Accurate diagnosis of PFO is easily made if the lesion is suspected and TEE is performed [Konstadt 1991]. Immediate cessation of PEEP and closure of the PFO by surgical or interventional maneuvers can solve this potentially fatal situation [Wang 1999, Allan 2001, Piechaud 2001].

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