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Review

Drug anesthesia for children undergoing magnetic resonance imaging: A review

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ABSTRACT

Children who are scheduled for magnetic resonance imaging (MRI) are usually required to take anesthesia to ensure a satisfactory conclusion of the scan. An adequate depth of anesthesia makes sure that the child is immobilized during the scan and erases the anxiety and auditory stimulation that result from being in the scanner core. Several IV anesthetic regimens are been used in children to prevent movements during scans, they including ketamine, propofol (with and without remifentanil), dexmedetomidine amongst others. Inhaled anesthetics for MRI scans have also been made possible by the use of MRI-compatible anesthetic workstations. In this review we focus on drug anesthesia for children undergoing magnetic resonance imaging (MRI). We first provide a brief commentary on the administration of anesthesia in MRI, next we discuss the prevalent anesthetic agents, then a short examination of the risks and adverse effects.

1. Introduction

MRI is a non-invasive, radiation-free diagnostic procedure. Clinically it is a magnetic field with the strength of 1.5–7 T that performs MRI. These magnetic forces orientate the protons in the magnetic field in a longitudinal direction and create a spin. A high-frequency radio impulse is then applied with the same frequency as of the spin. This then triggers the protons to absorb energy. After stopping the radio frequency, the protons return to their initial position and emit radio waves that serve as raw material for the MRI [1]. Depending on the purpose of diagnosis, an MRI scan can takes about 10–30 min. It is quite a noisy apparatus and the patient is moved into a narrow pipe with limited access. For best image quality, enabling accurate diagnosis, patients have to remain motionless. Metallic materials also have to be removed as they impair image quality and may cause undesirable side effects, e.g. warming [2]. MRI is considered to be one of the safest of all the diagnostic radiological procedures employed in medicine, in spite of these safety assurances, MRI creates a very powerful static magnetic field that imposes potential hazards [3]. Indeed, MRI's magnet can attract objects containing ferrous materials and transform them into dangerous projectiles. Furthermore, strong radio magnetic fields may result in device malfunction/failure and burns. The most common magnetic field interactions are shown in Table 1.

Propofol is generally used in children for anesthesia and sedation. It decreases the cross-sectional area of the entire pharyngeal airway in a dose-dependent fashion in patients with normal upper airway morphology [4]. Mason et al. stated that there has been recorded increase in interest in the use of dexmedetomidine (DEX) for imaging and procedural sedation in children patients [5]. In comparison to other sedative agents, DEX has sedative properties that parallel natural, non-rapid-eye-movement (NREM) sleep, without significant respiratory depression [6,7].

DEX has been suggested for sedation during management of the difficult airway when preservation of spontaneous respiration is required. These benefits render DEX an efficient agent for noninvasive procedural sedation in children with obstructive sleep apnea (OSA) [8].

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Table 1
Showing hazardous magnetic field interactions.

Magnetic field type	Hazard	Potential adverse effects
Static magnetic field	Translational force: powerful attraction of ferromagnetic object to intense magnetic field. Rotational force/torque: rotation of object to align with the magnetic field	"Missile effect": acceleration of object into the bore of the magnet
Radiofrequency electromagnetic fields	Heating owing to absorbed radiofrequency energy	Tearing of tissues, pain and dislodgement of some implants
Gradient magnetic field	Electromagnetic interference Induced currents in conductive tissues Induced currents in electrical devices	Overheating burns (thermal, electrical) Device malfunction; imaging artifact Nerve and muscle stimulation Device malfunction/failure

Propofol (PRO) and dexmedetomidine are commonly used for maintaining anesthesia and sedation, and both are safe and effective in children undergoing MRI. In a study by Chandler [9], where they compared PRO with pentobarbital, midazolam, and fentanyl techniques, they concluded that PRO produces a faster induction, reduced emergence, reduced duration in post-anesthesia care unit (PACU), and less interruptions during the MRI related to patient movement [10]. However, they recorded an arterial desaturation and hypotension intermittently with the PRO technique [10]. DEX, a selective a_2-adrenergic agonist, often administered with midazolam delivers a more better sedation results than pentobarbital and chloral hydrate and it has been suggested to be a very good and efficient alternative drug to propofol during pediatric MRI [11]. In a study conducted by McMorrow et al. [11] they compared the quality of PRO and DEX techniques by assessing the dimensions of timeliness, effectiveness and safety of anesthesia care, and patient (parent) satisfaction for longer-duration MRI. They concluded that PRO demonstrated significant advantages in timeliness, obvious by reduced induction, PACU stay, and total care time. Furthermore they stated that their results revealed patients in DEX group had significantly increased incidence of MRI disturbance due to body movement, which resulted to longer MRI duration caused by repetitive scans. In conclusion, judging by increased failure rate by a sole agent, DEX is not as effective as PRO in longer MRI setting. In another report by Heard and colleagues [12] they reported that the use of DEX for MRI sedation as a sole agent was more impulsive than PRO; DEX could be effectively co-administered with midazolam, fentanyl, or ketamine [13].

2. Anesthesia for MRI

Apparent the advantage of general anesthesia for MRI scanning is that it is independent of a child's ability to cooperate [14]. The entire process, from preparation to scan time, is more predictable, and the scan quality may be of benefit because the child is immobilized and scan interruptions due to sedation side-effects are minimized [15]. Furthermore, it is possible to perform breath-holding maneuvers for images that need absolute immobilization [16]. In this setting anesthesia is an effective and quality-guaranteeing method in this [17]. In newborns and infants at risk from very short times of respiratory insufficiency due to hypoxia and bradycardia, general anesthesia is performed for safety concerns [18]. In principle all types of general anesthesia techniques can be used in MRI. If the ventilator is equipped with a vaporizer, sevoflurane is an ideal inhalative narcotic for children [19]. However, on the other hand, propofol can be used for total intravenous anesthesia [20]. Laryngeal masks and tracheal tubes can be used in the MRI setting. The decision should depend on comorbidities, anatomy and fasting status in the individual case [21].

3. Anesthetic agents

3.1. Intravenous anesthetics

Ketamine is most often used in radiological procedures, but not routinely in some countries like the UK. Ketamine is effective for analgesia for painful procedures [29]. It has adverse effects, such as nausea and vomiting after the procedure, and laryngospasm. It is mostly combined with an anticholinergic for secretion control [30]. Combination with midazolam is also common, but the effectiveness of this in treating emergence dysphoria is debated. It is good to remember that ketamine is contraindicated in patients with intracranial hypertension [31] (Table 2).

Propofol is very close to an ideal sedating agent for non-painful procedures such as MRI scans or nuclear scans, but it may induce profound respiratory depression and loss of protective airway reflexes, making it suitable for use only by physicians trained in the administration of general anesthesia or by expert airway managers with great back-up systems [32]. The data from one study [33] suggest a greater variability with a loading dose in children younger than 1 year and with a maintenance dose in children older than 7 years. The effectiveness and smooth recovery nature of this drug have caused non-anesthesiologists to gravitate toward its use, despite concerns about monitoring and airway management [34]. The most effective drugs for general anesthesia (GA) are propofol and fentanyl, but the risk of needing an advanced airway management is high [35]. Kiringoda et al. [18] confirmed in a retrospective study a low incidence of adverse events and no long-term complications in high-risk children (ASA Class 3) who received propofol GA (PSA) by an anesthesiologist for research-related imaging studies.

3.2. Inhalational anesthetics

Nitrous oxide is a potent analgesic used in pediatric sedation for radiological procedures. The use of nitrous oxide mixed with 50% oxygen or less to induce moderate sedation is acceptable only in ASA Class 1 or 2 patients [36]. Nitrous oxide should not be used in specific situations such as pneumothorax, pneumocephalus, pneumopericardium, otitis media or bowel obstruction (apple peel atresia) [37]. Care must be taken when used in addition to other sedatives (local anesthetics), as deep sedation can easily result [38]. Sevoflurane, or fluorinated methyl isopropyl ether, has been used frequently for inhalation induction of anesthesia. Owing to its non-pungency, rapid induction and quick elimination, sevoflurane may be useful for anesthesia only by professionals who are skilled in general anesthesia [39].

3.3. Other anesthetic agents

Dexmedetomidine is a potent α-2 agonist with analgesic properties [40]. It is popular around the world and there has been