Anaesthesia for Paediatric Cardiac MRI

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Abstract

Background: General anaesthesia (GA) for cardiac magnetic resonance imaging (MRI) in patients with congenital heart disease (CHD) is challenging for the anaesthesiologist.

Methods: A retrospective review of anaesthesia for cardiac MRI between January 2002 and December 2005 was undertaken.

Result: 28 children with cardiac disease were subjected to general anaesthesia for cardiac MRI, of which four patients were in ASA Grade I, five in Grade II, seventeen in Grade III and two in Grade IV. Two patients had undergone previous cardiac surgery. All the cases were managed as inpatients, of which 18 had cyanotic cardiac defects (SpO₂ between 65 and 85%). On two occasions scans were interrupted because of low oxygen saturation or haemodynamic instability during GA. No patient was admitted to the hospital for complications related to general anaesthesia though all were kept under observation for two hours before being shifted to ward. Five patients had a brief episode of hypotension/desaturation during the MRI and responded quickly to interventions.

Conclusion: General anaesthesia for cardiac MRI can be administered safely in children with CHD.

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Key Words : Cardiac MRI; Congenital heart defects; General anaesthesia

Introduction

Magnetic resonance imaging (MRI) has emerged as an important diagnostic, noninvasive imaging modality for children with congenital heart disease (CHD) that overcomes some of the limitations of echocardiography and catheterization [1]. Cardiac MRI permits magnetic resonance angiography (MRA) with calculation of systemic and pulmonary blood flow ratio, cardiac output, stroke and ventricular volumes and ejection fraction [2].

General anaesthesia or deep sedation is necessary for most children undergoing MRI to avoid movement and imaging distortion. Provision of anaesthetic service is limited by unique MRI environment along with monitoring and equipment problems. In cardiac MRI prolonged breath holds are needed for image reconstruction which necessitates GA and controlled ventilation. This report presents our experience of using GA in children with CHD for cardiac MRI.

Material and Methods

The anaesthesia and MRI records of all patients who underwent cardiac MRI between January 2002 and December 2005 were reviewed retrospectively. Patient demographics, anaesthetic technique and management were evaluated. All the children underwent preoperative assessment which included chest radiograph, electrocardiography (ECG), haemoglobin, echocardiography, four limb pulse oximetry and cardiac catheterization data if available.

The entire process of anaesthetic care was completed in three stages (Figs. 1-3). The child was first anaesthetized outside the MRI suite and then shifted inside the suite with the anaesthesia machine. The child was then placed on the MRI table and was reconnected to the machine. At this stage a further reading of blood pressure was taken and the ECG leads and the body coil were applied. Once the ECG gating was satisfactory and scanning was ready to begin, the anaesthesia machine was again disconnected and shifted behind the gantry. The table was slid inside the gantry and the child was reconnected to the anaesthesia machine to continue ventilation. Two anaesthesiologists (one consultant and one resident) were involved with each case, one stayed inside the suite controlling ventilation and monitoring depth of anaesthesia while the second anaesthesiologist monitored the ECG screen on the central console.

A standard anaesthetic technique was adopted. All children were premedicated with injection glycopyrrolate and midazolam after establishing intravenous access following application of eutectic mixture of local anaesthetic cream whenever possible. The parents were present during induction of anaesthesia. General anaesthesia with neuromuscular blockade and tracheal intubation was performed in all patients. All patients except one were preoxygenated with 100% O₂ prior to an end expiration breath-hold used to facilitate image acquisition. 100% O₂ was allowed to flow during breath hold to achieve apnoeic oxygenation. One patient with transposition of great arteries was intubated and ventilated with room air to maintain pre-operative saturation of 85% and prevent fall in pulmonary vascular resistance and

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Figs. 1,2,3 : Stages of the anaesthetic process (Ref text)

consequent systemic hypotension. All the children were induced with ketamine (except cases of septal defects where Propofol was used) and volatile agents were avoided altogether. Anaesthesia was maintained with divided doses of ketamine. Neuromuscular block was established with atracurium and all cases were manually ventilated.

ECG using MR-compatible electrocardiographic leads, oxygen saturation and blood pressure were monitored in all cases. The ECG was monitored outside the suite whereas blood pressure was obtained intermittently with aneroid manometer. None of the children were subjected to invasive blood pressure monitoring. At the end of imaging, residual neuromuscular blockade was reversed using neostigmine and atropine. Trachea was extubated when the child was fully awake and maintained oxygen saturation equal to the one recorded immediately before induction.

MR imaging was performed using a 1.5 T (Magnetom Symphony, Siemens Medical Systems, Erlangen, Germany) using an integrated body coil. Contrast enhanced MR Angiography (CE MRA) was performed to evaluate the vascular anomalies associated with the cardiac defects following an IV bolus of gadolinium based MR contrast in a dose of 0.1 to 0.2 mmol/kg body weight.

Results

A total of 28 patients with CHD underwent general anaesthesia for cardiac MRI during the study period, the details of which are given in Tables 1 and 2. The age of children ranged from one month to five years. Amongst all the children, 18 cases had cyanotic cardiac defects with baseline oxygen saturation (SpO_2) between 65 and 85%. Two children in ASA IV had Tetralogy of Fallot (TOF) with congestive cardiac failure. All the patients were admitted on the day of the MRI procedure and discharged the next day. No child had to be specifically admitted because of any anaesthesia related event. All the patients underwent MRI for diagnostic purposes and planning for cardiac surgery. None of the patients were on any haemodynamic support or mechanical ventilation. There were no cases of difficult intubation. During induction, a brief episode of hypotension occurred in two cases which responded to intravenous phenylephrine. Three cases of TOF developed further desaturation during induction which responded to injection metoprolol. During the staged shifting, there were no adverse

Table 1

Patient demographics

Number	28
Male/female	20/8
Age (mean, range)	2.08 years (1.0 months–5 years)
Weight (mean, range)	11.7 kg (3.0–18 kg)
Previous cardiac surgery	2
ASA I	4
ASA II	5
ASA III	17
ASA IV	2

Table 2

Diagnosis

Tetralogy of Fallot	13
Septal defects	9
TGA	1
TAPVC	3
Dextrocardia	1
Coarctation of aorta	1

events. There were no extubation related complications.

Breath-hold duration varied between 6 and 60 seconds. On two occasions, scanning had to be interrupted because of desaturation during breath-hold which responded to ventilation with 100% oxygen. The average duration of each MRI procedure, from premedication to tracheal extubation, was 65 ± 1 minutes. There were no contrast related reactions. Clinically none of the cases had any significant hypothermia or hearing defects.

Discussion

Deep sedation or general anaesthesia is indicated in neonates, infants and small children for MRI. The challenges during MRI include limited access to patient and equipment, low ambient temperature with risk for hypothermia and a noisy unfamiliar environment with remote location from the operating room [3]. Acute resuscitation in the event of sudden cardio-respiratory deterioration is difficult as the patient needs to be withdrawn from the MRI room.

Presence of sternal wires and vascular clips cause

only minor disturbances. Hence MRI can be performed in patients who have undergone previous cardiac surgery. Absolute contraindications include patients with pacemakers and defibrillators. There is a formal recommendation to wait for six weeks between implantation of endovascular and intracardiac devices and implants that will be exposed directly to the magnetic field and may be dislodged. A shorter interval can be considered if the clinical indication to MRI outweighs the theoretical risk [4].

The challenges for cardiac MRI in infants and children are magnified significantly as smaller structures are being imaged. In addition, faster heart rates and regular breathing do not allow good image acquisition, since children are unable to hold breath during MRI and are likely to have limited cardio-respiratory reserve on account of their congenital cardiac defects [5]. The patients may include those with complex intracardiac defects, having mixing of oxygenated and deoxygenated blood, with pulmonary hypertension, cardiac failure and poor exercise tolerance. In our series there were no children on ventilator or vasopressor support unlike those described by Odegard et al [6].

Induction and maintenance of general anaesthesia for cardiac MRI are governed by similar principles for any anaesthetic technique in children with heart disease. A thorough understanding of the pathophysiology of each disease process and knowledge of the effects of various anaesthetic agents on ventricular function is essential. In our series, no inhalational agents were used irrespective of the cardiac status of the patient. We adopted this strategy as intravenous agents have less depressive effects on myocardium as compared to inhalational agents. However, inhalation induction and subsequent maintenance of anaesthesia with sevoflurane in cases with stable ventricular function has been reported [6]. The same authors however used etomidate 0.2–0.3 mg/kg for induction and inhaled sevoflurane, or a continuous infusion of remifentanyl for maintenance in children with limited haemodynamic reserve and concerns for haemodynamic instability. For patients with limited reserve, the risk-benefit for general anaesthesia and breath-hold vs the value of the acquired images must be thoroughly discussed with the MRI cardiologist.

Off-shore locations requiring anaesthesia services have poor resources to manage complicated cases [7]. This is especially true of cases with abnormal airway needing specialized management. However, in one report, tracheal intubation of children with difficult airway was initially accomplished with fiberoptic assistance in a fully equipped location close by and then they were transported to the MRI suite in a sedated

state. This however becomes impractical in MRI suites which are built as a separate unit away from the operation theater (OT) as in our case.

While our preferred technique is general anaesthesia with controlled ventilation, other authors have used only sedation in a large number of children undergoing cardiac MRI. In a series of 356 children <10 years of age, sedation was used in 35% of patients who were usually between six months and four years [8]. Another review advocated sedation for children <6 years, using either chloral hydrate, pentobarbital or an intramuscular injection of pethidine compound [meperidine 25 mg, promethazine 6.25 mg and chlorpromazine 6.25 mg/ml] [9]. While breath-holding images can be obtained in older children under light sedation sufficient to allow patient cooperation, this is not possible in infants and young children. In our series, the oldest child was five years. In our opinion, general anaesthesia with paralysis and controlled ventilation offers several advantages over intravenous sedation in infants and young children. These patients with limited cardiovascular reserve and cyanotic CHD are prone to desaturate to lower levels in the event of sedation induced respiratory depression or airway obstruction [10]. Besides, effects of sedation can be unpredictable and some of the drug combinations may be associated with delayed recovery. This view has been supported by the Odegard et al [6].

We maintained anaesthesia with supplements of ketamine intravenously. Occasionally we used manual infusion with the help of microdrip sets. However MR compatible infusion pumps have been introduced recently and it may be possible to use them for true total intravenous anaesthesia. We ventilated all the cases manually, thus helping us in keeping a close watch on the patients. We did not use longer breathing circuits as we were able to position the anaesthetic machine close to the scanner. The anaesthesia machines with longer circuits if used, can do away with the third stage of the conduct of anaesthetic care in our cases. However longer circuits are cumbersome, have the risk of disconnection and may add to the dead space significant enough in children. Respiratory gas analysis and capnography is considered mandatory to allow the anaesthetist to monitor the ventilation circuit integrity and anaesthetic gas concentration.

The importance of reliable monitoring cannot be overemphasized particularly during a cardiac MRI because image sequencing is synchronized with the ECG and children with CHD have poor cardio-respiratory reserve [11]. Pulse oximeter gives an early warning of worsening shunt during conduct of anaesthesia. We had to use beta blockers in three cases whereas phenylephrine was needed in two cases to bring up the

blood pressure. Electrocardiography introduces problems with image degradation from wire leads acting as antennas and the inability of the monitor to discern the ECG from the background static magnetic and RF pulses [12]. Good ECG monitoring is important for monitoring the patient and to perform ECG-gated imaging.

Optimal functioning of the MRI scanner requires a temperature of 15-17 degrees Celsius, which puts the children at risk of developing hypothermia. In our series, all patients were wrapped in blankets to prevent hypothermia, however temperature was not monitored.

During cardiac MRI, breath-hold is important to allow three-dimensional MRA and imaging of blood flow. In children with cyanotic heart disease, longer breath holds may result in desaturation. Hence one should limit the duration of breath holds and also keep the bag filled with oxygen in order to obtain PEEP like effect. This strategy may delay onset of desaturation. In our study there were only two instances of scan interruption. However it can be a significant problem as noted by Odegard et al [6].

In future, intravascular MR techniques are likely to open new approaches for interventional and therapeutic management of children with CHD. Even though these cases were conducted without respiratory gas and CO₂ monitoring, it must be emphasized that their presence would have greatly aided the management.

Conflicts of Interest

None identified

Intellectual Contribution of Authors

Study Concept : Lt Col DK Sreevastava

Drafting & Manuscript Revision : Lt Col DK Sreevastava,

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Study Supervision : Lt Col DK Sreevastava

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