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Abstract

Introduction

Magnetic Resonance Imaging (MRI) can be a challenging examination, particularly for children. The aim of this Clinical Perspective is to outline early experiences, based upon a service evaluation (defined as an assessment of how well the intended aims are achieved), of the Playful Magnetic Resonance Imaging Simulator (PMRIS) (Domed, Lyon, France) in reducing the number of children requiring general anaesthetic (GA) in order to undergo Magnetic Resonance Imaging (MRI).

Methods.

Baseline data from an audit of children undergoing MRI under GA in 2017 had previously been captured as part of the funding bid for the PMRIS. Estimation of costs associated with anaesthesia where made, then combined with the overall numbers of MRI under GA to estimate projected anaesthetic related cost-savings based on the reported effectiveness of the PMRIS. Once the PMRIS was in place, data were collected for children attending a Play Specialist supervised session. The number and age of children proceeding directly to MRI without requiring a GA was determined. The associated cost benefit of children was calculated and compared with the projections made in the initial funding bid.

Results.

Over a 7 month period 36 children, average age 6 years, age range 4 to 11 years, who had initially been triaged for MRI under GA, attended a Play Specialist led session on the PMRIS. Of these, 30, average age 6 years, age range 4 to 11 years proceeded directly to MRI without a GA. Based on the costings used for the initial funding bid, this equates to a gross cost-saving of £9,000 over 7 months.

Discussion.

This service evaluation shows a positive impact of Play Specialist sessions using the PMRIS with 30 out of 36 children having a successful awake MRI as a result. There are limitations to this evaluation, particularly that whilst all these children had been triaged for MRI under GA it cannot be known how many might have had an awake MRI with different preparation. Nevertheless, according to the local referral pathways these children would otherwise have had MRI under GA.

Conclusion.

This service evaluation has shown that the number of GAs required for children having MRI has reduced for this particular service through the use of the PMRIS, with Play Specialist support, with associated reduction in risk and cost savings.

Key words

MRI, paediatric, play, simulation, general anaesthesia

Classifications

Service improvement

Patient Pathways

Magnetic Resonance Imaging

Paediatrics

Abbreviations

GA	General Anaesthesia
MRI	Magnetic Resonance Imaging
PMRIS	Playful MRI Simulator

Title

Play Simulation for Children in Magnetic Resonance Imaging – A Clinical Perspective

Introduction

MRI can be a challenging examination for anyone to undergo due to the physical design of the scanner, the noise and the length of the imaging procedure and this has not significantly changed over time [1-9]. This is particularly the case when scanning the paediatric population and so it is usual for children (from infants up to children aged 7 or 8) to be scanned under general anaesthesia (GA) [9-12]. Older children with complex needs may also require GA in order to successfully undergo Magnetic Resonance Imaging (MRI). There are also, albeit rare, risks associated with exposure to, and recovery from, general anaesthesia which can include anaphylactic reactions and emergence agitation (13-16).

University Hospitals Plymouth NHS Trust provides both elective and emergency MRI for paediatric patients. For elective examinations, children are triaged by the referring team for one of the following: an awake MRI, a Play Specialist session to assess their capacity for an MRI with or without GA. Play Specialists, a long established role within healthcare, [17-19] have been shown to be able to ease psychological burden in children in hospital [20] by helping prepare both children and their families for difficult aspects of being ill including preparing for procedures and diagnostic tests [21]. Furthermore, play, when combined with preparatory resources and an appropriate MRI environment has been shown to significantly reduce the need for MRI under GA [22]. Within this service, already had a number of resources available to them including the use of a MRI Play Tunnel (Figure 1) built in the same dimensions as a 60 cm bore 1.5T scanner, with a head coil and recordings of scanner noises and the ability to arrange preparatory scanner visits. However, growing demand for MRI under GA is such that the two elective lists routinely provided were starting to be insufficient.

Figure 1: The MRI Play Tunnel in situ within the Children's unit (head coil not pictured).

In 2019 / 20 Plymouth Hospital Charity generously agreed to fund the procurement of a Playful Magnetic Resonance Imaging Simulator (PMRIS) (Domed, Lyon, France) for the MRI department (as shown in Figure 2). At this time the capital cost was £19,770 excluding value added tax. The PMRIS is a play MRI scanner that has the overall appearance of a rocket. It includes a mock head coil and simulates the MRI environment by generating scanner noises. The child is positioned within the play scanner and watches a cartoon whilst the scanner noise is played. During this period of time a camera with motion sensors records the child. Once the child is brought out of the scanner they are then able to watch the recording and are given feedback on how stationary the child has managed to keep. In this way the PMRIS can be used both to familiarise the child with being in a scanner but also to provide coaching on keeping still which is an important aspect for a successful awake MRI. The inclusion of the camera and motion sensors and the coaching aspect was felt to justify the procurement of the PMRIS to supplement the Play Tunnel. Whilst the Play Tunnel was found to be useful for familiarising children with the MRI environment it was found not to be fully preparing children for the scan in terms of remaining stationary for sufficient periods of time. The aim of this Clinical Perspective is to outline early experiences of the effectiveness of the PMRIS in terms of reducing the number of children requiring MRI under GA based on service evaluation data.

Figure 2: The Playful MRI Simulator (Domed, Lyon, France) in situ within the MRI department.

Methods

The proposal for data collection (both the prior baseline data and the implementation data) were registered with the Clinical Audit team who confirmed the project was within scope as a service evaluation (where a service evaluation is defined as an assessment of how well the intended aims are achieved [23]) rather than research. As this fell within scope as a service evaluation, no further ethical approvals were required. A data sharing agreement for all data related to this project was put in place between the NHS Trust and the primary author to ensure that all Trust requirements regarding anonymity and security were complied with.

In order to be able to establish costings within the funding bid, the anaesthetics team calculated a baseline cost per child for the provision of GA, excluding scanner costs.

For the purposes of costing staffing, the anaesthetics team defined their process as follows:

1. An initial pre-operative assessment via the paediatric anaesthetics team.
2. A team consisting of a consultant paediatric anaesthetist, paediatric operating department practitioner and paediatric nurse attending the MRI department for the scan itself.
3. Post-procedure recovery via the paediatric Day Case unit (necessitating bed capacity and trained Day Case personnel)

Also included in the costings were maintenance and servicing of the anaesthetics machine and monitoring equipment, medications and oxygen, consumables (such as MRI conditionally safe electrocardiogram dots, airways, and syringes). Excluded were building and maintenance costs including for the MRI scanner as an assumption was made that these would be the same for an awake MRI. These costs were estimated to be circa £300 per child. The cost of the scan itself (including Medical Imaging staffing costs) was not factored in as the scan would still be undertaken. It was, however, recognised that scanning under GA had the effect of reducing scanner capacity as the child is inducted / recovered in the vicinity of the MRI scanner meaning the scanner has periods of downtime when it is not possible to bring patients through to access the scanner. However, quantification of throughput is beyond the scope of this Clinical Perspective as the impact of the Covid-19 pandemic on service provision has meant that the PMRIS is not, as yet, being operated at full capacity. Likewise, potential impacts upon parents / guardians (such as time from work, travel and car-parking, potential child-care costs for siblings and so on) were also beyond the scope of this service review.

The baseline audit data providing information on the number of children scanned under GA had previously been obtained from an audit undertaken in 2017 as part of the funding bid for the PMRIS. These data explored the number of elective MRIs undertaken under GA during that year by age of child. To estimate the potential impact of the use of the PMRIS, a more

conservative evaluation suggesting a reduction of 61% for MRI under GA provided by an early adopter was used [24] rather than the manufacturer's then cited figures of being able to reduce the need for GA in 81% of cases [25].

These data were combined with the estimated cost data to provide a baseline suggesting potential reductions in MRI under GA, both in numbers of children and potential cost savings, against which to evaluate the effectiveness of the PMRIS in practice. Also presented as part of the baseline data were the recurring costs for the PMRIS. Whilst charitable funding was being sought to cover the capital costs (which were then £19,770 excluding value added tax for the scanner itself) recurring costs included annual servicing of the PMRIS as well as for the expertise of a Play Specialist.

The PMRIS service launched in the autumn of 2020. Data from October 2020 until May 2021 was collected. For the evaluation of the effectiveness of the implementation of the PMRIS service, children were selected who had specifically been triaged for MRI under GA, including some older children who were felt would not undergo MRI without this additional support. This is a decision generally made by the referrer based on their knowledge of the child, in consultation with the parents / guardians, with the option of discussion with the Play team, the Paediatric MRI Lead radiographer and / or Consultant Radiologist. The parents / guardians of selected children were given the option of attending for a PMRIS session and could decline. Inclusion criteria were aged four years and over, no severe learning disabilities or other co-morbidities. Three children were referred for examinations that required the administration of contrast, thereby requiring cannulation before they attended for the PMRIS session. Exclusion criteria were children aged three and under, severe learning disabilities and / or other co-morbidities. As this was a service evaluation, the usual processes for obtaining informed consent prior to MR imaging were followed.

Data about the outcome of the scan were collected from each PMRIS play session, all of which are led by the same Play Specialist with the Paediatric Lead MRI Radiographer supporting, undertaking the scanning and recording the information about scan outcome. A successful outcome was defined as a diagnostic scan, of sufficient image quality to be adequately reported by the consultant radiologist. Each session consists of a period of play on the PMRIS using the process as previously outlined. Once the play session is completed, the child is taken through to the MRI scanner (Intera dStream 1.5T, 60 cm bore, Philips Medical, Netherlands) for their scan. Each child is given a total appointment time of one hour to include both the play and the scanning time. During the scan, as per usual practice, the child is given the option of listening to music and / or being accompanied by an appropriately safety screened parent / guardian. The age, the type of examination and whether the child then proceeded directly to a successful awake MRI or were referred on for MRI under GA was then recorded. These data were then compared with the forecasts used in the funding bid, to determine whether this aligned with the projected cost benefits and whether the anticipated cost benefits were being realised.

Results

BASELINE DATA

Table 1 shows the number of MRI scans undertaken under GA in 2017. These data represent the most recent full calendar year at the time of initially preparing the funding bid for the PMRIS. This showed that 191 children (under 16) were scanned under GA.

Age (years)	Number of MRI scans
0 < 1	32
1 < 2	39
2 < 3	27
3 < 4	15
4 < 5	15
5 < 6	16

6 < 7	15
7 < 10	22
11 < 16	10

Table 1: Number of MRIs performed for paediatric patients under GA in 2017.

Whilst practice varies, it is generally suggested that children under the age of four would be unlikely to be suitable candidates for the PMRIS sessions, instead requiring anaesthesia or sedation [26, 27]. Hence the costing analysis for the funding bid had been based on the numbers of children aged 4 years and over. Based on the information provided by an early adopter [24], and using the data from table 1, it was calculated that applying the 61% value to the number of four and five year olds scanned in 2017 would result in a reduction in the need for GA for 19 cases. This would equate to an anaesthetics cost saving of 19 x £300 or £5,700 per annum. If a reduction in the need for GA was also seen in the older age group (aged six and over) at the same rate, there being no data available at that time, this would result in a further 28 GAs not being required and a further saving of £8,400. In total this could equate to a financial saving of circa £14,100 per annum in anaesthetics associated costs alone. As the older children referred for MRI under GA often have complex needs, so may have less successful outcomes with the PMRIS, further calculations showing the cost benefit of reductions in GA from 10% to 40% across these age ranges were also calculated and are shown in Table 2.

Age (years)	10% reduction in GA		20% reduction in GA		30% reduction in GA		40% reduction in GA	
	Number	£ saving	Number	£ saving	Number	£ saving	Number	£ saving
6 < 7	1.5		3		4.5		6	
7 < 10	2.2		4.4		6.6		8.8	
11 < 16	1		2		3		4	
Totals	4.7	**£1.4K**	9.4	**£2.8K**	14.1	**£4.2K**	18.8	**£5.6K**

Table 2: Cost benefits for varying effectiveness of the MRI Play Simulator.

These data were used as the baseline data for the financial case for the funding bid for the PMRIS and are used as baseline data here for assessing the effectiveness of the implementation of the PMRIS.

Any anaesthetics cost savings needed to exceed the recurring costs of operating the PMRIS. These were established to be circa £1,500 per annum for servicing. The pro rata cost of a Play Specialist was estimated at circa £5,000 excluding on-costs. Hence the annual running costs (servicing and Play Specialist) equated to circa £6,500 (excluding on-costs) at the time of the bid.

The installation of the PMRIS and the roll out of the play sessions was delayed due to the Covid-19 pandemic. This service commenced operations in October 2020, albeit at a reduced capacity. Following the installation of the PMRIS and the roll out of the service, data from October 2020 until May 2021 was collected. Of the 36 attendances, 30 children have proceeded to have a successful (meaning diagnostic) awake MRI without GA who would otherwise have been referred for GA. The range of examinations children were referred to the PMRIS play session for is shown in Column 3 in Table 3. Head scans include internal auditory meatus scans and contrast enhanced pituitary and orbital examinations. Spine scans included cervical, lumbar and whole spine scans. The 3 children referred for contrast enhanced MRI scans all successfully underwent them awake. Children unable to proceed to an awake MRI had been referred for heads (n = 5) and whole spine (n = 1) but the dataset is too small to discern any meaningful trends from these data. Of those who did not successfully undergo an awake MRI scan, one child is having a second attempt with the PMRIS and five were referred directly for MRI under GA for a range of reasons. Due to the

small dataset and in order to preserve anonymity, it is not possible to report more specific information.

Table 3 shows the breakdown by age and outcome with the associated anaesthetics cost-saving from proceeding to an awake MRI. Overall, for this particular group of children, the use of the PMRIS is associated with an 83% reduction in the need for GA across all age groups. Across the 4 – 6 year old (inclusive) age group this reduction is shown to be 75%.

Age (years)	Number of referrals	Exam type	Successful awake MRI following PMRIS session	MRI under GA following PMRIS session	£ saving
4 < 5	4	Head (n = 4)	2	2	£600
5 < 6	10	Head (n = 10)	8	2	£2,400
6 < 7	6	Head (n = 5) Spine (n = 1)	5	1	£1,500
7 < 10	15	Head (n = 8) Neck (n = 1) Pelvis (n = 1)	14	1	£4,200
11 < 16	1	Head (n = 2) Spine (n = 4)	1	0	£300
Totals	*36*	Head (n = 29) Spine (n = 5) Neck (n = 1) Pelvis (n = 1)	*30*	*6*	*£9,000*

Table 3: Breakdown of children referred for MRI via the PMRIS by age and outcome with associated anaesthetics cost savings.

Discussion

The data from this service evaluation have demonstrated that the early experience with the PMRIS is exceeding the forecasts given by the manufacturer and an early adopter of the PMRIS in terms of reducing the number of children requiring an MRI under GA. The associated anaesthetics cost savings identified by this service evaluation equate to £9,000 over a seven month period. This also means the financial savings indicated within the funding bid would currently appear to be being exceeded. However there are a number of limitations to this service evaluation. Firstly, it is not possible to determine how many of

these children may have had a successful awake MRI following a different type of intervention. However, these children had been referred for an MRI under GA according to local pathways so would otherwise have had MRI under GA within this service. As the service has Play Specialist provision with some MRI resources (e.g. Play MRI tunnel) already available, which are considered at referral, this could raise the possibility that parents / guardians may be more inclined for their child to attempt an awake MRI when a resource such as the PMRIS is available. Any impact of parent / guardian perceptions of methods to support attempts at awake MRI would therefore benefit from research and further exploration. Secondly, it is probable that there is selection bias in terms of the children who attend the Play Sessions which would then explain the higher apparent success rates shown as part of this evaluation compared with the limited literature [24, 25]. It is possible, therefore, that when normal service is able to resume post-pandemic, the proportion of successful awake MRI scans following a PMRIS play session may align more with prior data. Nevertheless, the department is observing a measurable reduction in children requiring MRI under GA.

It also needs to be borne in mind that children who have an unsuccessful session with the PMRIS will then require a second appointment (either MRI under GA or a further Play session) and the impact of this on capacity also needs to be considered. However, also not readily quantifiable is the additional clinical risk associated with giving a child a GA and scanning under GA. As with any drug, children can have an anaphylactic response to anaesthetic drugs [14]. Children can recover from anaesthetic with emergence delirium [15]. It is known the extended exposure to anaesthesia, or repeated exposure, can be associated with potentially detrimental neurodevelopmental effects, although these are most marked in children under 3 [13] who are unlikely to benefit from the PMRIS. Whilst there are apparently no reported anaesthesia related deaths (as of 2012) in children without significant co-morbidities, a range of fatalities is given from 1.6 to 115 cases per 10,000, varying with the

type of planned surgery with paediatric cardiac surgery being associated with the higher rate [28] and there has been a reported fatality associated with GA used to enable MRI in England due to underlying co-morbidities that were not fully recognised [16]. Whilst the absolute risk may be small, any move away from the use of GA has to be of benefit to the child.

There are also likely to be further associated benefits which were beyond the scope of this service evaluation. For example, at the time of preparing the case for funding for the Play Simulator (pre-pandemic), waiting times for routine referrals for paediatric MRI under GA had increased, and an additional GA list was being considered. In addition to the additional anaesthetics costs of performing additional MRI scans under GA, this would also have reduced overall scanner capacity as the throughput for paediatric GA lists is less than 50% compared with the work typically undertaken on that scanner. However, time and motion studies would not have been meaningful during this recent period of data collection as social distancing and enhanced infection prevention and control measures has meant that the roll out of the PMRIS sessions has not been at full capacity. Patient experience (both child and parent / guardian) were also not explored in this service evaluation and are important parameters that should be considered in the future.

Research could also be undertaken to inform how best to optimise the sessions for different ages of children, and children with different needs, to maximise the benefit. There may also be a transferable benefit in helping prepare children for other procedures that require them to remain stationary. There is also scope for exploring any benefit of the PMRIS in helping children who have regular MRI for chronic conditions and who are reluctant to transition to 'awake' MRI, to prepare for that change.

Nevertheless, the total numbers of children demonstrated as having an awake MRI following a play session with the PMRIS has demonstrated that, for this particular service, there

appears to be sufficient benefit for children as demonstrated by a reduction in the need for, and therefore associated costs of, MRI under GA, thereby also reducing GA risk.

Conclusion

This Clinical Perspective, based on small scale service evaluation, has demonstrated that, for this particular MRI service, with its particular referral pathways, the introduction of Play Specialist led sessions using a Playful MRI Simulator has reduced the number of children who would have otherwise have undergone MRI under GA. This has provided clear cost benefits for this department which appear highly likely to cover running costs in the shorter term. There is scope for further service evaluation in order to determine the impact upon scanner capacity as well as on service user satisfaction and research is needed on the optimal preparation of children for awake MRI as well as on overall patient and parent / guardian experience.

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