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Research Article

First Time Non-Provoked Seizure Presentation to the ED Decision Analysis

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Abstract

Background: Majority of pediatric patients who present to the Emergency Department (ED) with a first time unprovoked seizure are not fully worked up during their ED stay and are instead hospitalized for further evaluation. Obtaining a full work up in the ED has not been widely studied but could prove to ensure more cost-effective treatments, decrease resource utilization, and reduce physician work.

Methods: A retrospective chart review was performed for all patients under 18 years old presenting to the ED with first time unprovoked seizures from January 2014 through May 2022. 194 patients were included in the study and an evaluation strategy score was calculated for the patients who received a full evaluation (EEG, brain imaging, decision to start anticonvulsants) in hospitalized patients, ED patients (all elements completed in ED), and outpatient (all elements completed in ED and outpatient setting) patients. This score was a proxy measure for physician work and hospital resources consumed to manage the patient.

Results: Patients who received a full workup in the ED had the lowest evaluation work score (5.3) followed by those who received an outpatient workup (5.4) and inpatient workup (10.6) ($p<0.001$). The outpatient workup took the longest to receive their necessary EEG (836 hours) and brain imaging (1401 hours). The ED workup strategy took the least amount of time to receive their EEG (3.6 hours) and brain imaging (3.1 hours) which yielded a faster anticonvulsant decision.

Conclusion: Our decision analysis showed that the ED workup strategy had the lowest resource utilization score and was the fastest to complete the necessary EEG, brain imaging, and anticonvulsant medication decisions for patients presenting to the ED with a first time unprovoked seizure. The workup for a first time unprovoked seizure can be tedious, thus physicians should consider fully working up these patients in the ED.

Keywords: *Seizure, Convulsion, Disposition, Hospitalization, EEG, Neuroimaging, Brain Imaging, MRI Scanning, CT Scanning, Anticonvulsants, Antiepileptic Drugs, Decision Analysis, Resource Utilization*

Introduction

As many as 40,000 pediatric patients per year experience their first unprovoked seizure. Non-provoked seizures, as defined by the American Academy of Neurology, accounts for all seizures in a child that cannot be explained by seizure provoking factors such as fever, trauma, diarrhea, or other infections.[1] This first-time non-provoked seizure episode in a child is frightening from the parents' standpoint, and identifying the cause of such episodes can be challenging. Some patients with a first-time unprovoked seizure will only have a single seizure while others will go on to develop recurrent seizures.[2]

Obtaining an electroencephalogram (EEG) and/or magnetic resonance imaging (MRI) scan of the brain provides valuable information to fully assess the condition of the patient. However, for most patients who present to the ED with first time unprovoked seizures, an EEG and/or MRI are not obtained in the ED, usually because these studies are not available after hours. Instead, most patients are either hospitalized to obtain an EEG and MRI or discharged from the ED to have their imaging and EEG done as an outpatient. Both the inpatient and outpatient approaches have cost-related issues and can lead to delays in the initiation of anticonvulsant medications.[3] The role of EEG and neuroimaging obtained in the ED as part of the evaluation has not been widely studied but could prove to be a more timely and cost-efficient means to complete this evaluation.

The purpose of this study is to compare the evaluation resource utilization and timeline in children presenting to the ED with first time non-provoked seizures who had both neuroimaging and EEG completed during the initial ED visit, or were hospitalized for EEG and/or neuroimaging, or discharged from the ED for completion of EEG and/or neuroimaging as an outpatient.

Methods

This was a retrospective study utilizing the hospital's Epic electronic medical record (EMR) charts for all patients under 18 years of age presenting to the ED at a tertiary care Children's hospital (staffed 24/7 by board certified fellowship trained pediatric emergency physicians, annual 2019 pediatric ED volume of 30,000) for new-onset seizures from January 2014 to May 2022. This study period was chosen because of better MRI and EEG availability to a limited degree after hours since 2014. Ordering a brain MRI and/or EEG from the ED during regular business hours is generally available. Obtaining these after regular business hours is potentially available, but is more restricted. Sedation for MRI is potentially available 24/7, but this depends on the nature of the emergency, staff availability, and last oral intake (NPO) status.

This emergency department utilizes front end facility billing software that categorizes chief complaints, for which new-onset seizure is one of those categories. Patients were identified using a query of this chief complaint field. From these patients, those with a subsequent diagnosis of provoked or recurrent seizures (i.e., had a previous seizure history) were excluded from the data set leaving only those patients who presented to the ED with a first-time unprovoked seizure. Data from these remaining encounters were queried electronically via a smart database query to include detailed data on demographics, disposition, medications prescribed at discharge and as an outpatient, number and times of completed neuroimaging studies and EEGs, and whether those tests were abnormal or not. All charts were manually reviewed for additional details.

We defined full evaluations for these unprovoked seizure patients as those who completed an EEG, brain imaging either as a CT or MRI scan of the brain, and a decision on whether to start anticonvulsant medications (i.e., "all elements") in consultation with a pediatric neurologist. Patients were grouped based on the type of workup they received for their unprovoked seizure. The groups included hospitalized patients (patients presenting to the ED who were hospitalized to complete "all elements" during the ED and/or inpatient course) as group 1; ED patients ("all elements" completed in the ED, then discharged home) as group 2; outpatient ("all elements" completed in the outpatient setting following ED discharge) as group 3; EEG in the ED and neuroimaging as an outpatient as group 4; neuroimaging in the ED and EEG as an outpatient as group 5; incomplete inpatient (either EEG or neuroimaging not completed) as group 6; ED+outpatient incomplete ("all elements" not completed) as group 7; no neuroimaging and no EEG (i.e., neither study completed) as group 8. All groups are exclusive (i.e., a patient can only belong to one of these groups).

A non-validated resource utilization score was then calculated for each patient based on the hospital length of stay, the number of physician hospital evaluation/visits, the number of EEGs, MRIs, and CT scans completed, sedation episodes, outpatient primary care physician (PCP) follow up visits, and outpatient neurology follow up visits. These values were added up for each patient to create this score that is further described in table 1. While not all the points are equal in resources, the sum of these scores formed a rough proxy of the amount of physician work and hospital resources required to manage the patient. A decision analysis using this score was performed to compare the different clinical approaches to complete an "all elements" evaluation for children presenting to the ED with a first time non-provoked seizure.

Table 1: Resource utilization scoring system.

Item	Description
ED evaluation	1 point for ED staff evaluation and management including emergency physician evaluation. All patients get this point because all patients were initially evaluated in the ED.
Hospitalization	1 point for hospital admission (inpatient nursing and hospitalist evaluation and management plus additional work for the discharge process), plus the inpatient length of stay (a decimal number (difference between admission day/time and discharge day/time) multiplied by 2 because each day other than the initial day or night of admission almost always has a hospitalist visit/note and a neurologist visit/note.
EEG	1 point per completed EEG (includes technician study acquisition and interpretation by a neurologist).
Brain CT scan	1 point per brain CT completed (includes technician imaging acquisition and interpretation by a radiologist).
Brain MRI scan	1 point per brain MRI completed (includes technician imaging acquisition and interpretation by a radiologist).
Sedation	1 point per propofol sedation episode (sometimes needed for brain MRI scanning in children under 8 years of age or sometimes in older patients if the child's condition requires sedation performed by a credentialed sedation physician and hospital sedation nursing staff).
Outpatient	1 point for each outpatient visit with the patient's primary care physician or neurologist consulting physician. For this particular parameter, if the primary care physician used the Epic system for their office EMR, we captured all these visits, but if the primary care physician did not use the Epic system for their office EMR, we were not able to capture all these visits (we assumed 1 visit in this case which is likely an underestimate). Nearly all non-Inpatient and non-ED patients had only 1 primary care physician visit. A single patient was noted to have 6 primary care physician visits. The primary care physicians might have provided additional services that did not result in an actual patient visit such as obtaining insurance pre-authorization for neuroimaging, ordering neuroimaging, sedation, EEGs, and referrals to neurologists. This additional work, was not captured by this resource utilization score. All pediatric neurologists in this community use Epic as their office EMR and thus all outpatient neurology visits were captured. Outpatient visits were no longer counted once EEG and brain imaging were completed and determination for long term seizure medications were made.

Results

Of the 194 patients included in the study, 43 received a full workup as an inpatient (IP), 11 received a full workup in the ED, and 30 received a full workup as an outpatient (OP).

Patient demographics and resource utilization scores are summarized in table 2. In considering the 3 main groups (IP, ED, OP), patients who received a full workup in the ED had the lowest mean evaluation work score (5.3) followed by those who received a full outpatient workup (5.4), and full inpatient workup (10.6) ($p<0.001$ by analysis of variance). The true outpatient group mean is likely higher than 5.4 (i.e., it is an underestimate of the true score) since we were not able to track all the outpatient visits for primary care practices that did not chart in the Epic EMR. Additionally, some outpatients could have been referred for additional non-hospital MRI scans (e.g., a scan done at a private MRI facility) and/or non-hospital EEGs (e.g., an EEG done at a private EEG facility). Table 2 includes 95% confidence intervals of the mean (CIM) for all the groups' resource utilization scores to perform rough comparisons of the various groups.

The sex distributions were not significantly different between the 3 main groups (IP, ED, OP). The mean ages in these 3 groups were significantly different ($p=0.0056$ by analysis of variance) with the ED group having older patients (mean age 11.4 years compared to 6.0 and 8.0 years for the IP and OP groups, respectively). The ED group had ED arrival times just prior to or during regular business hours (included two Saturday mornings) which greatly facilitated the availability of ED MRI, EEG, and neurology consultation, while the other groups had ED arrival times at all hours and days of the week.

Table 2: Demographics and resource utilization scores in evaluation groups.

	Inpatient (IP)	ED	Out-patient (OP)	ED EEG + OP	ED Imaging + OP	IP Incomplete	ED+OP Incomplete	No CT/ MRI, No EEG
Group number	1	2	3	4	5	6	7	8
N	43	11	30	2	16	9	49	34
Mean total resource utilization score	**10.6**	**5.3**	**5.4**	**7.0**	**5.9**	**7.1**	**3.5**	**2.0**
SD	2.1	1.3	0.7	0	0.9	1.8	0.7	0.2
95% confidence interval of the mean	10.0-11.3	4.4-6.1	5.1-5.7	7.0-7.0	5.4-6.4	5.7-8.6	3.3-3.7	2.0-2.1
Number of males (% of group total)	27 (63%)	4 (36%)	16 (53%)	2 (100%)	10 (63%)	6 (67%)	30 (61%)	20 (59%)
Mean age	6.0	11.4	8.0	8.2	9.4	6.6	9.8	7.3
SD	5.7	3.4	4.2	1.4	5.1	6.5	5.4	5.7
Age <12 months	6	0	1	0	0	3	4	5
Age 12 months to 3 years	18	1	5	0	3	1	5	8
Age 4 to 12 years	11	6	19	2	7	3	21	13
Age 13 to 17 years	8	4	5	0	6	2	19	8

The neuroimaging results are summarized in table 3. In considering the 3 main groups (IP, ED, OP), initial neuroimaging was completed in a mean of 13, 3.1, and 1401 hours, respectively ($p<0.001$ by analysis of variance). The ED group was older suggesting that sedation requirements for younger children made it more difficult to complete the MRI in the ED. Table 3 confirms this showing that 30 of 38 (70%), 3 of 8 (38%), and 14 of 28 (50%) MRI scans required sedation in the IP, ED, and OP groups, respectively ($p=0.015$ by Chi-square).

It should be noted that some inpatients received their initial neuroimaging in the ED. Outpatients who received their initial neuroimaging in the ED were placed in group 5 (not the OP group 3). Brain abnormalities were identified by neuroimaging in 26%, 27%, and 10% of the IP, ED, and OP groups, respectively (not statistically different by chi-square). Brain CT scans were obtained on 64 out of the 194 patients. Brain MRI scans were obtained in 95 out of the 194 cases. Both brain MRI and brain CT scans were obtained on 31 patients. Of these, 29 CTs were obtained in the ED followed later by MRI scans. In 6 cases, the initial brain CT showed a normal brain, but the subsequent brain MRI scan showed an abnormal brain (false negative CT). Initial CTs showed brain abnormalities in 8 cases and of these, a subsequent brain MRI scan showed a normal brain in 4 cases (4 false positive CT). In the 31 cases in which both brain CT and MRI scans were obtained, the CT scan never provided additional information above that revealed on the MRI scan. Brain CT scans showed sinus and/or mastoid disease in 16 of 64 cases. Brain MRI scans showed sinus and/or mastoid disease in 23 of 95 cases.

Table 3: Brain imaging relevant parameters in the inpatient (IP), ED, and outpatient (OP) evaluation strategy groups and other groups.

	Inpatient (IP)	ED	Out-patient (OP)	ED EEG + OP	ED Imaging + OP	IP Incom-plete	ED+OP Incomplete	No CT/ MRI, No EEG
Group number	1	2	3	4	5	6	7	8
N	43	11	30	2	16	9	49	34
Completed brain imaging (CT or MRI or both)	43	11	30	2	16	0	26	0
Mean hours to first brain imaging (CT or MRI)	13	3.1	1401	2381	1.4	N/A	599	N/A
Both brain CT and MRI completed	18	1[A]	0	1	9	0	2	0
Initial brain CT in ED, MRI completed later	18	1	0	0	8	0	2	0
Brain abnormality identified on brain imaging	11 (26%)	3 (27%)	3 (10%)	0 (0%)	3 (19%)	0 N/A	1 (4%)	0 (N/A)
Normal brain CT, but abnormal brain MRI scan	5	0	0	0	1	0	0	0
Brain CT completed	23	4	2	1	15[B]	0	19	0
Mean hours to first brain CT if completed	1.3	1.8	2788	1332	150[B]	N/A	1.3	N/A
Abnormal brain findings on CT	5	0	0	0	2	N/A	1	N/A
Above CTs with normal MRI (false positive CT)	3	N/A	N/A	N/A	0	N/A	1	N/A
Brain CT with sinus disease, normal brain	4	1	2	0	6	N/A	3	N/A
Brain CT completed ED	23	4	0	0	14	0	19	0
Brain MRI completed	38	8[A]	28	2	10	0	9	0
Mean hours to first brain MRI if completed	26	454 (3.9[A])	1302	2389	651	N/A	1756	N/A
Abnormal brain findings on MRI	11	3	3	0	3	N/A	1	N/A
Brain MRI with sinus disease, normal brain	7	1	5	0	4	N/A	2	N/A
Brain MRI with abnormal brain + sinus disease	3	0	1	0	0	N/A	0	N/A
Sedation required for brain MRI	30	3	14	2	6	N/A	3	N/A
Brain MRI completed in ED	1	7	0	0	2	0	4	0

[A]MRI brain scan obtained in ED in 7 of 8 cases. In one patient a brain CT was completed in ED and brain MRI scan was completed as an outpatient 3606 hours after ED presentation. If this case is excluded, the mean hours to first brain MRI scan in the ED would have been 3.9 hours (instead of 454 hours).

[B]CT brain scan obtained in ED in 14 of 15 cases. 1 brain CT scan completed as outpatient 2232 hours after ED presentation. If this case is excluded, the mean hours to first brain CT scan in the ED would have been 1.1 hours.

EEG results are summarized in table 4. In considering the 3 main groups (IP, ED, OP), an EEG was completed in a mean of 22, 3.6, and 836 hours, respectively ($p<0.001$ by analysis of variance). It should be noted that some of the inpatients received their initial EEG in the ED. Outpatients who received their EEG in the ED were placed in group 4 (not the OP group 3). EEGs showed spiking (includes spiking, epileptiform discharges, electrographic seizures) in 26%, 45%, and 53% of the IP, ED, and OP groups, respectively ($p=0.048$). This yields an overall initial EEG spiking sensitivity of 85% (52 out of 61), because 9 additional patients showed a non-spiking initial EEG, but a subsequent EEG demonstrated spiking. This yields an overall false negative EEG rate of 7% (9 of the 133 patients who had an EEG in the denominator), or a false negative EEG rate of 11% (9 of the 81 patients who had a non-spiking EEG in the denominator). Five patients had EEG slowing without spiking. These patients were not counted as "spiking" EEGs. Two patients had EEG slowing with spiking and these were included as "spiking" EEGs.

Table 4: EEG relevant parameters in the inpatient (IP), ED, and outpatient (OP) evaluation strategy groups and other groups.

	Inpatient (IP)	ED	Outpatient (OP)	ED EEG + OP	ED Imaging + OP	IP Incomplete	ED+OP Incomplete	No CT/ MRI, No EEG
Group number	1	2	3	4	5	6	7	8
N	43	11	30	2	16	9	49	34
Completed EEG	43	11	30	2	16	9	22	0
Mean hours to first EEG	22	3.6	836	2.7	479	18	721	N/A
EEG completed in ED	6	11	1	2	0	2	7	0
Spiking on initial EEG	11 (26%)	5 (45%)	16 (53%)	1 (50%)	10 (63%)	1 (11%)	8 (36%)	0
Mean hours to the initial spiking EEG	14	3.8	979	2.6	700	15	117	N/A
Initial EEG normal but subsequent EEG shows spiking	3	0	2	1	1	1	1	N/A
EEG slowing without spiking	1	1	0	0	0	1	2	N/A
EEG slowing and spiking	0	0	1	0	0	0	1	N/A
Spiking on EEG + abnormal brain on neuroimaging	3 (7%)	2 (18%)	2 (7%)	0	2 (13%)	0	0	N/A

For IP Incomplete (group 6): 9 patients. All 9 had EEG completed and none of them had brain imaging completed.

For ED+OP Incomplete (group 7): 49 patients. 22 had EEG completed and 27 had brain imaging completed.

Spiking EEG = spiking, epileptiform discharges, or electrographic seizure activity identified on EEG

Long term anticonvulsant drug initiation results are summarized in table 5. Anticonvulsant drug initiation was determined by the prescription of anticonvulsant medications at discharge from the ED, inpatient service, or within 6 months following discharge. If an outpatient anticonvulsant was prescribed outside of Epic, our data query would have missed this. Long term anticonsulvants did not include short term benzodiazepine rescue medications. In considering the 3 main groups (IP, ED, OP), long term anticonvulsants were initiated in 53%, 64%, and 63%, respectively (not statistically significant by chi-square). Correlating the EEG spiking frequency to the anticonvulsant initiation frequency in the IP, ED, and OP groups, they pair as follows: 26%/53%, 45%/64%, 53%/63%, respectively. In the IP group, clinical observation of a second inpatient seizure or clinical suspicion for a seizure disorder likely prompted anticonvulsant therapy despite a negative EEG accounting for the 26%/53% mismatch. In the ED group, the 45%/64% mismatch could be due to clinical suspicion for a seizure disorder despite a non-spiking EEG. The OP 53%/63% mismatch was the smallest of the three groups.

Seven of the 43 patients (16%) in the IP group had another seizure during their inpatient stay. Patients returned to the ED with another seizure following their initial ED visit in 30%, 18%, and 34%, in the IP, ED, and OP groups, respectively (not statistically significant by chi-square).

Table 5: Anticonvulsant drug initiation, recurrent seizures, and relevant parameters in the inpatient (IP), ED, and outpatient (OP) evaluation strategy groups and other groups.

	Inpa-tient (IP)	ED	Out-patient (OP)	ED EEG + OP	ED Imaging + OP	IP Incomplete	ED+OP Incomplete	No CT/ MRI, No EEG
Group number	1	2	3	4	5	6	7	8
N	43	11	30	2	16	9	49	34
Patients started on any long -term AEDs (discharge or outpatient)	23 (53%)	7 (64%)	19 (63%)	2 (100%)	9 (56%)	3 (33%)	16 (33%)	0 (0%)
Leviteracetam	18	5	14	1	5	2	10	0
Oxcarbazepine	7	3	5	0	3	0	3	0
Other AEDs	2	0	2	1	1	1	3	0
Benzodiazepine rescue medications (not long-term)	19	3	11	1	7	3	5	5
Initial EEG spiking and started on long-term AEDs	9	5	14	1	6	1	7	N/A
Initial EEG not spiking, started on long-term AEDs anyway	14	2	5	1	3	2	1	N/A
Returned to ED for another seizure	13 (30%)	2 (18%)	10 (33%)	2 (100%)	8 (50%)	1 (11%)	10 (20%)	2 (25%)
Despite anticonvulsants started earlier	11	2	6	2	6	1	5	0
No anticonvulsants started earlier	2	0	4	0	2	0	5	2
Initial EEG spiking prior to return to ED	4	1	4	1	5	0	1	0

AED = antiepileptic drugs (anticonvulsant drugs)

EEG spiking = spiking, epileptiform discharges, or electrographic seizure activity identified on EEG

Discussion

In summary, the IP approach is more costly than the ED approach with no significant clinical advantages. The OP approach is not necessarily more costly than the ED approach, but it is significantly slower in obtaining initial neuroimaging and EEG. The ED approach is more efficient, but it requires additional work by the ED physicians and staff, and it greatly prolongs the ED length of stay, in a facility that is already very busy, often with patients waiting to be seen.

This study was initiated to compare the IP, ED, and OP approaches; however, our results found only 11 patients with all elements completed in the ED, due to the difficulty in obtaining "all elements" (neuroimaging, EEG, neurology consultation, and long term anticonvulsant recommendations) in the ED. Thus, this is more of a pilot study given the small numbers in the ED group. The results indicate that completing all elements in the ED only took place when the patient presented in the ED just prior to or during regular business hours highlighting the difficulty in obtaining all elements outside of regular business hours.

The IP group showed EEG spiking in 26%, neuroimaging brain abnormalities in 26%, and both of these findings in 7%. Thus, there are more hospitalized patients who have neither EEG spiking, nor a brain abnormality. These inpatients with a negative EEG and normal brain imaging had no significant benefit from hospitalization other than watchful monitoring.

This study shows that a first time non-provoked seizure evaluation completing all elements in the ED was only completed under limited circumstances (regular business hours and in older patients with less of a need for sedation). Yet when all elements were completed in the ED, this resulted in much lower resource utilization and physician work. The inpatient approach results in additional resources which includes more physician work. A single ED visit can potentially accomplish what a multi-day hospitalization can do, but limiting factors include: other simultaneous clinical responsibilities in a busy ED, other ED patients waiting to be seen, availability of MRI, availability of EEG, and availability of neurology consultation. These are the current realities of limited resources that are compelling. Inpatient beds are another important limited resource. While the ED approach requires much work, time, and resources, it is an option that could save an inpatient bed for a patient that has no other option. We could speculate that some of the ED evaluations could have been completed due to resource availability in combination with inpatient bed shortages, and/or requests from the inpatient service to complete the evaluation in the ED.

The practice of emergency medicine is always changing/evolving. In the 1980's, head trauma patients were hospitalized for observation since neuroimaging was not easily available. In the past, it took over an hour to obtain a CT scan of the brain with relatively poor image quality that often required sedation, and it was only available during regular business hours. Compared this to today when we can obtain a head CT scan in one second on a 24/7 basis at many EDs. MRI scanning is going through a similar evolution. It very likely will become faster and better. It would be unreasonable to assume that MRI technology will fail to advance. It very likely will become more available after-hours.

Payment transformation in healthcare is changing/evolving. Inpatient services are expensive resulting in greater pressure to develop alternative modes of delivering safe and effective care. Our study demonstrates that this can be done, but only sometimes due to resource limitations. However, as these evolve, ED practice will evolve as well. Payment transformation forces, advances in MRI technology, and better resource availability might eventually combine to shift more of these cases to be completed in the ED setting.

Most physicians are very busy (i.e., overworked), thus minimizing unnecessary physician work is beneficial. Pediatric emergency physicians are busy as well, but a single emergency physician can order a neuroimaging study and an EEG. While the neurologist must render an interpretation of the EEG, he/she does not need to report to the ED to evaluate the patient in most instances, since the emergency physician's evaluation can usually be relied on. A discussion between the two physicians in combination with EEG and neuroimaging results are often sufficient to decide on anticonvulsant therapy and disposition. If initiated, an anticonvulsant loading dose can be administered prior to ED discharge on oral maintenance anticonvulsants. This is additional work by the emergency physician, results in less hospital inpatient resources and less work for other physicians. The downside is that this additional work by the neurologist, EEG technician, MRI technician, and radiologists, might need to be outside of the standard business hours time period (i.e., nights, weekends, holidays).

The ED approach also shortens the time to neuroimaging and EEG. If a serious brain condition is present, obtaining neuroimaging in the ED permits its early identification, treatment, and inpatient disposition if indicated at which point, it should be a more certain high yield hospitalization. If a serious seizure disorder is present, obtaining an EEG in the ED permits its early identification and initiation of anticonvulsant therapy.

Both the ED and outpatient strategies had similar mean evaluation strategy scores of 5.3 and 5.4 respectively. This suggests that the ED and outpatient workups require the same amount of physician work and resources. However, the prolonged time to complete initial neuroimaging and EEG in the OP evaluation strategy does not compare favorably to the ED approach which obtains information about the patient's EEG and brain imaging status in a few hours, reducing the risk of more serious seizures in the future. The amount of physician work for the outpatient approach was probably underestimated with the scoring system used. Primary care physicians must often perform the following tasks: 1) obtain insurance pre-authorization for neuroimaging, 2) order and schedule the neuroimaging and EEG, 3) communicate the results of these studies with the patient families, and 4) obtain neurology consultation. This work is often performed behind the scenes and is not part of an office encounter. The ED approach eliminates the need for insurance pre-authorization and "scheduling", it facilitates communication of the neuroimaging and EEG results to the patient families, and it avoids the need for the neurologist to report to the hospital to examine the patient. The outpatient method requires more time and work on the part of patient families, since they must see their primary care physician, report to the hospital for neuroimaging and EEG, and report to the neurologist's office for consultation.

Discharge diagnoses for the some of the patients in this study might have been a non-seizure diagnosis, such as abnormal movements; however, these patients were still included in this study because, they presented to the ED with what was felt to be an unprovoked seizure. Physicians still had to evaluate the patient with or without brain imaging and EEG for a first-time unprovoked seizure, to conclude that the patient did not experience a seizure. The inclusion criteria for this study were any patient who presented to the ED with a first-time unprovoked seizure regardless of the patient's final diagnosis. Some presentations are of greater clinical risk than others. Note that groups 6, 7, and 8 likely contained patients with lower clinical risk since these patients had overall lower rates of brain imaging abnormalities, EEG spiking, anticonvulsant therapy initiation, and returning to the ED for another seizure, thus there was less priority on these patients to obtain neuroimaging and an EEG.

Prior studies have looked at the value of emergent neuroimaging and EEGs in first-time unprovoked seizure patients. One study recommended emergent neuroimaging for patients with predisposing conditions that put them at a higher risk for having an abnormal MRI or CT scan.[4]

Another study emphasized the usefulness of conducting EEGs in the ED as a tool to help decide which patients presenting with unprovoked seizures could be discharged and who needed to be admitted for further observation.[5]

Our study found that in patients where both brain CT and MRI were completed, MRI identified all abnormalities (i.e., brain CT added no additional information over MRI). CT scans had some false positive and some false negative results (using the brain MRI scan as the gold standard comparison which naturally favors the MRI scan results). This suggests that MRI scanning is preferred to CT scanning, yet the usual comparison factors remain: 1) CT exposes the brain to X-ray radiation, while MRI does not. 2) MRI scanning is slow and requires sedation in young children, while CT scanning is fast and does not require sedation. 3) CT is more readily available after hours compared to MRI in most hospitals.

Although previous studies have looked at the value of emergent neuroimaging and EEGs, this study is the first to evaluate the full workup of first-time unprovoked seizures in pediatric patients. Previous literature has not evaluated the utility of conducting both neuroimaging and EEGs in the ED nor compared the rates of receiving such tests between the different evaluation strategies.

Limitations

Limitations for this study include the utilization of a non-standard, non-validated resource utilization score; however, this score includes the major clinical elements that are costly (hospitalization expense, imaging expense, EEG expense) and require human staff work (nursing, EEG technician, MRI technician, neurologists, hospitalists, anesthesiologists, emergency physicians, primary care physicians). The IP, ED, and OP groups were not randomized. Thus, it should be assumed that the three groups have non-equal clinical risk. The anticipated expectation was that the IP group would have the highest clinical risk, the OP group would have the lowest clinical risk, and ED group would have an intermediate clinical risk, but the results demonstrated that the IP, ED, and OP groups were similar in the clinical risk outcomes described, suggesting that these three groups are reasonably comparable despite non-randomization.

Conclusion

In conclusion, our decision analysis demonstrates that a complete workup of first-time unprovoked seizure patients in the ED is the most efficient option to complete the necessary studies for a complete evaluation (faster, less overall work, and less overall cost) for patients presenting to the ED with a first time non-provoked seizure, but this is limited due to availability of these resources after hours.

Conflict of Interest

The authors declare they have no potential conflicts of interest to disclose.

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