

Fast MRI Compared With Head CT in Evaluating Pediatric Neurologic Emergencies

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abstract

BACKGROUND AND OBJECTIVES: We aimed to compare outcomes of patients who received a limited-sequence brain magnetic resonance imaging (fast MRI) with those receiving head computed tomography (CT) scans in the emergency department (ED). It was hypothesized that fast MRI would have less missed pathology while not increasing length of stay (LOS).

METHODS: We conducted a planned subanalysis of a prospective cohort of children evaluated for new neurologic complaints. We compared children who underwent fast MRI at presentation (the exposure group) with 3 comparison groups of children who received a CT scan first. Participants were excluded if they had known trauma, ingestion, or metabolic disease. Two comparison participants were matched to each case and analyzed in 3 arms: random, age, and diagnosis grouping.

RESULTS: Of 191 children receiving fast MRI scans, 159 were found to be eligible. These children were compared with 636 eligible children who received CT scans. Time from arrival to completed imaging was similar (fast MRI: 142 minutes vs CT: 139 minutes). Hospital LOS was also similar (fast MRI: 47 hours vs CT: 45 hours). Follow-up imaging found that fast MRI had less missed pathology than CT (MRI: 1.8% vs CT: 8.5%). Fast MRI was found to have a higher sensitivity (MRI: 95.8% vs CT: 63.0%) and a higher negative predictive value (MRI: 98.2% vs CT: 91.5%).

CONCLUSIONS: This planned subanalysis found that fast brain MRI had less missed pathology, higher sensitivity, and higher negative predictive value without increasing ED or hospital LOS for patients presenting to the ED with general emergent neurologic complaints.



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Drs Forman and Leonard conceptualized and designed the study, abstracted the data, reviewed and analyzed the data, and wrote and revised the manuscript. Mr Nash assisted with data abstraction, analysis, and writing and revising the manuscript. Dr Spencer assisted with conceptualization, and writing and revising the manuscript. Ms Helwig assisted with data review, analysis, and writing and revising the manuscript. Dr Drapeau assisted as content expert as a neurosurgeon and critically reviewed and revised the manuscript. Dr Jones assisted as content expert as a neuroradiologist and critically reviewed and revised the manuscript. (Continued)

WHAT'S KNOWN ON THIS SUBJECT: Fast brain magnetic resonance imaging (MRI) has been studied in specific instances like trauma and shunt evaluation. It is known to be a superior modality for vascular pathology. Fast MRI does not use ionizing radiation but is associated with increased resource use.

WHAT THIS STUDY ADDS: This study compares fast brain MRI with head computed tomography scan for general neurologic emergencies. This study shows less missed pathology, higher sensitivity, and higher negative predictive value associated with fast brain MRI while not increasing emergency department length of stay.

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BACKGROUND

Neurologic emergencies are among the most common reasons for presenting to the emergency department (ED), representing nearly 16% of all visits.^{1,2} Early recognition and identification of true neurologic emergencies from mimicking diseases directly impacts disease course and outcomes.^{3,4} The varied etiologies include life altering events like stroke, intracranial mass, infection, inflammatory disease, demyelinating disease, or electrolyte abnormalities. Common imitations consist of hemiplegic migraine, functional neurologic disorders, ingestion, atypical behaviors, and Todd's paralysis.⁵⁻⁸ Delayed recognition leads to delayed treatment, which contributes to increased risk morbidity and mortality.^{7,9} Therefore, it is important to provide efficient and reliable diagnostic evaluations for children presenting to the ED with neurologic emergencies.

Noncontrast computed tomography (CT) is the mainstay of neuroimaging in the ED. Adult centers use head CT in conjunction with angiography to evaluate for ischemic stroke, which, other than trauma, is the most common neurologic emergency in adults.^{10,11} Full-brain magnetic resonance imaging (MRI) may provide more pertinent and detailed data compared with CT based on the underlying disease process.¹²⁻¹⁴ Although thorough, full-brain MRI uses many resources from both anesthesia and radiology departments.¹⁵ On average, a full-brain MRI scan takes 50 minutes to complete, and many pediatric patients require procedural sedation or general anesthesia.^{16,17} These factors limit full-brain MRI use for pediatric neurologic emergencies in the ED. More commonly, children presenting with acute onset of neurologic symptoms receive a head CT scan with or without contrast, and if unrevealing, the children are admitted for observation, serial neurologic examinations, and/or full-brain MRI with or without sedation.¹⁸⁻²⁰

Fast brain MRI uses a rapid and focused sequence set to detect acute intracranial pathology, optimizing time and resource use in children presenting with an acute neurologic deficits.^{21,22} An examination can be performed in under 10 minutes, including diffusion weighted imaging (DWI), fluid attenuation inversion recovery (FLAIR) imaging, and susceptibility weighted images (SWI).²³⁻²⁶

There has been emerging literature describing the use of fast MRI for children in the ED.^{21,27} Many prior studies have evaluated limited MRI protocols for specific indications including shunt malfunction or in nonaccidental trauma evaluation.²⁸⁻³³ The purpose of this study was to evaluate the use of fast brain MRI compared with head CT for the evaluation of children presenting to the ED with more generalized emergent neurologic complaints. It was hypothesized that use of fast MRI for children presenting with new-onset neurologic complaints would increase diagnostic accuracy while decreasing ED length of stay (LOS) and hospital admission when compared with children who received head CT scans.

METHODS

Study Design

We conducted a planned subanalysis of a prospective cohort of pediatric patients treated under a standardized neurologic deterioration pathway.³⁴ We compared children who underwent fast MRI at presentation (the exposure group) with those who received alternative imaging modalities, primarily CT. Comparison groups were constructed using purposive sampling to ensure relevance and clinical comparability.³⁵ Children enrolled in the original cohort were aged 0 to 18 years presenting to the ED with new neurologic complaints and received neuroimaging from July 2016 to June 2021.

Setting

This study was conducted at a single large, quaternary children's hospital where the ED sees over 90 000 children per year.

Fast brain MRI protocol employed for this study included axial DWI, axial FLAIR, and axial SWI. Conventional DWI sequences were performed first, followed by FLAIR and SWI if there was no evidence of motion, each sequence requiring 2 to 3 minutes. In setting of motion, 6 direction diffusion tensor imaging was obtained, taking approximately 1 minute. Magnetic resonance angiography was added if DWI had positive results, taking 3 minutes.

DWI is sensitive for acute infarction, with cytotoxic edema classically light-bulb bright, but also reveals diagnostic information in the setting of encephalitis, abscess, empyema, and cellular tumor. Additionally, the $b = 0$ images, which are standard with DWI, provide a T2 weighted sequence that allows detection of gross brain edema and hemorrhage.^{23,24} FLAIR images are more sensitive for the vasogenic edema that can be found in encephalitis, autoimmune, demyelinating processes, and noncellular tumors.²⁵ SWI allows for MRI detection of parenchymal hemorrhage and extra-axial hematoma, and it may detect intracranial calcification as well.²⁶ All 3 sequences provide an assessment of ventricular caliber and hydrocephalus.

Patient Population

The exposure group (cases) consisted of those who received a fast brain MRI as the first imaging modality. The comparison groups comprised children who presented within 1 year of their matched case participant and received a head CT without contrast as their first imaging modality. Participants were excluded if presented to the ED with head trauma, suspected nonaccidental trauma, metabolic disease (eg, diabetic ketoacidosis), or known ingestion. The comparison participants were matched into 3 groups. The participants in the first head CT comparison group were randomly selected. The second head CT comparison group was matched based on age within 2 years to the

case participants. The third head CT comparison group was matched based on diagnosis categories. Diagnosis categories were determined using primary ED diagnosis by the *International Classification of Diseases, Tenth Revision* codes and then confirmed by manual review. In each head CT comparison group, we selected 2 comparison participants per case participant. Comparison participants were matched in batches so that as a participant was excluded, a new participant was assigned for eligibility review. A comparison participant could be in more than 1 comparison group but not duplicated within the same comparison group.

Data Collection

Information was abstracted from the electronic health record for the index visit through automated download when possible and manually if the variable was not contained within a discrete field. Variables included demographics, chief concern, neurologic symptoms, mode of arrival, imaging results, need for follow-up imaging, ED disposition, ED LOS, and hospital LOS if applicable. Data were compiled and stored on password protected files and within a REDCap® database in compliance of our institution's Institutional Review Board who approved this study to be conducted under waiver of informed consent.

Covariates

Participants were assigned by a study investigator to 1 of 8 diagnosis groupings: trauma, vascular, neoplastic, inflammatory/infectious, metabolic, seizure/epilepsy, migraine, and other.

Outcome Measures

Our primary outcomes were missed diagnoses, ED LOS, and hospital LOS. Pathologic findings were defined as imaging findings likely causing the presenting symptoms. Missed diagnosis was defined as any pathologic finding not identified on the initial imaging. If a pathologic finding on initial imaging led to the discovery of additional pathology on imaging to further characterize the finding, it was not considered a missed diagnosis. ED LOS in this study is defined as the time from arrival to the ED to the decision for final disposition. Secondary outcomes were follow-up imaging received and use of anesthesia for imaging purposes and test performance metrics.

Statistical Analysis

Descriptive statistics were calculated for patient demographics, presenting chief concerns, diagnosis groupings, LOS, disposition, and repeat imaging for cases and comparison groups as number of patients (%) or median (IQR), where appropriate. For all analyses, the fast brain MRI case group was compared with each of the 3 comparison groups separately. Comparison of demographics between case and

comparison groups were made using Wilcoxon signed rank tests for continuous variables and Fisher's exact tests for categorical variables. Proportions of each case and head CT comparison groups' presenting chief concerns, diagnosis groupings, dispositions, types of repeat imaging, and reasons for repeat imaging were compared using either 2 proportion *Z* tests or Fisher's exact tests, depending on observed counts for each category. LOS time differences across groups were assessed using Wilcoxon signed rank tests. Sensitivity and negative predictive values were calculated to assess fast brain MRI and CT performance. *P* values less than .05 were considered significant. All analyses were performed in R (v4.2.2).

RESULTS

During the study period, 1800 children underwent neuroimaging in our ED (Figure 1). Of 191 fast MRI scans, 31 were excluded for prior imaging and 1 for being known trauma, leaving 159 cases. A total of 1609 head CT scans were performed, and 161 were excluded (13 prior imaging, 106 head injury, 10 metabolic causes, 32 ingestions). This left 636 for analysis, with 812 not reviewed or matched. Although 30 cases in the diagnosis arm (20 vascular, 10 inflammatory/infectious) had only 1 match, comparison participants were matched 2 to 1 when possible.

The median age of participant was 12 years (Table 1). The patients were older on average than random and diagnosis-matched comparison participants. The age-matched CT comparison group had fewer females. Compared with random and age-matched comparison participants, patients who had fast MRI were more often white or Asian. The comparison groups more often arrived by emergency medical services, whereas patients who had fast MRI more often arrived by private vehicle or interfacility transfer.

Higher proportions of children in the fast brain MRI group had focal neurologic deficits such as weakness, facial droop, slurred speech, or atypical gait (Table 2). The head CT comparison groups had higher proportions of generalized symptoms such as seizure and altered mental status. There were large proportions of patients presenting with headache among all comparison groups.

The most common diagnosis group in the fast brain MRI group was migraine (Table 3). Notably, 12% of the conditions were ultimately diagnosed as hemiplegic migraine. The most common diagnosis group for the random and age-matched head CT comparison groups was seizure. In the fast brain MRI group, there were higher proportions of vascular and inflammatory diagnoses.

Head CT comparison participants were roomed faster (Table 4). Patients who had fast MRI had shorter time to imaging order (64 minutes vs 99 minutes) but longer from order-to-completion time (43 minutes vs 18 minutes), resulting in similar arrival-to-completion times (142 minutes vs 139 minutes). ED LOS and admission rates were

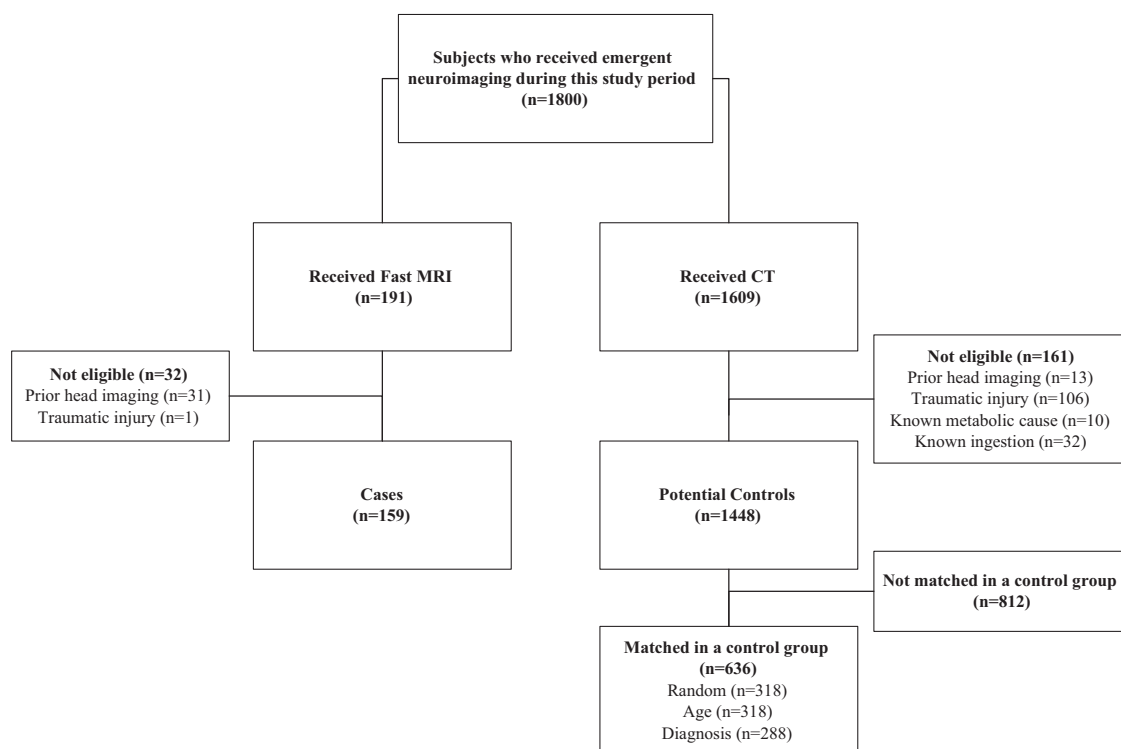


FIGURE 1.

Consort diagram. A total of 1800 patients presented with emergent neurologic complaints during the study period. 191 patients received fast MRI and 1609 received head CT. 159 patients who received fast MRI met inclusion and exclusion criteria. These were matched to 636 head CT patients in 3 control arms.

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

comparable across groups, with no difference in admission location. LOS for admitted patients was also similar. Imaging procedure time was longer for cases (15 minutes vs 11 minutes) but not significant.

The proportion of children with negative imaging results was less in the fast brain MRI group when compared with all head CT comparison participants (Table 5). The rate of repeat imaging was similar for all participants; however, the reason for repeat imaging was different. The fast brain MRI group had a higher proportion of repeat imaging for routine care or to further characterize imaging results. Random and age-matched arms of the head CT comparison groups had a higher proportion of repeat imaging to confirm the negative head CT results. In patients with negative initial imaging results, there were higher proportions of missed pathology with the head CT comparison groups compared with the fast brain MRI group (Table 5 and Supplemental Tables 1 and 2). This finding was most pronounced in the diagnosis-matched group. The proportion requiring anesthesia for repeat imaging was significantly lower in the fast brain MRI group, even when adjusted for age.

In terms of test performance, fast brain MRI had very high sensitivity (95.8%) and negative predictive value (98.2%). CT had significantly lower sensitivity (63.0%)

and negative predictive value (91.5%) than fast brain MRI (Supplemental Table 3).

DISCUSSION

In this planned subanalysis of a previously described quality improvement project, we found that use of fast brain MRI for evaluation of emergent neurologic complaints in children presenting to the ED was associated with less missed pathology compared with head CT without prolonging care. Specifically, this study found the sensitivity and negative predictive value of fast MRI to be 95.8% and 98.2% respectively, compared with 63.0% and 91.5% for CT. Fast brain MRI was not found to increase admission rate or LOS in the ED or hospital.^{20,36–38} This finding further emphasizes that, with a concerted effort, it is feasible to implement fast MRI in emergency settings. Because these sequences are motion insensitive and may be obtained rapidly, they are well suited for use in the ED. This study supports use of fast brain MRI in lieu of head CT as a screening tool in the ED for patients presenting with nontraumatic neurologic emergencies.

There has been increasing literature detailing the use of limited-sequence brain MRI for certain indications,

TABLE 1. Demographics and Mode of Arrival Distribution by Study Group

		Fast MRI (n=159)	Random Matched Comparison Group (n=318)		Age Matched Comparison Group (n=318)		Diagnosis Matched Comparison Group (n=288)	
		Median [IQR]	Median [IQR]	p	Median [IQR]	p	Median [IQR]	p
Age	Age (years)	12 [9]	6 [11]	<0.01 ^a	11 [10]	0.29	8 [12]	<0.01 ^a
		n (%)	n (%)	p	n (%)	p	n (%)	p
Sex	Female	90 (56.6)	156 (49.1)	0.07	150 (47.2)	0.03 ^a	149 (51.7)	0.20
	Male	68 (42.8)	162 (50.9)		168 (52.8)		139 (48.3)	
	Other	1 (0.6)	0 (0.0)		0 (0.0)		0 (0.0)	
Race	American Indian or Alaska Native	1 (0.6)	2 (0.6)	0.03 ^a	2 (0.6)	0.01 ^a	0 (0.0)	0.06
	Asian	6 (3.8)	3 (0.9)		2 (0.6)		5 (1.7)	
	Black or African American	36 (22.6)	74 (23.3)		78 (24.5)		74 (25.7)	
	White	108 (67.9)	201 (63.2)		195 (61.3)		178 (61.8)	
	Other	8 (5.0)	38 (11.9)		41 (12.9)		31 (10.8)	
Ethnicity	Hispanic	4 (2.5)	16 (5.0)	<0.01 ^a	10 (3.1)	<0.01 ^a	8 (2.8)	0.31
	Non-Hispanic	155 (97.5)	287 (90.3)		290 (91.2)		275 (95.5)	
	Other	0 (0.0)	15 (4.7)		18 (5.7)		5 (1.7)	
Mode of Arrival	Emergency Medical Services	15 (9.4)	117 (36.8)	<0.01 ^a	119 (37.4)	<0.01 ^a	85 (29.5)	<0.01 ^a
	Private vehicle	114 (71.7)	169 (53.1)		163 (51.3)		169 (58.7)	
	Transfer	30 (18.9)	31 (9.7)		31 (9.7)		31 (10.8)	
	Unknown	0 (0.0)	1 (0.3)		5 (1.6)		3 (1.0)	

^a Denotes significant difference in distribution between Fast MRI Cases and Control (p<0.05).

TABLE 2. Presenting Chief Complaints by Study Group

	Fast MRI (n=159)	Random Matched Comparison Group (n=318)		Age Matched Comparison Group (n=318)		Diagnosis Matched Comparison Group (n=288)	
	n (%)	n (%)	p	n (%)	p	n (%)	p
Weakness	93 (58.5)	24 (7.5)	0.02 ^a	14 (4.4)	0.33	12 (4.2)	0.71
Headache	66 (41.5)	95 (29.9)	0.07	116 (36.5)	0.47	113 (39.2)	0.75
Confusion	42 (26.4)	32 (10.1)	0.51	18 (5.7)	1.00	18 (6.2)	0.25
Altered mental status	41 (25.8)	74 (23.3)	<0.01 ^a	62 (19.5)	<0.01 ^a	77 (26.7)	<0.01 ^a
Facial droop	40 (25.2)	3 (0.9)	0.62	2 (0.6)	0.15	1 (0.3)	0.92
Slurred speech	38 (23.9)	3 (0.9)	0.02 ^a	5 (1.6)	0.69	2 (0.7)	0.54
Seizure	26 (16.4)	147 (46.2)	<0.01 ^a	122 (38.4)	<0.01 ^a	92 (31.9)	<0.01 ^a
Abnormal gait	23 (14.5)	15 (4.7)	<0.01 ^a	9 (2.8)	<0.01 ^a	11 (3.8)	<0.01 ^a
Vision changes	20 (12.6)	16 (5)	0.01 ^a	18 (5.7)	0.01 ^a	15 (5.2)	0.01 ^a
Eye problem	17 (10.7)	15 (4.7)	0.02 ^a	14 (4.4)	0.02 ^a	16 (5.6)	0.07
Lethargy	16 (10.1)	61 (19.2)	<0.01 ^a	27 (8.5)	<0.01 ^a	36 (12.5)	<0.01 ^a
Imbalanced	12 (7.5)	3 (0.9)	<0.01 ^a	1 (0.3)	<0.01 ^a	4 (1.4)	<0.01 ^a
Dizziness	10 (6.3)	14 (4.4)	<0.01 ^a	20 (6.3)	<0.01 ^a	10 (3.5)	<0.01 ^a
Abnormal sensation	9 (5.7)	1 (0.3)	<0.01 ^a	2 (0.6)	<0.01 ^a	0 (0)	<0.01 ^a
Vomiting	8 (5)	33 (10.4)	<0.01 ^a	23 (7.2)	<0.01 ^a	18 (6.2)	<0.01 ^a
Other	0 (0)	44 (13.8)	<0.01 ^a	47 (14.8)	<0.01 ^a	33 (11.5)	<0.01 ^a

Each patient could have more than one chief complaint recorded, so columns do not ways add up to 100%.
^a Denotes significant difference in distribution between Fast MRI Cases and Control (p<0.05).

TABLE 3. Diagnosis Groupings

	Fast MRI (n=159)	Random Matched Comparison Group (n=318)		Age Matched Comparison Group (n=318)		Diagnosis Matched Comparison Group (n=288)	
		n (%)	n (%)	p	n (%)	p	n (%)
Trauma	0 (0.0)	1 (0.3)	-	6 (1.9)	-	0 (0.0)	-
Vascular	17 (10.7)	2 (0.6)	<0.01 ^a	2 (0.6)	<0.01 ^a	14 (4.9) ^b	0.03 ^a
Neoplastic	3 (1.9)	5 (1.6)	1.00	5 (1.6)	1.00	6 (2.1)	1.00
Inflammatory/infectious	27 (17.0)	21 (6.6)	<0.01 ^a	17 (5.3)	<0.01 ^a	44 (15.3) ^c	0.74
Metabolic	3 (1.9)	8 (2.5)	0.91	4 (1.3)	0.89	6 (2.1)	1.00
Seizure/epilepsy	25 (15.7)	117 (36.8)	<0.01 ^a	100 (31.4)	<0.01 ^a	50 (17.4)	0.76
Migraine	46 (28.9)	60 (18.9)	0.02 ^a	81 (25.5)	0.49	92 (31.9)	0.58
Other	38 (23.9)	104 (32.7)	0.06	103 (32.4)	0.07	76 (26.4)	0.64

^a Denotes significant difference in distribution between Fast MRI Cases and Control (p<0.05).
^b Twenty vascular cases had only one available diagnosis matched control.
^c Ten inflammatory/infectious cases had only one available diagnosis matched control.

TABLE 4. Length of Stay and Disposition

	Fast MRI (n=159)	Random Matched Comparison Groups (n=318)		Age Matched Comparison Groups (n=318)		Diagnosis Matched Comparison Groups (n=288)		
		Median [IQR]	Median [IQR]	p	Median [IQR]	p	Median [IQR]	p
Time from arrival to room in ED (minutes)	11.9 [27.2]	8.1 [41.0]	0.91	9.2 [32.9]	0.67	11.5 [41.8]	0.47	
Length of stay in ED (hours)	5.2 [2.1]	5.0 [2.8]	0.92	5.0 [2.6]	0.88	5.2 [2.8]	0.37	
Time from arrival to order (minutes)	64.17 [104.8]	100.59 [127.1]	<0.01 ^a	95.4 [114.1]	<0.01 ^a	100.0 [134.2]	<0.01 ^a	
Time from order to image (minutes)	43.0 [36.6]	15.74 [29.5]	<0.01 ^a	19.2 [32.2]	<0.01 ^a	17.5 [30.8]	<0.01 ^a	
Length of imaging (minutes)	15 [10]	12 [8]	<0.01 ^a	11 [8]	<0.01 ^a	11 [7.25]	<0.01 ^a	
Time from arrival to finished imaging (minutes)	142 [123.5]	139 [137.3]	0.42	137 [125]	0.68	139.5 [139.5]	0.67	
Length of stay in the hospital (hours) ^b	46.8 [94.8]	38.7 [34.5]	0.07	46.0 [49.3]	0.59	48.8 [76.5]	0.86	
	n (%)	n (%)	p	n (%)	p	n (%)	p	
Disposition	Admit	83 (52.2%)	0.39	175 (55.0%)	0.16	147 (51.0%)	0.93	
	Discharge	75 (47.2%)		141 (44.3%)		168 (52.8%)		140 (48.6%)
	AMA	0 (0%)		2 (0.6%)		0%		0 (0%)
	Transfer	1 (0.6%)		0 (0%)		0%		1 (0.3%)

Abbreviation: AMA, Against Medical Advice.
^a Denotes significant difference in distribution between Fast MRI Cases and Comparison Groups (p<.05).
^b Length of stay in the hospital for subjects that were admitted ONLY.

specifically, trauma, nonaccidental trauma, and cerebrospinal fluid shunt malfunction.^{20,29,39} This study further supports current literature in finding that pediatric stroke is a rare phenomenon, with many mimicking symptoms. Our study originated as a part of the implementation of a stroke alert model.³⁴ These data indicate that fast MRI is a noninferior screening imaging modality for this heterogeneous group of pathologies that present with acute onset generalized neurologic symptoms. Thus, we aimed to describe an emerging indication for obtaining fast MRI in

the ED. We have demonstrated that with applied effort, it is feasible to obtain fast MRI without increasing ED LOS. This further emphasizes that fast MRI could become the screening neuroimaging modality of choice for patients presenting to the ED with emergent neurologic complaints.

Fast MRI allows for rapid diagnostic neuroimaging without the adverse effects of ionizing radiation. Many studies have demonstrated the ramifications of ionizing radiation for diagnostic neuroimaging purposes. Most recently, Hauptmann et al found a relative risk of a single head or

TABLE 5. Repeat Imaging

	Fast MRI (n=159)	Random Matched Comparison Group (n=318)		Age Matched Comparison Group (n=318)		Diagnosis Matched Comparison Group (n=288)		
		n (%)	n (%)	p	n (%)	p	n (%)	p
Negative initial imaging	113 (71.1)	274 (86.2)	<0.01 ^a	275 (86.5)	<0.01 ^a	243 (84.4)	<0.01 ^a	
Repeat imaging within 30 days	53 (33.3)	109 (34.3)	0.92	100 (31.4)	0.75	94 (32.6)	0.96	
Missed pathology	2 (1.8)	23 (8.4)	<0.01 ^a	20 (7.3)	<0.01 ^a	24 (9.9)	<0.01 ^a	
Anesthesia required for repeat imaging	17 (32.1)	66 (60.6)	<0.01 ^a	48 (48)	0.08	52 (55.3)	0.01 ^a	
Reason for repeat imaging	Confirm true negative	30 (56.6)	86 (78.9)	<0.01 ^a	78 (78)	<0.01 ^a	64 (68.1)	0.23
	Further characterize diagnosis	14 (26.4)	19 (17.4)	0.26	16 (16)	0.18	26 (27.6)	1.00
	Routine follow-up	9 (17.0)	3 (2.8)	<0.01 ^a	5 (5)	0.03 ^a	3 (3.2)	0.01 ^a
	Unrelated	0 (0)	1 (0.9)	-	1 (1)	-	1 (1.1)	-

^a Denotes significant difference in distribution between Fast MRI Cases and Matched Controls (p<0.05).

neck CT on future brain cancer to be 1.6, with an increased risk with cumulative doses.⁴⁰ Most pediatric institutions attempt to use as low radiation as possible, and many are transitioning to radiation sparing imaging techniques such as MRI.³⁹⁻⁴³ Fast brain MRI allows for a more detailed view of the brain without the negative consequences of radiation exposure.

A high number of patients in our study presenting with isolated seizures or headaches received head CT and had negative neuroimaging results. This finding mirrors current literature, suggesting that there is an overuse of neuroimaging in the ED for patients presenting with isolated headache and seizures as presenting symptoms.^{44,45} Finally, we noted race and ethnicity differences between those receiving fast MRI compared with head CT, except when matched by diagnosis. This supports the growing body of literature that shows health care inequities in emergency diagnostic evaluations.⁴⁶ Further research is needed to delineate these findings and reduce variability in ED imaging practice.

Clinical prediction rules are useful to guide decisions regarding when to perform certain diagnostics.^{44,47,48} During the study time period, a clinical pathway was introduced in the ED focusing on neurologic emergencies and decreasing time to diagnostic imaging.³⁴ Our study showed the lowest rate of missed pathology in the fast brain MRI group compared with all head CT comparison groups. Missed pathology was highest in the diagnosis-matched CT group. This finding suggests a need for a clinical prediction rule for nontraumatic neurologic emergencies. The pathway could serve as a framework for creating such a prediction rule.

Anesthesia use for repeat imaging was significantly lower with fast MRI than with head CT, even after adjusting for age. Although evidence is inconclusive, concerns remain about anesthesia's potential impact on the developing brain.⁴⁹⁻⁵¹ Additionally, sedation for imaging demands substantial personnel and health care resources.⁵² There has been an increasing demand for MRI. Although clinically

valuable, greater emergent reliance on MRI strains already limited availability and scheduling capacity. There is also limited MRI availability in community or free-standing ED facilities, further highlighting the value of a clinical prediction rule to reduce unnecessary neuroimaging.^{41,45}

Use of fast MRI resulted in less missed pathology when compared with head CT. There were 2 participants that missed pathology. On follow-up MRI, 1 patient was noted to have findings of Bell's palsy, while the other had findings of status epilepticus. Neither of these diagnoses are typically made by neuroimaging, but it is important to note that full-brain MRI did show findings suggestive of these, while the initial fast brain MRI did not. Despite these misses, the participants had a much lower rate of missed pathology (1.8% vs 8.5%). When matched by diagnosis, there was an even higher missed pathology rate (9.9%). This was particularly notable for the comparison participants with vascular or infectious or inflammatory pathology. One major difference between case participants and comparison participants was the reason for follow-up imaging. The cases in our study had a higher proportion of follow-up imaging for routine care or to further characterize known pathology. The comparison participants had a higher proportion of follow-up imaging to confirm negative imaging results, and many were found to have missed pathology.

Limitations

Not all patients received full-brain MRI with or without angiography, so missed diagnoses with fast MRI or head CT are estimates. To mitigate this, we used a diagnosis-matched head CT comparison group and reviewed all neuroimaging within 30 days of presentation, assuming findings beyond that timeframe were less clinically relevant. Some follow-up imaging at outside facilities may have been missed, but given our institution's role as the only pediatric center in a large region, such imaging would likely be uploaded for continuity of care.

We did not track false positives (eg, incidental findings), limiting our ability to assess specificity and positive predictive value. Additionally, this was a subanalysis of a quality improvement project that introduced a new institutional pathway for sudden-onset neurologic symptoms, centered on fast MRI.³⁴ This may be a possible confounder, and because vascular pathology was the pathway's focus, it could also explain fewer vascular diagnosis comparison participants.

CONCLUSION

Our study demonstrated that in examination of children with undifferentiated neurologic emergencies in the ED, fast brain MRI resulted in fewer missed pathologic findings and thus had a higher sensitivity and negative predictive value when compared with head CT. Use of fast brain MRI for the children did not result in increased ED LOS or hospitalization. A prospective cohort study comparing fast brain MRI and head CT with full-brain MRI is needed to determine true specificity and negative predictive values.

Another opportunity for future study includes evaluating the cost-effectiveness of fast brain MRI compared with head CT in the diagnostic evaluation of pediatric neurologic emergencies. Finally, the use of neuroimaging for children in the emergency setting should be evidence-based, and efforts should be focused on deriving and validating clinical prediction rules for neuroimaging in children.

ABBREVIATIONS

AMA: against medical advice
CT: computed tomography
DWI: diffusion weighted imaging
ED: emergency department
EMS: emergency medical services
FLAIR: fluid attenuation inversion recovery
LOS: length of stay
MRI: magnetic resonance imaging
SWI: susceptibility weighted image

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