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Risk of cardiac catheterization under anaesthesia in children with pulmonary hypertension

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Background. Children with primary pulmonary hypertension (PHT) are a high-risk group who require assessment by cardiac catheterization under anaesthesia. Complications, including death, have occurred during anaesthesia in these patients, but the true risk has not been quantified.

Methods. The clinical records of children with PHT undergoing general anaesthesia for pulmonary vascular resistance studies were reviewed retrospectively. Data collected included pre-catheter measures of severity of disease, details of clinical management, and complications occurring within 24 h of the start of anaesthesia.

Results. During the past 5 yr, 75 consecutive patients were catheterized and usable records were available in 70. The age range was 0.1–18 yr (mean 7.1). Four children required external cardiac massage [6% (95% confident limits 1–11%)] and one of these died. Of the four, two had an arrhythmia related to the mechanical effects of catheterization, one was hypotensive during anaesthesia and the other had fatal cardiac failure in recovery. All four had severe PHT as judged by echocardiographic estimation of tricuspid regurgitant jet velocity > 4 m s^{-1}.

Conclusions. Resuscitation or death occurred in 6% of cases. Any associated risk factors could not be determined because the number of complications was too small. Risks may be highest in children with severe idiopathic PHT and symptoms of chest pain, syncope, or dizziness.

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Children with primary pulmonary hypertension (PHT) are a high-risk group who, untreated, have a median survival rate of approximately 10 months.[1] If they are carefully investigated and treated with appropriate medication, their median survival can be increased to 8 yr or more, without transplantation.[2] Investigation includes cardiac catheterization to measure directly the pulmonary artery pressure and cardiac output (CO) for calculation of pulmonary vascular resistance (PVR). This is undertaken while the child breathes air and then repeated to test the pulmonary vasodilatation effects of hyperoxia and nitric oxide. General anaesthesia is used for practical reasons to ensure physiological stability and to enable the control of inspired oxygen and nitric oxide. Complications, including death, have occurred during anaesthesia in these patients, but the risk has not been quantified. Data exist for adults with PHT undergoing these procedures under local anaesthesia.[3] Although there are data published about the rate of complications occurring in children undergoing cardiac catheterization, these are not specific to children with PHT.[4] We have reviewed our own data in children with both primary and secondary disease to estimate the risk of cardiac catheterization under general anaesthesia and to identify any features associated with complications.

Methods

The clinical records of children with PHT undergoing general anaesthesia for PVR studies over a 5-yr period,

between July 1999 and November 2004, were reviewed retrospectively. The project was registered with the Research and Development office and the Chairman of the Local Research Ethics Committee considered that parental (or patient) consent was unnecessary for this retrospective study.

We collected data from 94 consecutive anaesthesia records from 75 patients, as some patients had more than one anaesthetic for procedures in addition to cardiac catheterization. A standard data collection form was used and data included patient details, measures of severity of disease from the pre-anaesthetic clinical history, examination and investigations, the pre-anaesthesia echocardiographic examination (echo), drug therapy, anaesthesia management, cardiovascular measurements from the PVR study, and complications during both the procedure itself and over the following 24 h. Electrocardiographs were examined for signs of right ventricular strain, including ST depression in leads V1-3, aVR, or III, and any other abnormalities. Radiologists' chest X-ray reports were noted. Echocardiographic assessment was performed by trained technicians and from their reports, the following were recorded; (i) right ventricular function (classified as good, moderate, or poor), (ii) the presence of dilatation or hypertrophy of the right ventricle, (iii) any restriction of the left ventricle due to the size of right ventricle, and (iv) estimation of the systolic pulmonary artery pressure (sPAP) in mm Hg based on the velocity of the regurgitant systolic jet through the tricuspid valve utilizing a modified 'Bernoulli equation' (see the appendix).[4–7]

During the audit period, anaesthesia management for cardiac catheterization involved muscle relaxation, tracheal intubation with a cuffed tracheal tube, and mechanical pulmonary ventilation with oxygen, air, and a volatile agent. The inspired concentration of isoflurane was adjusted to achieve steady heart rate, arterial pressure, and end-tidal concentrations of isoflurane and carbon dioxide. Local anaesthesia skin infiltration was used to minimize stimulation.

A volume generator ventilator (Siemens Servo 900C, Solna, Sweden) delivered a mixture of oxygen and air to the patient from which all exhaled gas was collected into a mixing chamber. End-tidal carbon dioxide was measured with a capnograph (Hewlett Packard, Palo Alto, CA, USA), and exhaust from this instrument was directed into the expiratory mixing chamber. A mass spectrometer (Amis2000, Innovision, Denmark) measured inhaled and exhaled gas fractions and calculated minute ventilation oxygen consumption and carbon dioxide production.

The cardiac catheterization technique depended on cardiac anatomy but most often involved femoral vascular access. Catheters were inserted to measure both the pulmonary arterial and pulmonary venous pressures and oxygen content. In the presence of an intra-cardiac shunt, catheters were manipulated into the left atrium or pulmonary vein to determine pulmonary venous saturation and pressure. When no intra-cardiac shunt existed, systemic arterial blood samples and pulmonary capillary wedge pressures were measured instead. Intravascular pressures were measured using strain gauge pressure transducers and stored by a haemodynamic recording system (Siemens Sensis, Sweden). Total blood oxygen content was calculated from haemoglobin oxygen saturation measured by an oximeter (Radiometer, Copenhagen), and dissolved oxygen from blood gas analysis. CO was derived by the Fick principle and PVR was calculated from Ohms law. Cardiac index (CI) was calculated by dividing CO by body surface area. PVR was indexed (PVRI) using CI in the calculation, expressed in Woods units m^2 (see the Appendix). Surface area was estimated from the crown to heel length and body weight using a nomogram. Measurements were recorded during two conditions; first, a baseline, with low inspired oxygen concentration ($<25\%$) and second, attempted pulmonary vasodilatation using oxygen enrichment (60%) together with inhaled nitric oxide (20 parts per million).

Major complications were defined as hypotension, hypoxia or arrhythmia occurring during or within 24 h of anaesthesia that required resuscitation either by external cardiac massage, direct current electrical shock, rapid i.v. fluid bolus greater than 20 ml kg^{-1}, inotrope or anti-arrhythmic drug administration, unplanned tracheal intubation or mechanical ventilation. Minor complications were defined as transient self-limiting disturbances in blood pressure, oxygenation, or cardiac rhythm that required either minimal therapy (e.g. oxygen or fluid only) or no treatment at all.

The number and percentage of children with clinically important symptoms, physical signs, or results of investigations present before anaesthesia was calculated in the groups of children with and without complications (Table 2). To determine whether or not pulmonary artery pressure or resistance was related to important complications or clinical features, we compared the distributions of pressures and resistances between children who did and did not have complications or selected important clinical features.

Only data from 'first anaesthetics' were analysed and are presented with descriptive statistics. The frequencies of important features of disease in children with and without complications were compared by assessing using multiple Fisher's exact tests. *T*-tests were used to compare pulmonary artery pressures and resistances. $P < 0.01$ were considered significant because of the multiplicity of statistical comparisons.

Results

Of 75 consecutive patients catheterized over 5 yr, records were missing in four cases, insufficient in one and consequently only the remaining 70 were studied. Some patients