Case reports

Reactive pulmonary hypertension after a switch operation
Successful treatment with glyceryl trinitrate

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SUMMARY After an arterial switch operation (anatomical correction for transposition of the great arteries) in a 6 month old child reactive pulmonary hypertension developed six hours after cardiopulmonary bypass. Intravenous glyceryl trinitrate was the only means by which the pulmonary hypertension could be reversed.

In patients with pulmonary hypertension due to pulmonary vascular disease postoperative mortality is appreciably increased. Episodes of acute reactive pulmonary hypertension have been reported after surgical correction of several congenital cardiac abnormalities.[1][2] To prevent a fatal outcome of these episodes prompt treatment with vasodilating drugs and hyperventilation with pure oxygen is mandatory.[3] Numerous pulmonary vasodilators have been described, but the pulmonary response to all these drugs is unpredictable. Laboratory studies have shown glyceryl trinitrate to be an effective pulmonary vasodilator.[4] It also lowers patients' pulmonary artery pressures considerably.[5][6] To our knowledge glyceryl trinitrate has not previously been used to treat a pulmonary hypertensive crisis in a child after cardiac surgery. We report the successful use of the drug in a case of reactive pulmonary hypertension after a switch operation for transposition of the great arteries.

Case report

Transposition of the great arteries with a large ventricular septal defect was diagnosed in a child on the day of birth. At 6 months (weight 5700 g, length 66 cm) we decided to perform an arterial switch operation and close the ventricular septal defect. At catheterisation one week before operation the following pressures were found: right atrium mean 4, left atrium mean 5, right ventricle mean 77, aorta 72/45 (mean 57), and left ventricle mean 72 mm Hg. The pulmonary artery pressure could not be ascertained during the investigation. The ventricular septal defect was closed with a double velours Dacron patch through the tricuspid valve; the aorta and pulmonary artery were transposed with reimplantation of the coronary arteries into the "new" aorta.[7] Total cardiopulmonary bypass time was 131 minutes, and the aorta was crossclamped for a single period of 78 minutes. After the release of the aortic clamp the heart started beating spontaneously in sinus rhythm at a temperature of 24°C.

Pressures directly after cardiopulmonary bypass were: right atrium mean 3, right ventricle mean 80, pulmonary artery 60/10 (mean 29), left atrium mean 8, left ventricle mean 90, left ventricular end diastolic 14, and radial artery 90/35 (mean 53) mm Hg. The heart rate at this stage was 150 beats/min. The systemic arterial blood gases were: pH 7·49, $PaCO_2$ 3·2 kPa (24 mm Hg), PaO_2 53 kPa (400 mm Hg), base excess −3 mmol/l. One hour after cardiopulmonary bypass a 5 French gauge thermodilution Swan-Ganz catheter was introduced percutaneously via the internal jugular vein. The pressures were: right atrium mean 6, right ventricle 60, pulmonary artery 26/15 (mean 21), pulmonary artery wedge and left atrium mean 9, radial artery pressure 90/33 (mean 54) mm Hg.

About 20 minutes later the chest had to be

reopened because of signs of cardiac tamponade. Inappropriate clotting with diffuse bleeding was found. In the four hours before the chest could be safely closed again fresh frozen plasma, platelets, and one litre of fresh blood were transfused. During the whole of this period the pulmonary arterial systolic pressure was 40–75% of the systemic arterial systolic pressure.

Six hours after the bypass procedure a steady but severe increase in the pulmonary arterial pressures was noted over a period of 20 minutes. The pulmonary artery pressure rose to 123/75 (mean 96) mm Hg, and the systemic pressure at this stage was 112/60 (83) mm Hg. The heart rate (163 beats/min) and cardiac index (5·0 l/min/m²) remained essentially unchanged. Systemic arterial blood gases were normal: pH 7·44, $PaCO_2$ 5 kPa (40 mm Hg), PaO_2 35 kPa (259 mm Hg), base excess +4 mmol/l. The oxygen saturations were 68, 72, and 96% in the superior vena cava, pulmonary artery, and radial artery respectively. Serum glucose and calcium concentrations were normal. Hyperventilation with pure oxygen, injection of 7 μg/kg fentanyl and 0·7 μg/kg isoprenaline intravenously, and injection of 1 μg/kg prostaglandin E_1 directly into the pulmonary artery all had no effect on pulmonary hypertension. A bolus injection of 10 μg glyceryl trinitrate intravenously lowered the pulmonary artery pressure to 74/49 (57) mm Hg without lowering the systemic pressure. This favourable change was maintained by a continuous infusion of glyceryl trinitrate 12 μg/kg/min. Thirty six hours later it was decreased and stopped 72 hours postoperatively. During this period the pulmonary arterial systolic pressure never rose above 70% of the systemic arterial systolic pressure and gradually decreased to 40%. The cardiac index remained between 3·7 and 4·6 l/min per m². On the fourth postoperative day he was extubated and 10 days later discharged home without any further postoperative complications.

Discussion

Pulmonary hypertension often occurs in patients with cardiac disease associated with an appreciable increase in pulmonary blood flow.[8] The increased flow stimulates the growth of muscle fibres in the pulmonary artery. Before irreversible pulmonary hypertension develops three histological components are present: increased muscularity of the small pulmonary arteries, hyperplasia of the intima, and a decrease in the number of intra-acinar arteries.[9]

Histological studies have indicated that the reactivity of the pulmonary vascular bed to vasoconstrictor agents is noticeably increased in these preconditioned arteries.[2 9–11] Hypoxia, acidosis, hypercapnia, microatelectasis,[1 2 12] hyperinflation,[13]

cold environment,[14] aspiration,[3] and, especially in neonates, hypocalcaemia, hypoglycaemia, or polycythaemia[2] may all act as stimuli for reactive pulmonary vasoconstriction to develop postoperatively. Pulmonary hypertension may accompany episodes of systemic hypertension during light general anaesthesia.[15] Acute pulmonary hypertension may occur during withdrawal from cardiopulmonary bypass or after withdrawal of ventilatory support but also without any obvious cause during apparently optimal ventilation.[1 2 16]

None of the above known stimuli was present in our patient. Detachment of the ventricular septal defect patch was a consideration but could be ruled out as there was no appreciable increase in the oxygen saturation between the right atrium and the pulmonary artery. Administration of one litre of blood could have led to the development of pulmonary hypertension by infusion of microaggregates, but the blood was less than 12 hours old and therefore unlikely to have formed microaggregates.[17] Extensive laboratory investigations also failed to show any sign of intravascular clotting.

Hyperventilation with pure oxygen, fentanyl, and isoprenaline failed to change the pulmonary artery pressure. Prostaglandin E_1 dilates the pulmonary as well as the systemic vessels. The effect on the pulmonary circulation is unpredictable,[18 19] and our patient did not respond to a relatively high dosage of 1 μg/kg infused directly into the pulmonary artery. Tolazoline has successfully been used in the treatment of pulmonary vasoconstriction,[1 2 20] but because we had previously noted an equal fall in the systemic and pulmonary arterial pressures tolazoline was not used.

Sodium nitroprusside and glyceryl trinitrate relax the musculature of both the systemic and pulmonary vessels. At normal dosages glyceryl trinitrate mainly effects the venous system without lowering the systemic arterial pressure unduly.[5 6] The action of sodium nitroprusside on the pulmonary vessels normally becomes effective only after considerable changes in systemic resistance and pressure[21 22]; its successful use has, however, been reported in a patient who could not be weaned off cardiopulmonary bypass because of pulmonary hypertension.[16]

Methaemoglobinaemia can be a complication of treatment with intravenous glyceryl trinitrate. At infusion rates of less than 7 μg/kg/min the methaemoglobin concentration, normally less than 1 g/dl, does not exceed 2 g/dl.[23] The maximum dosage used in our patient was 12 μg/kg/min, at which rates it may be advisable to monitor methaemoglobin concentrations. The extent to which the ratio between the pulmonary and systemic arterial pressures should be lowered postoperatively is not known. In a retrospective study of ventricular septal defects it appeared that

a preoperative ratio of <0·45 was associated with the lowest postoperative mortality.[24] Increases in the pulmonary arterial pressure >60% of the systemic arterial pressure have been reported to be dangerous and should be lowered if possible.[25]

Treatment of reactive pulmonary hypertension must be prompt to prevent acute dilatation and failure of the right ventricle.[1] Glyceryl trinitrate has been found to be an effective pulmonary vasodilator, and we think that its use should probably be recommended in preference to other more generally used drugs because a minimal and predictable effect on the systemic pressure is achieved while cardiac output is increased.

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