Anaesthesia for MRI in the paediatric patient

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Purpose of review
The purpose of the present review is to focus on the literature in the past year and specifically the development of recent guidelines, the debate on who does the sedation anaesthesia for MRI in a paediatric patient, the use of medications and techniques, and the use of monitors and equipment.

Recent findings
The revised guidelines of American Academy of Pediatrics and American Academy of Pediatric Dentistry underline the serious risks associated with the sedation of paediatric patients and emphasize the need for proper preparation and proper evaluation. Most children require deep sedation for MRI and the practitioner must have appropriate skills to rescue the patient from general anaesthesia. In the debate on 'who does the sedation', the most important goal is to achieve uniformity in the formal training of the practitioners in key practice elements (airway management, resuscitation, vascular access, medications). Recent findings about the use of anaesthetic techniques, monitors and equipment, and complications are reported.

Summary
The MRI suite is a challenging environment for anaesthetists and nonanaesthetists, and has serious risks. A systematic approach, similar to that of anaesthesia provided in the operating room, is mandatory. A well equipped anaesthesia machine, standard monitoring, trained personnel and adequate planning should be standard for all procedures out of the operating room.

Keywords
anaesthesia, MRI, paediatrics, sedation

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Introduction

MRI requires an immobile patient for a successful study. Therefore, infants and small children need to be sedated or anaesthetized. However, because of insufficient manpower, anaesthesiologists cannot meet the increasing workload of providing sedation for each patient adequately and the nonanaesthesiologist healthcare professionals (paediatricians, emergency medicine physicians, intensivists and advanced nurse practioners) have taken on (mainly in the United States, Canada, Australia and New Zealand) an increasing responsibility of providing sedation and analgesia in children [1•].

The purpose of the present review is to focus on the literature in the past year in this field and specifically discuss the development of recent guidelines, the debate on who does the sedation anaesthesia, the anaesthetic techniques, the use of monitors and equipment, and the complications.

Guidelines

In 2006 [2], the American Academy of Pediatrics (AAP) and the American Academy of Pediatric Dentistry (AAPD) published revised guidelines for monitoring and management of paediatric patients during and after sedation for diagnostic and therapeutic procedures. The purpose of this updated statement is 'to unify the guidelines for sedation used by medical and dental practitioners, add clarification regarding monitoring modalities, provide new information from medical and dental literature, and suggest methods for further improvement in safety and outcomes'.

Specifically, the guidelines state that the sedation of children requires a systematic approach including

(1) no administration of sedating medication without the safety net of medical supervision;
(2) careful presedation evaluation;
(3) appropriate fasting for elective procedures;
(4) in urgent procedures, a balance between depth of sedation and risk;
(5) a focused airway examination;
(6) a clear understanding of the pharmacokinetic and pharmacodynamic effects of medications;
(7) appropriate training and skills in airway management;
(8) appropriate equipment for airway management and venous access;

(9) appropriate medications and reversal agents;
(10) sufficient number of people to carry out the procedure and monitor the patient;
(11) appropriate physiological monitoring during and after the procedure;
(12) a properly equipped and staffed recovery area;
(13) recovery to presedation level of consciousness before discharge;
(14) appropriate discharge instructions.

Moreover, the guidelines stress the serious risks associated with the sedation of paediatric patients (hypoventilation, apnoea, airway obstruction, laryngospasm, cardiopulmonary impairment) and the concept of rescue. Practitioners of sedation must be able to recognize the various levels of sedation and have the skills necessary to rescue the patient from a deeper level than that intended and to provide appropriate cardiopulmonary support, if needed. The document underlines the need for a proper preparation, encourages the use of capnography and clarifies the interactions of nitrous oxide with other medications.

In 2007 [3], the European Board of Anaesthesiology of the European Union of Medical Specialists (EUMS) published the guidelines for sedation and/or analgesia by nonanaesthesiologists. Many passages of the document are similar to the guidelines of the American Academy of Pediatrics and the American Society of Anesthesiologists (AAP–ASA) (patient selection, training of the staff), but, differing from those, the definitions of the sedation levels are an adaptation from the scale originally developed by Ramsay *et al.* [4], and so introducing a new variance.

Unfortunately, the scale by Ramsay *et al.* [4] is not as detailed as the traditional classification (minimal, moderate, deep sedation and general anaesthesia), which also gives full details about the responsiveness, airway, ventilation and cardiovascular function of the different levels of sedation.

Who does the sedation?

The practice of paediatric procedural sedation for MRI is different in different parts of the world.

In many countries (in most parts of Europe, Asia, Africa and Latin America), the sole practitioners are the anaesthesiologists. In France, sedation is performed by anaesthetists and nurse anaesthetists. Nonanaesthetist healthcare providers able to provide sedation also include emergency care specialists. In the UK, few trained nonanaesthesiologist practitioners do sedation/analgesia in different locations. A recent Internet survey of French university hospitals showed that anaesthesia for children was performed by paediatric anaesthetists in 85% of cases [5].

In the United States, Canada, Australia and New Zealand, paediatricians, cardiologists, emergency medicine physicians, intensivists, radiologists and advanced nurse practitioners represent the majority of specialists providing sedation and analgesia to children [1•]. Individual specialty societies have issued their own guidelines to standardize procedural sedation and analgesia and improve patients' safety. Unfortunately, these guidelines are often too generic and leave the implementation to local institutions [6]. Moreover, the professional qualification of practitioners to administer moderate or deep sedation is not uniform and a substantial variation in how the model of procedural sedation is fitted to local needs, resources, traditions and politics exists.

Krauss and Green [7•], in a very interesting review, analyse the advantages of the US model.

The first advantage is that the model seems to work as demonstrated by a high number of studies that confirm a remarkable overall safety profile.

Secondly, it allows great flexibility for hospitals to adjust their guidelines to local needs and resources.

Finally, it permits a modification of the protocols, for example the introduction of new drugs, monitoring and equipment.

The most important disadvantage is the lack of uniformity. Some hospitals may license a radiologist to perform sedation. The specialty societies have issued sedation guidelines that are sometimes inconsistent 'in open rejection of the AAP–ASA guidelines' and 'the ASA has issued statements saying that propofol use and all deep sedations are inappropriate for specialists not trained in the administration of general anesthesia'. Krauss and Green [7•] conclude advising the European and the UK anaesthetists to pursue the US model while attempting to avoid its divisiveness.

Nevertheless, in our opinion, it is difficult to shift European standards to the American model in the short term. Today, in Europe, an anaesthetist plays a leading role, being in charge of anaesthesia for children, and the concept of nurses or radiologists giving sedation to paediatric patients for MRI scans causes great concern for the safety of the patients in the anaesthesiological community.

Coté [8••] asserts that all sedation services should be under the direct supervision of the Department of Anaesthesiology and summarizes well, at the end of his review, that anaesthesiologists 'must take the lead in training, education, and establishing a collegial working relationship with nonanaesthesia colleagues'. The common goal should be to train sedationists on the requisite skill set: airway management, drug pharmacology, vascular access and resuscitation. The anaesthesiological team must provide them with appropriate monitoring and adequately staffed recovery facilities with strict discharge criteria.

The ideal approach would allow anaesthetists to play a significant and constructive role, including the development of appropriate training and credentialing processes.

Anaesthetic techniques

The practice of anaesthetizing children for MRI is poorly standardized. The technique (depth of sedation/anaesthesia) and the drugs and monitoring used vary greatly from one institution to another, despite guidelines and identical goals. General anaesthesia with tracheal intubation or laryngeal mask airway (LMA) and mechanical ventilation probably provides the best prevention of patient motion. This is compulsory if complete muscle relaxation is necessary, as for the breath-hold MRI technique [9•]. Unfortunately, this technique is invasive, time and resource consuming, and associated with equipment-related complications. Sedation is less invasive, cost and time saving, but the rate of failure and incidence of complications vary widely from one study to another.

The survey from Bordes *et al.* [5], performed through e-mailing, reports the organization of anaesthesia for MRI in 28 French university hospitals. In 80% of hospitals, children were managed by a paediatric anaesthesiologist. A routine premedication was administered and parents were admitted during induction in 52% of institutions. In 92% of cases, an intravenous (i.v.) line was routinely placed. Anaesthesia was maintained with sevoflurane in 62% of cases, with isoflurane in 22% and with propofol in 16%. Tracheal intubation was mandatory for 36% of hospitals, but 80% routinely used tracheal intubation or LMA. All patients were monitored by pulse oximetry, capnography and blood pressure monitoring. Forty-eight per cent of institutions had a recovery room close to the MRI unit and 72% of the patients were discharged after at least an hour.

The results of this survey probably account for the practice in other European countries. An international inquiry is lacking and could be useful to compare such different habits for a single procedure.

No extensive studies with sufficient power to estimate success rate, safety, advantages and disadvantages of different techniques were published last year. Nevertheless, some publications focus on drugs and strategies commonly used to sedate children during MRI.

Chloral hydrate is widely used as a sedative to carry out nonpainful procedures in children. An Italian study retrospectively evaluated 1104 chloral hydrate sedations provided by anaesthesiologists during MRI [10]. The drug was given orally at doses ranging from 50 to 100 mg/kg (up to 1.5 g). After 30 min, if the anaesthesiologist judged the sedation to be insufficient (Skeie Scale <3), a 'rescue' i.v. drug was administered (midazolam 0.025–0.5 mg/kg, or pentobarbital 4–6 mg/kg or ketamine 1–2 mg/kg). The success rate of chloral hydrate was 80.4%, and the overall failure rate was 2.3%. The chloral hydrate induction time was 39.1 ± 20.5 min, and the sedative effect lasted 164 ± 85 min. With this sequential approach, authors reported a low incidence of side effects: SpO_2 below 90% in 0.4% of patients, respiratory obstruction in 2.4%, vomiting in 0.2% and agitation in 1.5%. No patient was bag-mask ventilated or intubated and no scan was cancelled for respiratory complications.

This study confirms the low reliability of chloral hydrate when used alone for MRI sedation. The failure rate of nearly 20%, long and variable induction time, and sedative effect are not a good profile for a drug to provide sedation in an efficient MRI service. Despite the low incidence of adverse effects, the authors conclude that the drug is not completely well tolerated, and this highlights the importance of having a physician skilled in advanced airway management.

Dexmedetomidine is a selective alpha2 adrenergic receptors agonist. Heard *et al.* [11] used dexmedetomidine in 21 children aged 1–8 years scheduled for MRI. Eight patients received a bolus dose of 0.5–1.5 μg/kg followed by a continuous infusion of 1–1.5 μg/kg per hour, but most patients moved during the MRI. Midazolam (0.1 mg/kg i.v.) was given to the following 13 patients and the dexmedetomidine dose was reduced to a 1 μg/kg bolus and 0.5–1 μg/kg per hour continuous infusion. The addition of midazolam significantly reduced the incidence of movement without any complications. In this retrospective study, dexmedetomidine has unpredictable effects in children and by itself is often inadequate to produce deep sedation as required during paediatric MRI.

Midazolam–pentobarbital–fentanyl (MPBF) combination is frequently used to induce deep sedation in children especially in the United States where nonanaesthesiologists manage paediatric procedural sedation. The overall success rate and the incidence of complications vary widely with this technique.

Propofol has many advantages for MRI anaesthesia: rapid onset, effective and adjustable anaesthesia with rapid recovery, and, in addition, prevention of nausea and vomiting. A prospective randomized trial comparing MPBF and propofol for deep sedation during MRI was carried out by paediatric emergency physicians [12]. In this study, 60 patients aged 1–17 years randomly received a sequential i.v. dose of midazolam (0.1 mg/kg), pentobarbital (2 mg/kg and 1 mg/kg when needed) and, if adequate sedation was not achieved, fentanyl (1 μg/kg) or a loading dose of propofol titrated on the desired level of sedation and followed by continuous infusion (initiated at 6 mg/kg per hour to a maximum of 15 mg/kg per hour). A modified Ramsay scale was used to measure the depth of sedation and a score higher than four was the goal. A blind observer assessed discharge readiness (Aldrete score ≥8). In both groups, no sedation failures or major adverse events were recorded. Propofol provided significantly shorter recovery, induction and total scan times, and better caregiver satisfaction scores. Propofol adverse events were transient hypotension (four patients) and respiratory depression during induction (four patients), but orotracheal intubation was never used in any patient. MPBF sedation was associated with transient hypotension (one patient), emergence agitation (6.7%) and prolonged sedation (20%). Authors conclude that in a busy sedation service, the favourable induction and recovery profile of propofol has clinical significance and potential economic impact by optimizing the use of the MRI scanner.

Propofol was also used in a small study including 32 children over 3 years of age. Authors compared children affected by metachromatic leukodystrophy (MLD) with those without brain alterations. Patients were induced with 1–1.5 mg/kg i.v. propofol and maintained with 0.1–0.15 mg/kg per minute continuous infusion. All patients completed the scan without any complications and were sent back to the ward after 15 min. Children with MLD do not require different doses of propofol from healthy patients [13].

Drugs, doses and success rates of the techniques are shown in Table 1.

Monitoring and equipment

The strong magnetic field and the radiofrequency emissions require the use of special MRI-compatible equipment. ECG pads, pulse oximetry wires and probes can induce thermal injuries. Special pads and probes are mandatory to avoid coiling wires.

Pulse oximetry, noninvasive blood pressure (NIBP) and capnography are the standards for safe anaesthesia during MRI [2,5,9•,11,12]. Pulse oximetry is not a reliable ventilation monitoring procedure because there is a variable lag time between the onset of hypoventilation and the lowering of oxygen saturation, especially if continuous O_2 is administered [14]. Although measurement of expiratory CO_2 is the earliest indicator of respiratory compromise, the position of the child's head and the motion of the chest wall should be checked frequently to ensure airway patency [2].

Complications

There are no large multicentre studies with sufficient importance to estimate the incidence of infrequent events associated with sedation.

The most common serious complications of sedation involve compromise of the airway or respiratory depression, but the reported incidence of serious adverse events in reviewed literature is low [9•,10–13,15]. However, the frequency of events that have potential to harm and require prompt rescue interventions is significant. Chloral hydrate is associated with respiratory obstruction in 2.8% of patients and with prolonged desaturation (SaO_2 <90%) in 0.4% [10]. Major adverse events requiring resuscitative assistance occurred in 1.2% of patients given a MPBF combination [16].

Atelectasis is a described complication of general anaesthesia. Two studies analysed the influence of general anaesthesia and sedation on atelectasis formation in children undergoing MRI.

Lutterbey *et al.* [9•] compared general anaesthesia with tracheal intubation and propofol sedation, performing two additional lung scans (before and after the main scan) in children undergoing routine MRI. Atelectasis scores were markedly higher in the general anaesthesia group than in the sedation group (80 vs. 42% in the first scan, 94 vs. 84% at the end). Atelectasis scores were higher in young children, but all children had normal oxygen requirements and saturations. After this study, the authors modified their habits, preferring propofol sedation; consequently, the frequency of tracheal intubation for paediatric MRI decreased by 50%.

Table 1 Doses and success rates of drugs used for paediatric MRI sedation (explanation in the text)

Drugs	Doses	Success rate	Reference
Chloral hydrate	50–100 mg/kg	80.4%	[10]
Dexmedetomidine	0.5–1.5 μg/kg + 1–1.5 μg/kg per hour	Unpredictable	[11]
MPBF	Midazolam, 0.1 mg/kg; pentobarbital, 2–4 mg/kg; fentanyl, 1–2 μg/kg	100%	[12]
Propofol	1–1.5 mg/kg + 0.1–0.15 mg/kg per minute	100%	[13]

MPBF, midazolam–pentobarbital–fentanyl.

Atelectasis in children anaesthetized for cardiothoracic MRI was also studied by Blitman *et al.* [15]. Authors compared a group of children requiring no anaesthesia and a group receiving various anaesthetic medications including general anaesthesia with positive pressure ventilation. Thirty-seven per cent of anaesthetized patients developed significant atelectasis independently of the anaesthesia technique (none in the control group). A strong risk factor was age younger than 1 year (atelectasis incidence 80%).

Conclusion

The most important goal of paediatric sedation is safety. As children are particularly vulnerable to the adverse effects of sedation and anaesthesia, an anaesthetist must have both the experience and equipment necessary to deal with sedated patients. The use of sedation and anaesthetic techniques requires a rigorous respect of the rules (proper preparation, proper evaluation, appropriate skills to rescue the patient, proper recovery) [8••].

The future development of sedation anaesthesia for MRI in children must provide for improving the training of practitioners and safety of the procedure. The training must be shared and as uniform as possible to avoid differences in complication rates between different groups of practitioners. The safety of the procedure is defined by the possibility of having equipment, monitoring and medications suitable for different levels of sedation.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:
- • of special interest
- •• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 526–527).

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