Diagnostic and therapeutic value of magnetic resonance imaging in children. A single-center retrospective cohort study

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Abstract

Background: **The use of clinical imaging in pediatric patients has expanded significantly over the last decades. Particularly in younger age groups, some form of sedation is often required to perform the time-consuming scan. Providing anesthesia to children, specifically within the MRI suite, poses certain risks. This study aims to analyze the indications and therapeutic consequences of pediatric MRI procedures, along with potential adverse effects of both MRI procedure and general anesthesia in this patient population. As a final outcome, this study aims to provide a cost-benefit analysis of pediatric MRI in terms of patient safety, diagnostic value and resulting potential therapeutic consequences .**

Methods: **This study was conducted as a retrospective longitudinal data analysis in a single secondary care hospital. Data were collected for all children (aged 6 months to 16 years) undergoing MRI under general anesthesia at our hospital. The time frame for data collection was November 2016, the start of our program, through March 2023. The primary and key secondary outcome are the diagnostic value and the therapeutic value of pediatric MRI, respectively. Secondary outcomes include the anatomical regions undergoing imaging, adverse events related to anesthesia or MRI procedure, including hospital admissions, and the impact of the COVID pandemic on the primary and key secondary outcome.**

Results: **During the study period (November 2016 - March 2023) a total of 437 MRI scans were performed under general anesthesia. The primary indication of MRI was the exclusion of intracranial abnormalities (n=321; 73.5%). The most frequent pre-existing symptoms were developmental delay (n=143; 32,72%) and other symptoms (n=153; 35%). MRI resulted in a diagnosis for 70 patients (16%), and treatment changes occurred after 33 MRIs (7,6%). During the COVID-19 pandemic, with restricted indication for MRI, the diagnostic and therapeutic value of pediatric MRI increased significantly to 37.3% (p<0,001) and 14,5% (p<0,01) respectively. No post-procedural serious adverse effects of general anesthesia or MRI were reported in the medical files.**

Conclusions: **MRI remains a viable tool for diagnostics in the pediatric population. Sedation or general anesthesia enables accurate and reliable imaging in cases where patient cooperation is challenging. However, redefining indications might improve resource allocation and prevent futile interventions.**

Presentation: This work shall be presented by shared first author S Buelens as part of his master's thesis defense on the BeSARPP Graduation Day, 01/06/2024.

Board review: This study is approved by the ethical committee of Jessa Hospital, Hasselt, Belgium, presided by prof. dr. Koen Magerman. Approval was granted on 25th April 2023 (f/2023/045). Written informed consent was waived considering the retrospective nature of this study. Inclusion started on 18/11/2016 and lasted until 31/03/2023.

Introduction

The use of clinical imaging in pediatric patients has expanded significantly over the last few decades[1]. Magnetic Resonance Imaging (MRI) offers advantages over other imaging techniques such as Computed Tomography (CT), as it provides superior imaging of soft tissue, ligaments and organs. Most importantly, the concern for radiation exposure with CT scanning and the associated risk of carcinogenesis, particularly in children, have made MRI the preferred diagnostic tool in pediatric settings[2-4].

Advancements in MRI technology have led to decreased scanning times, higher resolution images and fewer motion artifacts. However, even the shortest MRI procedure still takes fifteen minutes, and depending on the anatomical area, it usually lasts 30-45 minutes. To minimize artefacts, the patient should be able to remain motionless and may also need to perform breath holds for certain sequences[4]. Therefore, some form of sedation or general anesthesia is generally required for MRI in children, especially in the younger age group (6 months to 6 years old)[5].

Nowadays, general anesthesia (GA) is considered very safe with a very low complication rate, but risks may vary according to individual patient characteristics. Especially in younger children with comorbidities, minor morbidity due to GA is more frequently observed[6,7]. Additionally, in 2016, the FDA published a warning regarding the prolonged use of anesthetic drugs in children less than three years old[8]. The warning followed animal models suggesting that anesthetic drugs could have a potential neurotoxic effect on the developing brain, possibly leading to long-term cognitive effects such as learning disabilities and behavioral issues. However, this statement is currently not supported by the involved European Societies (ESAIC, ESPA, EACTAIC, EuroSTAR) due to insufficient evidence in humans[9].

In addition to the risks of GA or sedation, MRI has specific risks for both the patient and attending healthcare personnel. These risks have been extensively described in literature[10]. Potential MRI safety risks include projectile injury, burns, magnetic interference with implants and other medical devices, and acoustic injuries. When following standard MRI safety procedures these risks are minimal[11]. Additional risk is involved with the use of gadolinium-based contrast agents (GBCA) for tissue contract enhancement. Patients with renal insufficiency require a dose reduction as nephrogenic systemic fibrosis is a possible but uncommon toxic reaction to GBCA. Allergic reactions to GBCA are infrequent (0.1%) but categorized as severe in 7–20% of cases[10].

The MRI facility's limited accessibility and need for specialized MRI-compatible equipment create additional risk during sedation or GA. Consequently, in the event of complications, the availability of MRI compatible equipment (e.g. videolaryngoscopy) and personnel support is limited. When assessing the potential for adverse events, it is crucial to consider the physical separation between patient and anesthesiologist, particularly when the child is being imaged in the MRI unit[4,12].

There is extensive literature regarding the indications for MRI scans in a pediatric population for various conditions. Guidelines exist on the role of MRI in children with autism spectrum disorders and developmental delay. Currently, there is no support for brain MRI as a routine investigation in autism spectrum disorders or developmental delay, without additional findings[13-15]. MRI investigation of the lung could be an alternative to US and CT, while providing anatomical and functional assessment of the chest in one session. Indications are extensive; acute and chronic infection, airway disease (e.g. cystic fibrosis), interstitial lung disease, pulmonary masses and congenital malformations[16]. There is a role for cardiac MRI for evaluating the structure and function of the heart. In children and adults with congenital heart disease, MRI is indicated for various reasons. MRI can, for example, identify pulmonary and systemic venous anomalies, assist in the quantification of shunts, stenoses and regurgitations and be helpful for postoperative follow-up[17]. Even in an acute setting, MRI can be indicated, as MRI appears to be equivalent to CT scan for confirming and excluding acute appendicitis in children and adults[18].

Literature on the therapeutic implications of MRI scans is limited. Although neuroimaging studies can reveal nonspecific abnormalities, it only contributes to diagnosis of the etiology in developmental delay in only 0,2-2,2% of cases[19]. Additionally there is a high incidence of incidental findings when performing MRI brain scans in children. One prospective trial reported 35,5% normal findings, 27,1% pathological findings and 37.4% incidental findings in 436 symptomatic pediatric patients[20]. A more recent meta-analysis found 16,4% of incidental findings in healthy children brain MR of which only 0,4% required treatment[21]. Mogensen et al. reported abnormal findings in 33 out of 208 girls with precocious puberty and no other neurological symptoms, with 20 considered incidental[22].

General anesthesia for MRI in the pediatric population was introduced in our institution in

2016. In this study, we report on the indications and therapeutical consequences of MRI scans under GA in young children. With this analysis of our current practice, we aim to make improvements for the future.

This study aims to analyze the indications and therapeutic consequences of pediatric MRI procedures in our institution, along with potential severe adverse effects of both the MRI procedure and GA in this patient population.

Material and Methods

Study design and patient selection

This mono-center, investigator-initiated, longitudinal, retrospective observational cohort study was performed at the Jessa Hospital, Hasselt, Belgium. This study is approved by the ethical committee of Jessa Hospital, Hasselt, Belgium, presided by prof. dr. Koen Magerman. Approval was granted on 25th April 2023 (f/2023/045). Written informed consent was waived considering the retrospective nature of this study. This study is reported according to the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) statement[23].

All pediatric patients (aged 6 months - 16 years) scheduled for an MRI procedure under general anesthesia in the Jessa hospital from the start of our pediatric MRI program in November 2016 to March 31th 2023, were included in the study These patients were identified based on yearly reports of our radiology department. Planned pediatric MRI cases are scheduled only once monthly.

Data collection

The following data were collected from the patient files: baseline demographics comprising age, gender, weight, length, BMI. Medical history; indication for MRI scan, pre-procedural symptoms, anatomical region scanned with MRI, clinical outcomes. The electronical medical health record (EMR) was screened for following serious adverse events: debilitating dizziness, nausea and vomiting, diarrhea, new onset headache, skin irritation or rash, burns, serious behavioral problems, unplanned overnight hospital stay and mortality.

Outcomes

The primary outcome of this study is to evaluate the diagnostic value of pediatric MRI, defined as the total number of MRI scans that showed any abnormalities divided by the total number of MRI scans performed. The key secondary outcome is the therapeutic value, defined as the total number of MRI scans that resulted in a (change in) medical therapy divided by the total number of MRI scans performed. Therapeutic implications were considered when there was a change in prescribed medication, the need for surgery or other interventions (e.g. physiotherapy). Other secondary outcomes are the anatomical regions undergoing imaging, adverse events related to GA or the MRI procedure, including hospital admission, and the impact of the COVID pandemic on the primary and key secondary outcome and the associated financial implications.

Magnetic resonance imaging and general anesthesia procedure

The MRI scan employed for our pediatric population utilizes a magnetic field of 1,5 Tesla. The MRI protocol is adapted according to the indication and the anatomical region requiring imaging.

In our institution, MRI in children is performed under GA with an attending anesthesiologist and assisting anesthetic nurse. There is no specific protocol for providing anesthesia in children at our hospital. The technique used is based on the experience and preferences of the attending anesthesiologist. The majority of patients receive inhalational anesthesia with sevoflurane, both for induction and maintenance of general anesthesia. An intravenous access is achieved after induction with inhalational anesthesia. Airway is secured by a laryngeal mask. Patients remain on spontaneous ventilation in most cases. Post procedural care is provided in the same location with a bed-side pediatric nurse, so the patients are monitored at all times with an anesthesiologist nearby. Continuous monitoring is provided with standard MRI compatible monitoring (ECG, pulse oximetry, blood pressure) including capnography on a MRI-compatible ventilator.

Statistical analysis

Continuous data are shown as mean ± SD (25%, 75%) and categorical data are presented as frequencies (%). Comparisons between groups were performed with the Student t test. Categorical variables were analyzed with a Chi-Square test. A p-value <0.05 was considered statistically significant. All analyses were performed with SPSS Version 29 (IBM SPSS Statistics, IBM Corporation).

Results

Between 18th November 2016 and 31st March 2023, a total of 513 MRI scans were planned. A STROBE flowchart depicting inclusion and

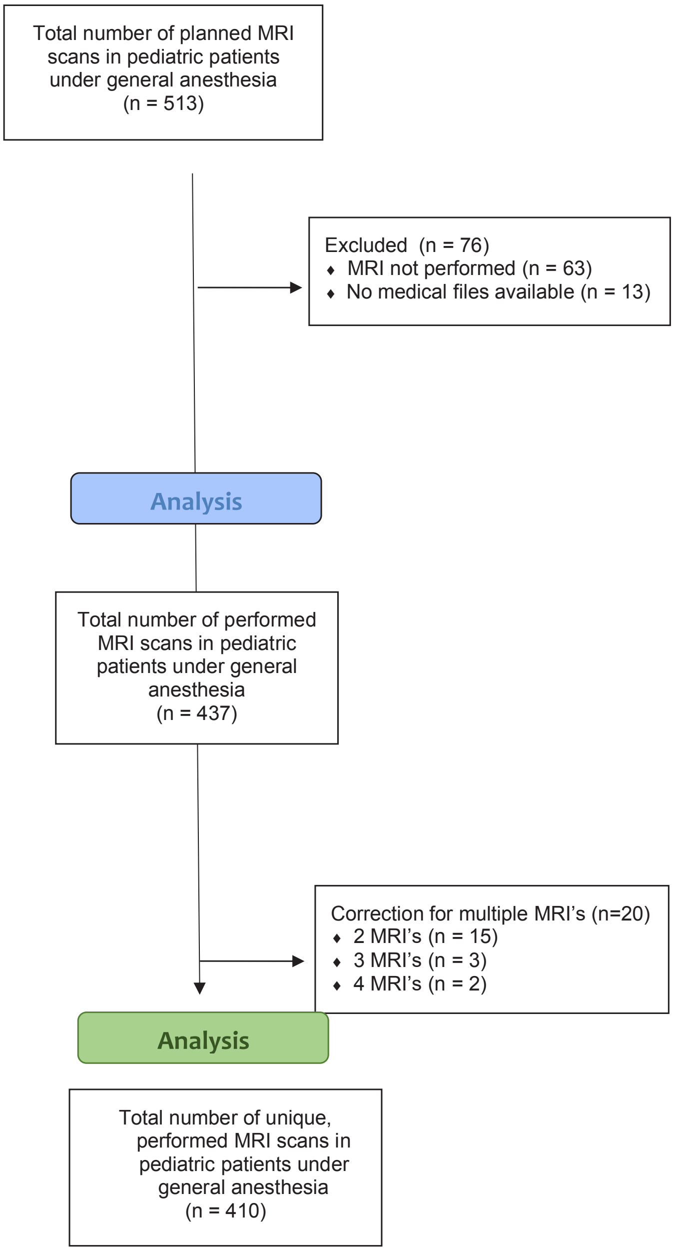

Fig. 1 — STROBE flowchart depicting inclusion and exclusion.

exclusion of patients is presented in Figure 1. In total, 437 planned MRI scans were performed under general anesthesia in a pediatric population. After correction for multiple MRIs, our study involved 410 unique patients (Figure 1).

Figure 2 shows the numbers of planned and conducted MRI scans per year, excluding 2016 and 2023 due to incomplete data for those years. A reduction in planned and conducted MRIs per years was observed during the COVID19 pandemic in 2020 and 2021.

Baseline characteristics are presented in Table 1

The age distributions showed the majority of children undergoing GA for MRI being younger than 6 years old with 118 of 410 unique patients (28,78%) being under 2 years old and 210 patients (51,49%) between the age of 2 and 6 years. Male sex was slightly overrepresented (n=226; 55.12%). About half of the children had a previous medical history (n=231; 56,34%) with respiratory disease (8,05%), autism (9,27%) and epilepsy (7,07%) being the most common. 129 Patients (31,46%) were prescribed medication for these or other health problems (Table I).

Primary and secondary outcomes

Indications for MRI, pre-existing symptoms and anatomical regions visualized by MRI are listed in Table II. Exclusion of intracranial abnormalities (n=321; 73,5%) and exclusion of malignancies in other regions (n=51; 11,7%) were the main indications for MRI. The two most common pre-existing symptoms were developmental delay (n=143; 32,72%) or other symptoms (n=153; 35%). MRI of the brain was the anatomical region

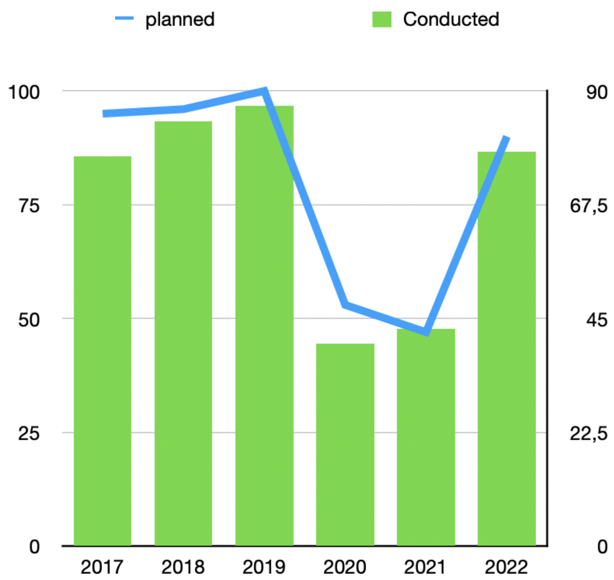

Fig. 2 —Numbers of planned and conducted MRI per year. Excluding 2016 and 2023 due to incomplete data for those years.

most frequently visualized, accounting for 391 cases (89.49%).

For the primary outcome, i.e. the diagnostic value of pediatric MRI, 70 out of 437 MRIs (16%) resulted in a diagnosis. For the key secondary outcome, i.e. the therapeutic value of pediatric MRI, 33 MRI procedures (7.6%) resulted in a (change in) medical therapy. Out of 438 scans, 12 resulted in a change in drug therapy (2.73%), 15 led to surgery (3.42%) and 6 led to the initiation of physiotherapy (1.36%). Further analysis in the developmental delay group, (n=143), only 19 scans (13,3%) led to a diagnosis. In the 410 unique patients, the diagnostic rate was even lower, with only 15 out of 137 scans (10,9%) being diagnostic.

A sub-analysis for different age groups, i.e. patients under 2 years old, 2 to 6 years old and above 6 years of age is presented in Table III. MRIs conducted in the youngest age group (under 2 year old) showed a slightly but not significantly higher diagnostic rate (21 out of 129 MRIs or 18,6%) compared to older age groups. A MRI diagnosis was reported in 32 out of 221 scans (14,5%) for children aged 2 to 6 years and 14 out of 87 scans (16,1%) for those above 6 years old. No statistically significant difference was noted between groups when analyzing for therapeutic implications or overnight stay after MRI (Table III). The three patients staying overnight were respectively 10 months, 11 months and 2 years 10 months old. Indications for staying overnight were the diagnosis of a large cerebellar tumor

Table I. — Demography of 410 unique patients. Data are expressed as frequencies (%).

	Unique patients (n=410)
Gender	
Male	226 (55.12%)
Female	184 (44.88%)
Age	
< 2 years old	118 (28.78%)
1-6 years old	210 (51.22%)
>6 years old	82 (20.00%)
Previous medical history	231 (56.34%)
Cardiovascular disease	5 (1.22%)
Hypertension	2 (0.49%)
Diabetes	1 (0.24%)
Obesity	10 (2.43%)
Respiratory disease	33 (8.05%)
Malignancies	1 (0.24%)
Chronic kidney disease	4 (0.98%)
Chronic liver disease	2 (0.49%)
Chronic bowel disease	12 (2.93%)
Chronic nerve disease	8 (1.95%)
Cerebrovascular disease	11 (2.68%)
Hematological malignancy	6 (1.46%)
Syndrome of Down	1 (0.24%)
Autism	38 (9.27%)
Cerebral palsy	4 (0.98%)
Pubertas praecox	12 (2.93%)
Epilepsy	29 (7.07%)
Other	12 (2.93%)
Home medication (yes)	129 (31.46%)
1 medication	82 (63.56%)
2 medications	20 (15.50%)
More than 3 medications	27 (20.93%)

Table II. — Clinical indications, pre-existing symptoms and body part visualized in MRI scan for all scans. Data are expressed as frequencies (%).

	All scans (n=437)
Clinical indication for MRI	
Exclusion of intracranial abnormalities	321 (73.5%)
Exclusion of malignancies	51 (11.70%)
Follow-up of epilepsy	2 (0.46%)
Exclusion of osteomyelitis	9 (2.06%)
Other	61 (14.00%)
Symptoms	
Vomiting	24 (5.49%)
Headache	65 (14.90%)
Developmental delay	143 (32.72%)
Sleep issues	4 (0.90%)
Swelling	14 (3.20%)
Seizures	50 (11.44%)
Balance problems	17 (3.89%)
Conduct disorders	47 (10.76%)
Febrile convulsions	14 (3.20%)
Other	153 (35.00%)
Anatomical region visualized	
Head	391 (89.49%)
Pituitary gland	10 (2.28%)
Lower extremities	7 (1.60%)
Spinal column	14 (3.20%)
Pelvis	10 (2.29%)
Neck and soft tissues	5 (1.14%)

Table III. — Subanalysis for different age groups. Data are expressed as frequencies (%). Differences between groups were analysed with a Chi X test. A p<0.05 is considered statistically significant.

All MRIs (n=437)	<2 years (n=129)	2-6 years (n=221)	>6 years (n=87)	p-value
MRI resulting in diagnosis				0.60
Yes	24 (18.6%)	32 (14.5%)	14 (16.1%)	
No	105 (81.4%)	189 (85.5%)	73 (83.9%)	
MRI resulting in treatment (yes)	12 (9.3%)	14 (6.3%)	7 (8.0%)	0.60
Drug treatment	2 (16.7%)	5 (35.7%)	5 (71.4%)	0.09
Surgery	6 (50%)	8 (57.1%)	1 (14.3%)	
Physiotherapy	4 (33.3)	1 (7.1%)	1 (14.3%)	
Overnight stay after MRI: Yes	2 (1.6%)	1 (0.5%)	0 (0.0%)	0.33
Patient deceased on 01/05/2023	0 (0.0%)	0 (0.0%)	1 (1.1%)	0.13

Table IV. — Sub-analysis for period of MRI scan, with or without COVID-19 restrictions. Data are expressed as frequencies (%). Differences between groups were analyzed with a Chi X test. A p<0.05 is considered statistically significant.

All MRIs (n=437)	No COVID (n=354)	COVID (2020-2021) (n=83)	p-value
MRI resulting in diagnosis			<0.001
Yes	39 (11.0%)	31 (37.3%)	
No	315 (89.0%)	52 (62.7%)	
MRI resulting in treatment (yes)	21 (5.9%)	12 (14.5%)	<0.01
Drug treatment	9 (2.5%)	3 (3.6%)	
Surgery	9 (2.5%)	6 (7.2%)	0.54
Physiotherapy	3 (0.8%)	3 (3.6%)	
Overnight stay after MRI: Yes	1 (0.3%)	2 (2.4%)	0.03

on MRI for one patient and the two others were already hospitalized because of failure to thrive. No adverse events of general anesthesia or MRI procedure itself were observed.

A second sub-analysis was performed to assess the impact of the COVID-19 pandemic restrictions (Figure 2) on the primary and key secondary outcome and the associated financial implications (Table IV). Due to the restrictions, the diagnostic and therapeutic value of pediatric MRI increased significantly in 2020 and 2021 to 37.3% ($p<0,001$) and 14,5% ($p<0,01$) respectively.

No post-procedural adverse effects such as dizziness, nausea, vomiting, diarrhea, headache, drowsiness, hearing problems, burns or behavioral disorders of general anesthesia or MRI were reported in the medical files. One patient died during the time frame of the data collection, due to a pre-existing medical condition. No patients were admitted to the hospital for unplanned overnight stay.

Discussion

In this cohort study with a descriptive analysis of all MRI scans performed under general anesthesia at the JESSA Hospital Hasselt in children (aged 6 months - 16 years) during a 7-year period, the following important observations were made: the main indication for pediatric MRI is exclusion of intracranial abnormalities (73,5%) and consequently MRI of the brain accounts for the majority of all cases (89.49%). The diagnostic and therapeutic value of pediatric MRI procedures is relatively low given the fact that only 16% of all MRI´s resulted in a diagnosis and only 7.6% of all MRI´s had therapeutic implications. However, during the COVID-19 pandemic with restricted indication for MRI´s, the diagnostic and therapeutic value of pediatric MRI increased significantly to 37.3% ($p<0,001$) and 14,5% ($p<0,01$) respectively. Diagnostic rates reported in our report seem low, but when compared to the reported 0.2-2.2% diagnostic rate in a group of patients undergoing MRI for developmental delay in the literature, this is an acceptable rate[19]. General anesthesia and the MRI procedure itself are found to be safe with no single documented serious adverse event in 437 procedures. As we extracted data only from the EMR, adverse effects that were easily treated or not deemed necessary to report on, might have been missed, leading to information bias.

Notably, infants under the age of 6 months were not included as they receive MRI scans in our institution during their natural sleep process, avoiding general anesthesia or sedation at this very early age. The feed-and-swaddle method used is described in the literature as a mean of avoiding anesthetic drugs in very young infants[5,24]. This also explains the rather restrictive number of scans performed in a 6 year period.

The low rate of significant diagnoses and therapeutic implications was not within our expectations. Regarding the indications for scanning, the majority was for neurological indications. With developmental delay being the most common described symptom besides “other symptoms”. Diagnosis of the etiology of delayed development is essential for providing treatment options. International guidelines do exist that describe algorithms for the screening in global developmental delay and intellectual disability. History and physical examination thereby remain the first steps in search for a diagnosis. Brain imaging, with MRI being the modality of choice, is only recommended in patients with indications on clinical examination, e.g. microcephaly[13,14]. Although neuroimaging studies can reveal nonspecific abnormalities, it contributes to diagnosis of the etiology in developmental delay in only 0,2-2,2% of cases[19]. In this regard a diagnosis in 16% of all scans and 13,3% of scans performed for developmental delay the indications for performing a MRI scan in our institution are quite accurate. Incidental findings are included in these numbers.

The observed decrease in MRI procedures observed during the COVID-19 pandemic is in line with the reduction in national numbers of hospital related procedures in 2020 and 2021[25]. Interestingly, this decrease is associated with a significant increase in both diagnostic rate and therapeutic implications. This might implicate that, during periods of resource scarcity, efficient allocation was ensured. Further analysis of the indications during this period could lead to less unnecessary planned MRI scans with associated financial burden for society and need of general anesthesia in children. However, further statistical analysis would be needed to make a statement on correlation between these findings.

Although providing general anesthesia to children is considered safe, the risks for adverse events are never non-existent. Major morbidity, including cardiac arrest, brain damage and death, are rare[6]. There were no major incidents noted in our study. The death of one patient during the course of our analysis was not related to the MRI procedure or associated anesthesia but as a consequence of underlying conditions during the time frame of our data collection. Minor morbidity, especially respiratory events and vomiting, are more common. The likelihood of minor events increases in children under the age of 1 and in patient with a higher ASA status (3 and above)[6]. We did not detect any adverse effects of the general anesthesia or the MRI procedure. However, seeing as we only had access to the EMR, there is a risk for information bias. According to other extensive reports, serious adverse events remain rare even in tertiary pediatric centers with high volumes and a complex patient population[7,26].

GA for MRI procedures in our hospital is provided with inhalational anesthetics. A similar retrospective study by Vinson et al. including 24.052 patients showed more adverse events when using volatile only anesthesia. Both the incidence of hypotension and mild desaturation episodes were significantly increased in the volatile only groups compared to volatile + propofol groups[7]. Recently newer agents, e.g. dexmedetomidine, have become available. Studies suggest that this offers a feasible, effective and safe alternative for inhalation agents and could even be applied by trained nurses[5,7]. Lastly, a retrospective study by Machado-Rivas et al. showed that, among other co-variates, MRI scan time was the strongest predictor of anesthetic medication exposure in children undergoing MRI with sedation. The use of inhalational anesthetics is increasingly being scrutinized because of the environmental impact of halogenated vapors such a sevoflurane and the use of nitrous oxide. Especially when used in a location without proper scavenging systems or when low flow anesthesia is not possible, excess amounts of these drugs might be released into the environment, adding to the total carbon footprint of these procedures. Suggestions to reduce scan time and therefore anesthetic drug dose are a higher field strength, unenhanced technique and single body part imaging[27]. Even in the absence of significant incidents, conducting a review and revising our current practices could enhance the safety and the sustainability of our anesthetic procedures.

Administering general anesthesia to children undergoing MRI comes at a cost[5,28]. The cost of performing a single MRI under general anesthesia in our institution is about 580€, which is almost completely covered by the national health care system. Only about 10% of this budget is a contribution for the anesthesiologist. Considering the time invested and the risks associated with administering anesthesia to children outside of operating rooms, there is a need to enhance the cost-effectiveness of these procedures. A cost-effective analysis of the anesthetic regimen for children undergoing MRI in Japan concluded that sedation by anesthesiologists is the most cost-effective. In comparison with sedation by non-anesthesiologist and general anesthesia by anesthesiologists[28]. A formal cost-benefit analysis cannot be made with our reported data, however. We should strive to improve our resource allocation.

A large meta-analysis by Thestrup and colleagues evaluated the usefulness of non-pharmacological interventions for children and youngster (2-18 years) undergoing MRI. The interventions in the different studies included mock scanners, toy models, videos and reading material about MRI, art therapy and various distraction methods. The authors concluded that non-pharmacological interventions reduce the need for sedation or general anesthesia, especially in 3 to 10 years old children. In addition these interventions reduce total scan time and retain image quality for all age groups[29]. In our hospital the use of non-pharmacological interventions for this age group is currently limited and could be extended in order to reduce the number of patients that require general anesthesia or sedation.

Out of the originally scheduled 513 MRI scans, 63 were unexpectedly omitted and the reasons remain unidentified. No discernible reasons for cancellations were evident in the electronic medical records. Possible explanations may include cancellations initiated by the radiology department, the anesthetic department or at the request of the patient and their parents (or legal guardian). As this a considerable number further analysis is needed to, again,improve efficacy and resource allocation.

There are several limitations to consider. First, the generalizability of these results might not be applicable to other institutions performing MRI scans in children due to the single center design of this study. Second, incidental findings on MRI were considered abnormal adding to the number of diagnostic scans. Thirdly, interpretation of our findings might be further limited since this is a retrospective study. Indeed, minor per- or post-procedural adverse events, such as hypoxia, bradycardia or hypotension might have occurred during or shortly after the procedure, but may not have been documented in the electronic medical record. Finally, we were unable to retrieve the data of patients undergoing MRI without any form of sedation to make a comparison.

Conclusion

MRI remains a viable asset for performing diagnostics in the pediatric population. Some form of sedation or general anesthesia enables accurate and reliable imaging in cases where patient cooperation is challenging.. There is substantial cost involved, and more stringent preoperative screening and clinical examination might lead to improved diagnostic and therapeutic rates, thereby also increasing cost-effectivenes and resource allocation. As for our institution re-evaluation of the existing MRI protocols, adding non-pharmacological interventions and refinements in anesthesia techniques could provide us with faster and safer options, especially for the very young patient population. This analysis will lead to changes in our institution offering improvements in safety, cost-effectiveness and overall patient outcomes.

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doi.org/10.56126/76.S1.03