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Review of Fast Brain MRI for Perioperative Evaluation of Pediatric Intracranial Arachnoid Cyst Fenestrations

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ABSTRACT

Fast brain MRI is an increasingly popular rapid and radiation-free imaging technique. It has been shown to be a viable alternative to CT and standard MRI for certain indications with reduced risk. For the past 10 years, it has been used for the evaluation of arachnoid cyst fenestrations and has gained increasing popularity among referring physicians at our institution. We reviewed the perioperative imaging techniques and their anesthesia requirements in 84 pediatric patients who underwent arachnoid cyst fenestration and found an increasing trend in the utilization of the fast brain MRI technique with a concurrent decrease in the use of CT and standard MRI over time. Our findings suggest fast brain MRI can be a safe and useful alternative to these conventional imaging techniques for the perioperative assessment of arachnoid cyst fenestrations in children.

Keywords: Fast brain MRI; Fast MRI; Ultrafast MRI; Quick brain MRI; MR ventricle; Arachnoid cysts

INTRODUCTION

Ventricular shunts are commonly employed to treat children with hydrocephalus. Complications after ventricular shunt placement can occur and children with shunt-dependent hydrocephalus may require serial imaging either for diagnostic or surveillance assessment [1]. Historically, the imaging choice for these children has been consecutive brain Computed Tomography (CT), which exposes these patients to cumulative radiation doses. It has been found that children are approximately 2 -5 times more radiosensitive compared with their adult counterparts and are therefore at a higher risk of developing specific cancers due to radiation exposure [2-4]. The alternative to brain CT is Magnetic Resonance Imaging (MRI), a radiation-free imaging technique. However, standard MRI is time consuming, sensitive to motion artifacts, and may require sedation or anesthesia and therefore add risk [5,6]. Recent data in children has shown an association between anesthesia exposure and central nervous dysfunction which may result in injury to the developing brain [6-9].

Advancements in MRI have allowed for faster imaging of the body, brain and extremities [10-12]. In recent years, fast brain MRI (i.e. ultrafast MR, rapid MRI, MR ventricle exam) has become an increasingly popular rapid and radiation-free imaging technique initially introduced in children with shunt-dependent hydrocephalus to evaluate ventricular size [13-15]. As it negates the need for anesthesia, it has become a viable alternative to standard MRI in children and less compliant patients. Its use has been described in the literature and has expanded to non-hydrocephalic indications including evaluating macrocephaly, certain structural congenital anomalies (such as Chiari malformation), acute ischemic strokes, acute intracranial hemorrhages, surveillance of intracranial cysts and postoperative follow up [15-20].

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In 2007, we implemented fast brain MRI at our institution in an effort to decrease the number of brain CT studies and help avoid the associated risks of radiation exposure in our neurosurgical pediatric patients. Initially, assessing hydrocephalus was the primary indication for its use but this technique quickly gained substantial physician, family and patient satisfaction which led its use for non-hydrocephalic causes. One such cause is the assessment and surveillance of children who undergo arachnoid cyst fenestrations. Previously, our standard practice was to image these patients with a head CT and/or standard brain MRI, but since its implementation at our institution, fast brain MRI is steadily replacing these techniques in the imaging of children with arachnoid cysts. To date, there have been no reports in the literature on the use of fast brain MRI in children with intracranial arachnoid cysts. We therefore assessed its use in this patient population at our institution throughout the last several years to provide insight into its effectiveness.

MATERIALS AND METHODS

Subjects

Children who underwent perioperative imaging for an arachnoid cyst fenestration from 2007 to 2016 at our institution were included in this retrospective study. Institutional Review Board approval was obtained and informed consent was waived. Patients who had multiple arachnoid cyst fenestrations and those who required extensive brain imaging due to other pathologies were excluded. The mean age of the subjects was 6.4 years at the time of the cyst fenestration, with a standard deviation of 5.4 years. The age range was from 0.0-18.2 years. We identified 84 children who fit the inclusion criteria (53 male, 31 female).

Assessment Measures

The subjects' electronic medical records were reviewed to determine the number of imaging exams they received and the modalities used for the perioperative evaluation of their arachnoid cyst fenestrations. The type and number of pre- and post-operative imaging studies performed were recorded for each individual and the total number of studies from all patients was tallied each year and subdivided based on imaging modality (brain CT, standard brain MRI or fast brain MRI). The percentage of brain imaging studies were then compared based on modality to assess their change in use over time.

We defined pre-operative exams as those occurring either the day of the surgical procedure up to two weeks prior. Post-operative exams were defined as those occurring immediately after the procedure and up to one year post-surgery, including follow-up exams within that period. A review of anesthesia requirements for each brain imaging study was performed based on imaging modality.

Imaging Technique

The fast brain MRI exams were performed on a 1.5 Tesla Siemens Magnetom Avanto magnet (Siemens Medical Solutions, Erlangen, Germany), a 3 Tesla GE (General Electric, Milwaukee, WI) Discovery MR750, or a 1.5 Tesla SignaHDxt scanner (GE Healthcare, Waukesha, Wisconsin, USA). Each scanner was equipped with its respective proprietary software. The GE scanners utilized an 8-channel high resolution head coil and performed a Single Shot Fast Spin Echo (SSFSE), a T2 weighted Fast Spin Echo sequence. The Siemens scanner utilized a 12-channel head matrix coil and a half-Fourier single shot turbo spin echo sequence (HASTE). Three standard orthogonal planes were obtained following the standard localizer. The SSFSE sequence included; matrix size of 256 x 224; TR/TE 2000/80 with a slice thickness of 5 mm; skip 1 mm, and FOV 240 mm. The HASTE sequence parameters included a matrix size of 256 x 256, TR/TE 2000/77 with a slice thickness of 5 mm; skip 1 mm, and FOV 230. The mean time for a single fast brain MR sequence ranged from 40 to 60 seconds and was dependent on the number of slices acquired. The total scanning time, including patient preparation, positioning, localizers and slice planning for a fast brain MR study ranged between 3-5 minutes.

The standard non-contrast full brain MRI sequences included axial T1-weighted (500 TR/9.1 TE), axial and coronal T2-weighted (4,000 TR/98 TE) and diffusion weighted (7,200 TR/84 TE), axial FLAIR (9,000 TR/98 TE) and susceptibility weighted (49 TR/40 TE) imaging sequences, with a scanning time ranging from 2 to 5 minutes per sequence.

RESULTS

A total of 431 brain imaging studies were reviewed for the 84 patients that fit the inclusion criteria. Of these, 74 (88%) received at least one fast brain MRI for either pre- or post-operative evaluation. Of the 431 studies, 59% were fast-brain MRI studies, while 22% and 19% were standard brain MRI and head CT respectively (**Tables 1, 4 and 5**). We observed that there was an overall increase over time in the percentage of fast brain MRI studies performed out of all brain imaging modalities (brain CT, standard brain MRI and fast brain MRI) for the pre and post-operative evaluation of arachnoid cyst fenestration since its introduction in 2007. A linear correlation with a Pearson correlation coefficient (PCC) of 0.81 was found between time and percentage of all perioperative fast brain MRI studies (pre and post-operative combined). **Table 1** and **Figure 1** show the combined count of both pre- and post-operative fast brain MRI studies performed each year, the total number of brain imaging studies, and the percentage of those that were fast brain MRI studies. A similar trend was observed in the percentage of post-operative fast brain MRI exams out of all post-operative brain imaging studies performed(PCC=0.86) (**Figure 2, Table 2**). However, a definitive trend was not observed in pre-operative fast brain MRI (**Figure 3,Table**

3). On the other hand, the percentage of CT scans performed for both pre- and post-operative evaluation of arachnoid cyst fenestrations decreased throughout the years (PCC=0.72). **Table 4** and **Figure 4** show the negative linear trend in CT usage. A similar inverse relationship between time and percentage was also observed instandard brain MRI (PCC=0.81) (**Table 5** and **Figure 5**).

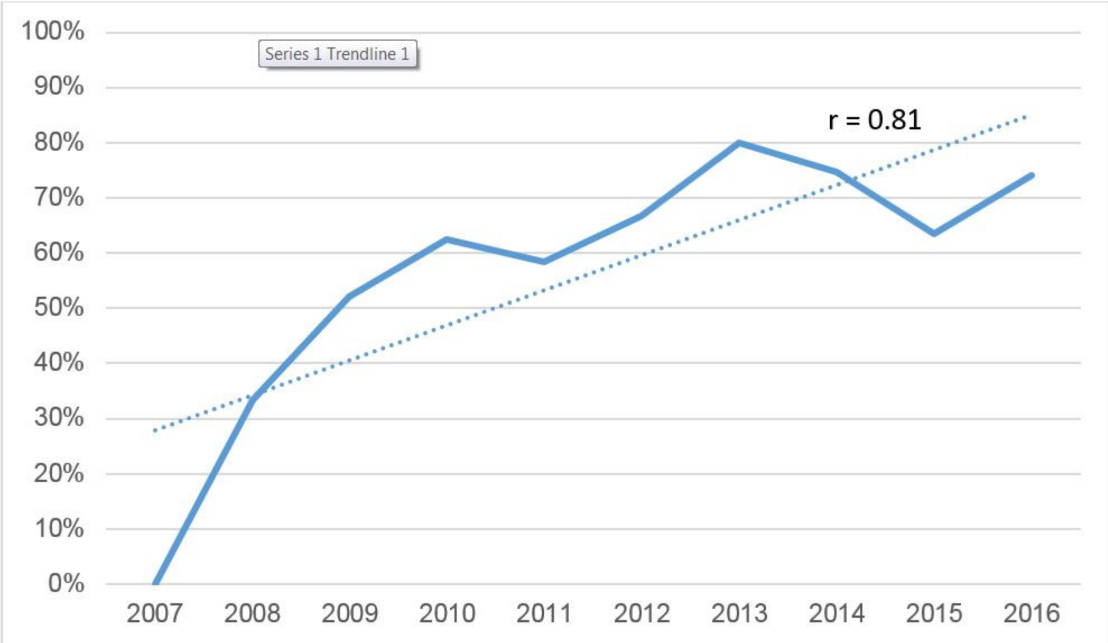

Figure 1. Percentage of pre and post-operativefastbrain MRI studiesover time.

Table 1. Use of fast brain MRI for pre- and post-operative arachnoid cyst fenestration evaluations from 2007-2016 combined

Year	Number of fast brain MRI studies	Number of brain imaging studies	% fast brain MRI out of all brain imaging studies
2007	0	18	0%
2008	16	48	33%
2009	24	47	51%
2010	40	64	63%
2011	21	36	58%
2012	32	48	67%
2013	16	20	80%
2014	47	63	75%
2015	26	41	63%
2016	34	46	74%
Total	**256**	**431**	**59%**

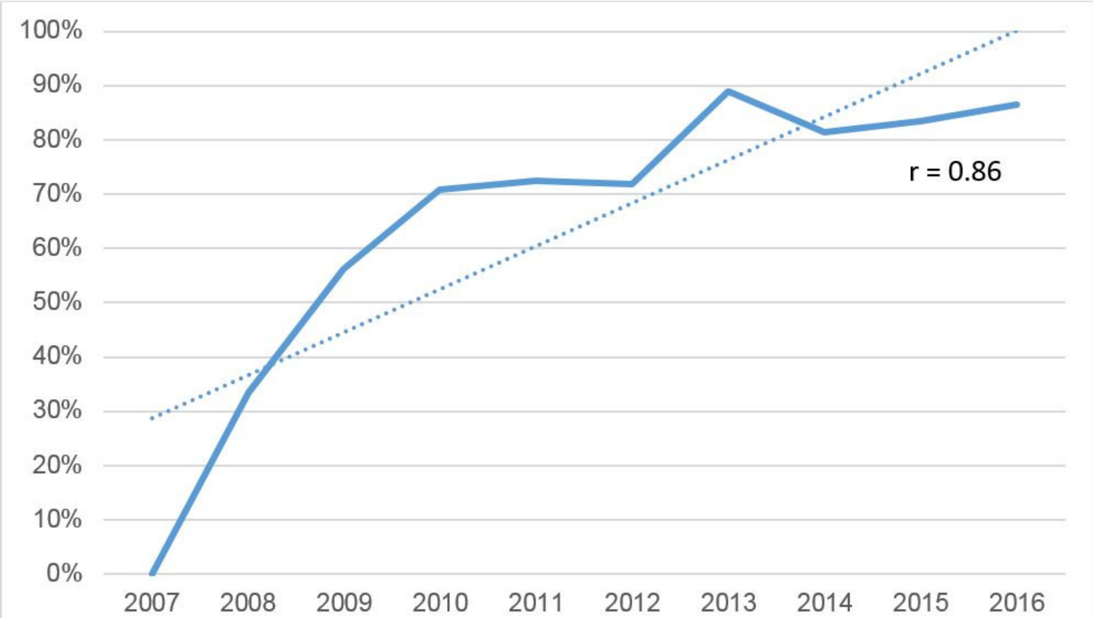

Figure 2. Percentage of post-operative fast brain MRI studies over time

Table 2. Use of fast brain MRI for post-operative arachnoid cyst fenestration evaluation from 2007-2016

Year	Number of post-op fast brain MRI studies	Number of post-op brain imaging studies	% post-op fast brain MRI out of all post-op brain imaging studies
2007	0	13	0%
2008	14	42	33%
2009	23	42	55%
2010	39	55	71%
2011	21	29	72%
2012	28	39	72%
2013	16	18	89%
2014	44	54	81%
2015	25	30	83%
2016	32	37	86%
Total	**242**	**359**	**67%**

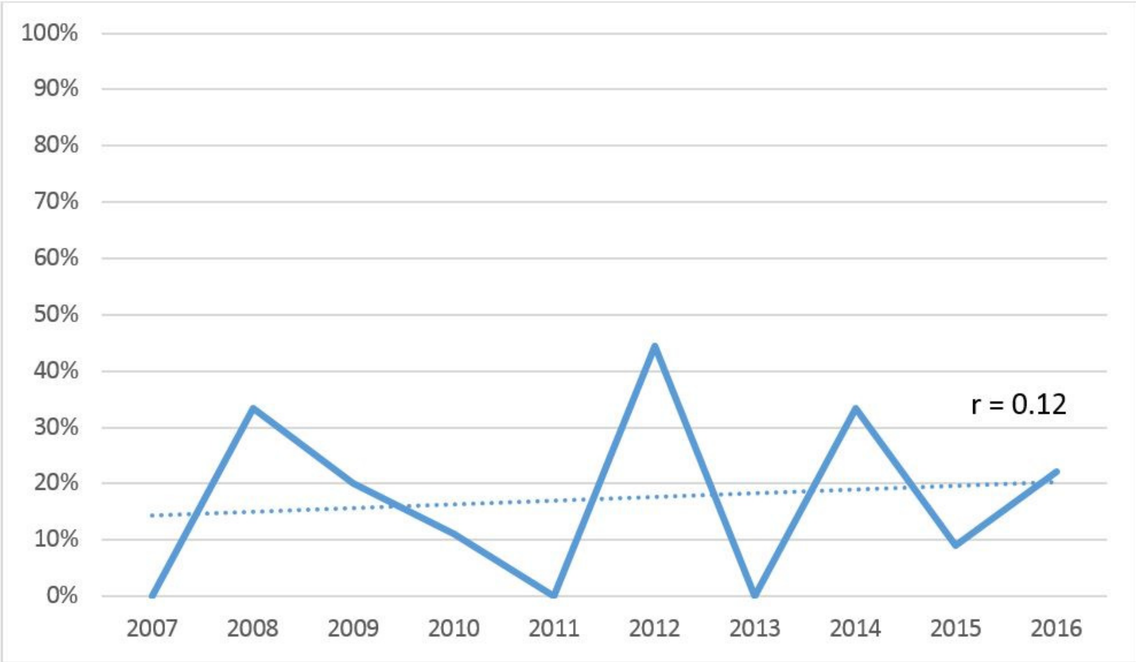

Figure 3. Percentage of pre-operative fast brain MRI studies over time

Table 3. Use of fast brain MRI for pre-operative arachnoid cyst fenestration evaluation from 2007-2016

Year	Number of pre-op fast brain MRI studies	Number of pre-op brain imaging studies	% pre-op fast brain MRI out of all pre-op brain imaging studies
2007	0	5	0%
2008	2	6	33%
2009	1	5	20%
2010	1	9	11%
2011	0	7	0%
2012	4	9	44%
2013	0	2	0%
2014	3	9	33%
2015	1	11	9%
2016	2	9	22%
Total	**14**	**72**	**19%**

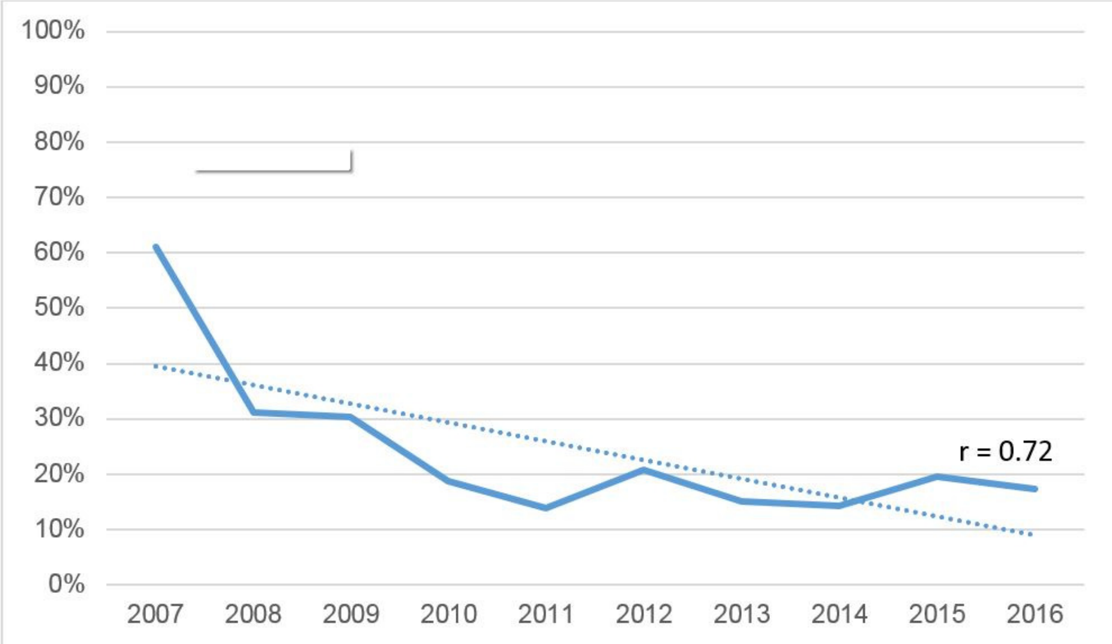

Figure 4. Percentage of brain CT studies over time

Table 4. Use of brain CT for pre- and post-operative arachnoid cyst fenestration evaluations from 2007-2016 combined

Year	Number of brain CT studies	Number of brain imaging studies	% CT out of all brain imaging studies
2007	11	18	61%
2008	15	48	31%
2009	14	47	30%
2010	12	64	19%
2011	5	36	14%
2012	10	48	21%
2013	3	20	15%
2014	9	63	14%
2015	8	41	20%
2016	8	46	17%
Total	**95**	**431**	**22%**

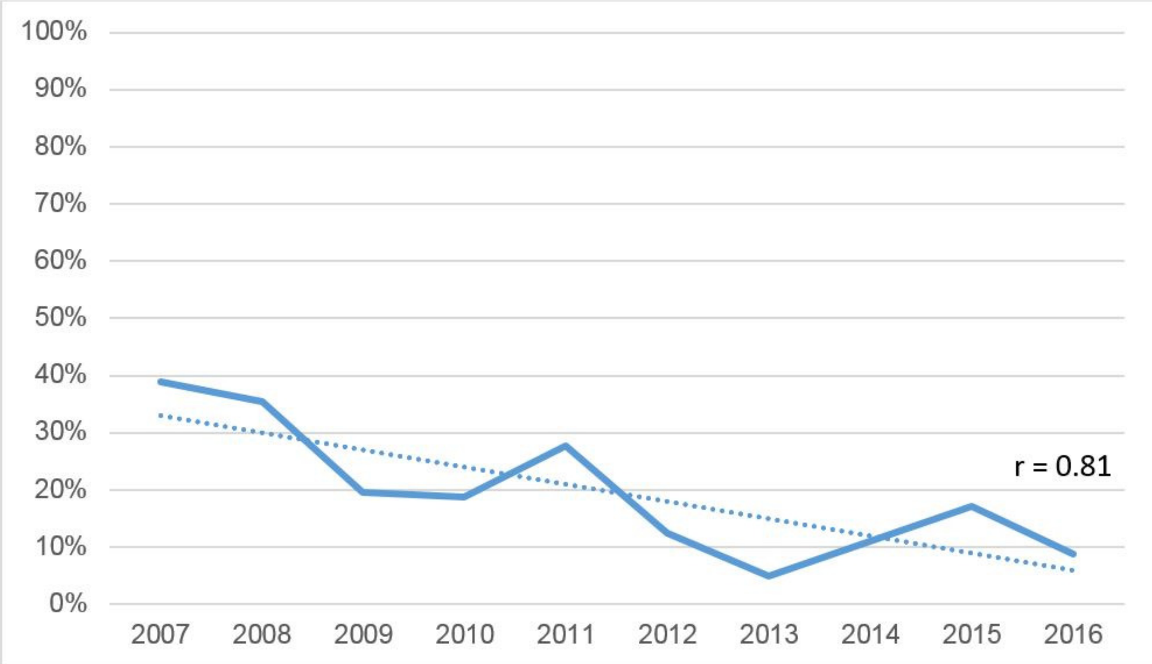

Figure 5. Percentage of standard brain MRI studies over time

Table 5. Use of standard brain MRI for pre- and post-operative arachnoid cyst fenestration evaluations from 2007-2016 combined

Year	Number of standard brain MRI studies	Number of brain imaging studies	% Standard MRI out of all brain imaging studies
2007	7	18	39%
2008	17	48	35%
2009	9	46	20%
2010	12	64	19%
2011	10	36	28%
2012	6	48	13%
2013	1	20	5%
2014	7	63	11%
2015	7	41	17%
2016	4	46	9%
Total	**80**	**431**	**19%**

Anesthesia Review

We reviewed the anesthesia requirements for each patient for their pre- and post-operative imaging studies. Of the 74 patients who underwent a fast brain MRI for their arachnoid cyst evaluations, none received general anesthesia. On the contrary, 38 out of the 55 patients who had a pre and/or post-operative standard brain MRI required anesthesia **(Figure**

6). From the 51 patients who had a pre and/or post-operative head CT, 5 were performed under anesthesia.

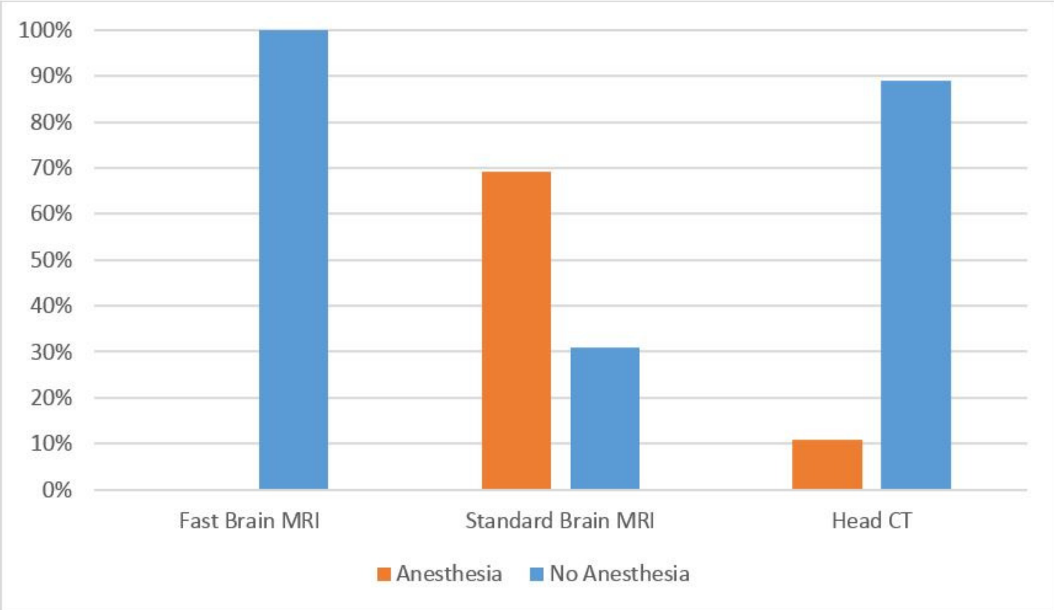

Figure 6. Anesthesia requirements based on imaging protocol

Discussion

Arachnoid cysts are benign, nonneoplastic encapsulated cerebrospinal fluid (CSF) collections covered by the arachnoid membrane (one of the 3 membranes that cover the neural axis) and the brain, and less commonly the spinal cord. They account for 1% of all intracranial masses [21,22]. Although found in approximately 1.7% of the adult population, arachnoid cysts are more frequently diagnosed in children, with a prevalence of 2.6%, and most appear as congenital anomalies diagnosed between 1 and 5 years of age [23,24]. Similar to other childhood mass lesions, the clinical presentation for arachnoid cysts include progressive macrocephaly, headache, intracranial hypertension, hydrocephalus and developmental delay [24-26]. Some may require treatment based on symptoms of headache, developmental delay, increasing head circumference, and hemorrhage, to name a few. Treatment is dependent on the location and size of the cyst and requires long-term clinical and radiological monitoring given their increased risk of complications. Small asymptomatic cysts are typically treated conservatively and are refrained from any intervention with regular clinical and imaging surveillance [27]. The larger symptomatic arachnoid cysts may undergo surgical manipulation, commonly by endoscopic fenestration which is the accepted treatment of choice, but may also involve an open fenestration. Shunting procedures are rarely performed because of shunt dependency and malfunction rate [21,28].

Arachnoid cysts are best seen on cross sectional imaging studies. While MRI is the imaging modality of choice given its greater spatial resolution which allows for better detection of smaller cysts, CT is better at assessing the adjacent bony structures [22,29]. They are most frequently located in the middle cranial fossa (50-60%) and are often found in the suprasellar cistern, posterior fossa, interhemispheric fissure, cerebral convexity, ventricles, basal cisterns or spinal canal [21]. Intracranial arachnoid cysts appear as non-enhancing and sharply demarcated lesions that can deform the adjacent brain and cause scalloping to the adjacent calvarium. Internally, the cysts follow the same signal intensity as CSF and may demonstrate different signal characteristics when internal bleeding occurs [21,30].

Our fast brain MRI examinations included either a single-shot fast spin echo technique (SSFSE) or half-Fourier acquisition single-shot turbo spin echo (HASTE), depending on the scanner. These rapid techniques had a total study time of 3-5 minutes compared to approximately 30 minutes for a non-contrast standard brain MRI study. Fast brain MRI typically avoids the need for anesthesia (as confirmed by our review) and has also been shown to provide adequate diagnostic capability even in motion-prone patients [16,20,31]. It also avoids the potential risk for radiation exposure from CT imaging. **Figure 7.** shows fast brain MRI images of an arachnoid cyst in the three standard orthogonal planes.

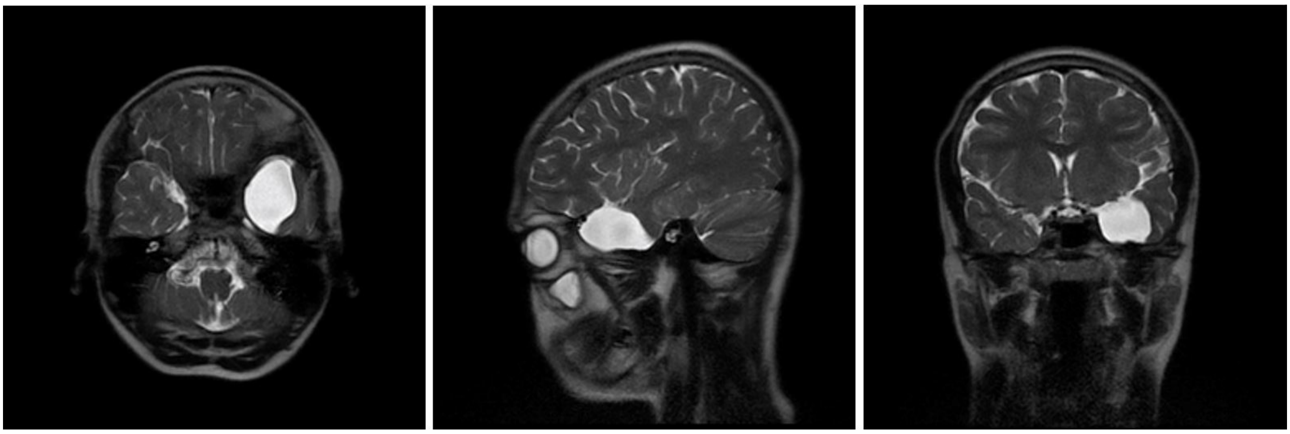

Figure 7. Axial, sagittal and coronal fast brain MR images demonstrating an arachnoid cyst in the left middle cranial fossa in a 13-year-old-male

Our analysis revealed an increasing trend at our institution in the use of fast brain MRI for the perioperative evaluation of arachnoid cysts compared to the standard imaging techniques. In fact, while an upward and linear trend is observed over time in the proportion of fast brain MRI use, an inverse relationship is seen in the use of both head CT and standard brain MRI in the pre and post-operative evaluation of arachnoid cysts. Additionally, out of the 84 patients identified in this study, 74 (88%) underwent at least one fast brain MRI. These finding demonstrate the increase in confidence in using fast brain MRI for the evaluation of arachnoid cyst fenestrations at our institution and may suggests its practical advantage over CT and standard brain MRI. Although we did not compare imaging quality or diagnostic performance, the observed increase in the use of fast brain MRI over time as the imaging choice (primarily post-operatively) suggests that it may offer comparable performance for arachnoid cyst fenestration evaluation relative to head CT and standard brain MRI protocols. Although we found a positive trend in post-operative fast brain MRI use, the same pattern was not observed for pre-operative studies. This is likely because a majority of our patients received a stealth MRI examination which is sufficient for surgical guidance and cyst localization and avoids the need for a pre-operative fast brain MRI.

Although anesthesia requirements vary on an individual basis based on age and contraindications, our anesthesia review nevertheless suggests the value and safety of fast brain MRI in reducing the need for anesthesia compared to standard brain MRI and head CT. While 69.1% and 10.8% of the patients who received a standard brain MRI or a head CT respectively required anesthesia for either pre or post-operative evaluation, there were no patients who required anesthesia for their fast brain MRI exam. These numbers demonstrate fast brain MRI's safety over standard brain MRI and head CT and potentially explain its increased use over time for the evaluation of patients who undergo a work-up for arachnoid cyst fenestration.

CONCLUSION

The measured positive trend in the use of fast brain MRI for arachnoid cyst fenestration evaluation suggests an increase in confidence in its use at our institution. These findings demonstrate that fast brain MRI may be a safe and useful tool for the post-operative assessment and surveillance of arachnoid cyst fenestrations. Future studies should explore patient clinical outcomes and imaging quality across the conventional modalities to confirm its safety and effectiveness in this patient population.

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