

## Patency of the Foramen Ovale in the Critically Ill Patient

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The foramen ovale, which is essential for fetal circulation, closes at or soon after birth in about 80 per cent of normal hearts. In the remainder, a slit-like opening, valvular in nature, persists. An isolated foramen ovale is of no clinical or functional significance. But in conditions associated with increased right atrial pressure or reduction of left atrial pressure, venous blood can be shunted from the right side of the heart to the left. In the management of critically ill patients treated in intensive care facilities with continuous monitoring, the significance of a patent foramen ovale should be recognized. Postoperative complications such as pulmonary embolus and the use of positive-pressure ventilation can increase right atrial pressure. This can result in development of a right-to-left shunt if there is a patent foramen ovale. The shunt leads to a decrease in partial pressure of oxygen in the arterial blood which cannot be corrected with higher concentrations of inspired oxygen.

### REPORT OF A CASE

A 42-year-old Caucasian man had aortocoronary bypass surgery on August 6, 1973.

Preoperative arterial blood-gas and pH determinations with the patient resting and breathing room air showed  $P_{O_2}$  89 torr,  $P_{CO_2}$  35.5 torr, pH 7.48, and base excess zero. Vital capacity was 4.8 l, resting minute ventilation 8.1 l/min, and maximum voluntary ventilation 39.4 l/min (limited by angina).

The operative procedure consisted of implantation of two aortocoronary bypass grafts using the saphenous vein. Morphine sulfate (60 mg), sodium secobarbital (50 mg), and *d*-tubocurarine (52 mg) were used for anesthesia, together with supplemental oxygen and nitrous oxide. The patient was on cardiopulmonary bypass for two hours and 7 minutes. In the intensive care unit after operation, respirations were controlled using an Emerson postoperative ventilator with 100 per cent oxygen with a tidal volume of 850 ml and a respiratory rate of 14/min. The inspired oxygen concentration was reduced to 70 per cent as the patient showed improvement in oxygenation and carbon dioxide was

added to maintain a normal  $P_{aCO_2}$ . Positive end-expiratory pressure (PEEP) of 2.5 cm H<sub>2</sub>O was added to improve oxygenation further. Inspired oxygen concentration was reduced to 50 per cent. PEEP was increased to 5 cm H<sub>2</sub>O. During the night the patient became febrile and restless, and vomited. At this time the patient showed sudden deterioration of arterial oxygenation. Repeated roentgenograms of the chest showed no significant change.  $P_{aO_2}$  could not be improved despite increasing  $F_{iO_2}$  and increasing PEEP.

Pulmonary embolism with an intracardiac shunt possibly through a patent foramen ovale, was suspected. The pattern of oxygen exchange with reference to inspired oxygen concentration can be seen in figure 1. There were minor variations in partial pressures of oxygen due to unsteady state and variations in the magnitude of shunt.

An indicator dye-dilution curve showed a right-to-left shunt. PEEP was discontinued and the inspired oxygen concentration was reduced, with careful monitoring of arterial blood gases, until  $F_{iO_2}$  was 0.45 torr. As the patient's condition stabilized, periods of breathing without the ventilator were tried. The trachea was extubated during breathing of 50 per cent inspired oxygen. The patient continued to be febrile until later in the convalescent period, when the fever was found to be drug-induced. Eleven days after operation the patient suddenly developed left-sided hemiplegia with left hemianopsia. Cardiac catheterization 14 days after operation revealed a mean right atrial pressure of 1 torr, an "a" wave of 3 torr, right ventricular pressure of 19/1 torr and pulmonary arterial pressure of 19/3 torr. Pulmonary wedge pressure was 2 torr. A simultaneous indicator dye-dilution curve demonstrated a small right-to-left shunt at the atrial level, suggestive of a patent foramen ovale. A lung scan using <sup>133</sup>Xe (29.2 millicuries) iv showed smaller areas of decreased perfusion of the right upper and lower lobes and decreased perfusion of the left lower lobe suggestive of pulmonary emboli.

X-rays remained clear until 15 days after operation when pulmonary infiltrates developed in the right lower lobe; these cleared later.

The course of the patient's recovery was gradual but progressive, with alleviation of residual hemiparesis and persistent left homonymous hemianopsia, and he was dismissed from the hospital. The patient remained moderately hypoxic throughout the postoperative period.

### COMMENT

The patent foramen ovale found in 20–25 per cent of normal individuals<sup>1</sup> may be 1 cm or more in diameter in adults. It has a valvular

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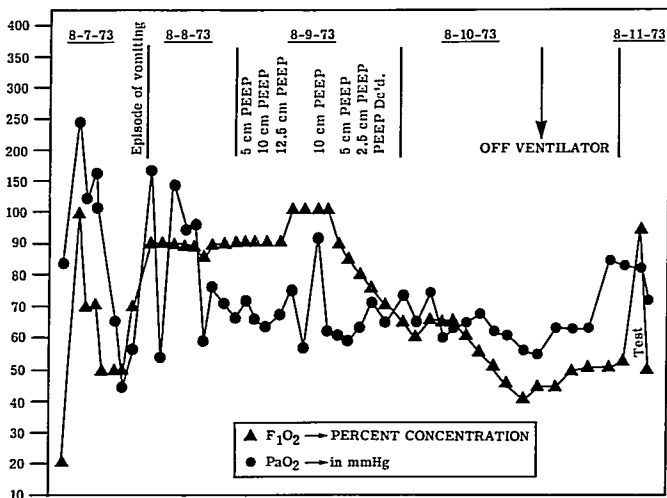


FIG. 1. The relation between inspired oxygen concentrations and partial pressures of oxygen in arterial blood during the first five postoperative days. Increases in inspired oxygen concentration had no significant effect on the partial pressure of oxygen in the arterial blood following the episode of vomiting. This probably is when pulmonary embolism took place with development of the right-to-left shunt at the atrial level. Vertical axis, partial pressure of oxygen in the arterial blood in mmHg; Pa<sub>o<sub>2</sub></sub>, PEEP = positive end-expiratory pressure; Dc'd = discontinued; F<sub>1</sub>O<sub>2</sub> = concentration of oxygen in inspired air.

construction which allows passage of blood from the right to the left side of the heart only. Usually a patent foramen ovale is of no significance because the higher pressure in the left atrium keeps the valvular foramen closed. However, if the pressure in the right atrium exceeds that in the left, blood flows from the right to the left.<sup>2</sup> This can occur following pulmonary embolism.<sup>1</sup> If there are further emboli, paradoxical embolism may result. Pulmonary stenosis,<sup>3</sup> pulmonary hypertension,<sup>4</sup> and ventricular septal defects<sup>5</sup> may also be associated with a right-to-left shunt through a patent foramen ovale, a shunt which can involve not only blood but also solid material,<sup>2</sup> including emboli.

Hypoxemia, positive-pressure ventilation and PEEP,<sup>7</sup> chronic congestive heart failure,<sup>8</sup> and pulmonary embolism<sup>1</sup> can lead to elevation of right atrial pressure. This can result in a right-to-left shunt through the patent for-

men ovale. The shunt may be so large that the Pa<sub>o<sub>2</sub></sub> cannot be improved even with administration of 100 per cent oxygen. If this possibility is not borne in mind, the patient may be exposed to the risk of pulmonary oxygen toxicity without significant improvement in Pa<sub>o<sub>2</sub></sub>.

Sudden deterioration of oxygen exchange in the absence of significant clinical and radiologic changes in the lungs should make one suspect the possibility of intracardiac shunting through the foramen ovale. In such situations positive-pressure ventilation and PEEP may not improve oxygenation, but may further increase the shunt. Pulmonary embolism should be suspected as an important predisposing factor in these situations. Routine x-ray of the chest may not show an abnormality in a significant number of cases of pulmonary embolism.<sup>7</sup>

For detection of intracardiac right-to-left shunts, an indicator dye-dilution curve is use-

ful even though small shunts involving less than 5 per cent of cardiac output may not be detected. The procedure is simple and safe. It is particularly useful in critically ill patients to assess circulation time, cardiac output, and the presence or absence of intracardiac shunts. Our patient had pulmonary embolism followed by development of a right-to-left shunt through the foramen ovale as demonstrated by an indicator dye-dilution curve. Even though the results of hemodynamic measurements were within normal limits at the time of cardiac catheterization, the shunt at the atrial level was confirmed by the indicator dye-dilution curves simultaneously performed. This emphasizes that the difference in pressure between the right and left atria, rather than the increases in the absolute values, is important in causing for shunt.

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## Prolongation of a Pancuronium-induced Neuromuscular Blockade by Clindamycin

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Several antibiotics augment the neuromuscular blockade induced by nondepolarizing muscle relaxants.<sup>1</sup> There are no reports which suggest that Clindamycin is one of these antibiotics. This case report suggests that a pancuronium-induced blockade was pro-

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longed as a result of intravenous administration of Clindamycin phosphate. Neostigmine was an ineffective antagonist of this blockade, and indeed may have prolonged it.

#### REPORT OF A CASE

A 54-year-old Caucasian woman, 50 kg in weight, was scheduled for an emergency incision and drainage of an abscess of the sigmoid colon. Two months previously, she had received general anesthesia with morphine and nitrous oxide for renal transplantation. Muscle relaxation was provided by pancuronium bromide, 3 mg, which was antagonized completely as judged by the response to peripheral-nerve stimulation by neostigmine, 3 mg, and atropine, 1.2 mg, intravenously. During the operation the patient received chloramphenicol, but not Clindamycin.

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