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Reassessment: Neuroimaging in the emergency patient presenting with seizure (an evidence-based review)

Report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology



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ABSTRACT

Objective: To reassess the value of neuroimaging of the emergency patient presenting with seizure as a screening procedure for providing information that will change acute management, and to reassess clinical and historical features associated with an abnormal neuroimaging study in these patients.

Methods: A broad-based panel with topic expertise evaluated the available evidence based on a structured literature review using a Medline search from 1966 until November 2004.

Results: The 15 articles meeting criteria were Class II or III evidence since interpretation was not masked to the patient's clinical presentation; most were series including 22 to 875 patients. There is evidence that for adults with first seizure, cranial CT will change acute management in 9 to 17% of patients. CT in the emergency department for children presenting with first seizure will change acute management in approximately 3 to 8%. There is no clear difference between rates of abnormal emergent CT for patients with chronic seizures vs first. Children <6 months presenting with seizures have clinically relevant abnormalities on CT scans 50% of the time. Persons with AIDS and first seizure have high rates of abnormalities, and CNS toxoplasmosis is frequently found. Abnormal neurologic examination, predisposing history, or focal seizure onset are probably predictive of an abnormal CT study in this context.

Conclusions: Immediate noncontrast CT is possibly useful for emergency patients presenting with seizure to guide appropriate acute management especially where there is an abnormal neurologic examination, predisposing history, or focal seizure onset. *Neurology*® 2007;69:1772-1780

INTRODUCTION The Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology is charged with developing guidelines for the use of therapeutic modalities, diagnostic tests, and screening procedures. This reassessment is an update of the previous practice parameter from 1996¹ and employs improved methodology for the development of clinical practice guidelines. This practice parameter summarizes evidence for the usefulness of performing an immediate neuroimaging procedure in the emergency department on persons presenting with seizures. In this updated assessment, the authors specifically sought evidence for the likelihood

that neuroimaging would lead to an acute or urgent change in management, and further, for characteristics of patients likely to have an abnormal neuroimaging study in this setting. Therefore, this reassessment is aimed at analyzing the usefulness of neuroimaging as a screening procedure for altering management of the emergency patient presenting with a seizure, and at determining which clinical and historical characteristics indicate the need for a neuroimaging study for such patients.

DESCRIPTION OF THE ANALYTICAL PROCESS Panel selection. Physicians with specialties related to the review (neurology, epilepsy, neuro-

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radiology, neurosurgery, emergency medicine, pediatric emergency medicine, and pediatric epilepsy) were appointed by the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. One panel member from the previous assessment was specifically included (Robert D. Zimmerman, MD). One panel member was officially appointed by the American College of Emergency Physicians (J. Stephen Huff, MD, FACEP).

Description of literature review. A literature search was performed using Ovid Medline[®] for relevant articles published from 1966 until November 2004 using the following key words: diagnostic imaging, neuroimaging, seizures, epilepsy, emergency medical services, emergencies, craniocerebral trauma, neurocysticercosis, HIV infection, and status epilepticus. These last three were specifically searched since these are common conditions known to be associated with structural brain lesions and seizures, especially first seizures. The search was limited to reports in humans and abstracts available in English. Standard search procedures were used and subheadings were applied as appropriate. The initial search yielded 73 articles. A second search was performed shortly after the first search using the above terms but specific for studies in children; this yielded an additional 19 articles for a total of 92 articles.

This list was refined by reviewing the citation abstracts with exclusion of the following types of articles: review articles without primary data, case reports, articles for which the abstract did not indicate that a neuroimaging evaluation of seizures in an urgent or emergent setting was performed. Twenty-five of 92 articles met inclusion criteria and were selected for complete review. From these 25 articles, further selection was made for inclusion in the analysis if they reported features important for generalizability and for key elements in evaluating the usefulness of a screening procedure. Criteria for further selection were that the report included the source of patients (emergency department), age and gender of the population studied, clinical criteria for performing an imaging study, study design (prospective or retrospective), sampling method, type of neuroimaging procedure (cranial CT or MRI of the brain), and completeness (the number of patients who underwent imaging out of the total study population). Fifteen reports met these criteria and are included in the analysis. At least four committee members reviewed each abstract and classified each article; disagreements were resolved by discussion and consensus.

Data extraction for the analysis included the information previously stated for evaluation of a screening criterion and its generalizability, epilepsy diagnosis (first seizure or chronic epilepsy), the presence of an underlying neurologic diagnosis such as HIV infection or cysticercosis, whether the seizure was febrile or nonfebrile for studies in children, the results of the imaging studies, and the action taken upon those results. The evidence tables included this information to the fullest extent available. The evidence was rated according to the criteria for screening (questions 1 to 4) and for diagnoses (question 5) (appendix 2).

Clarification of terms. *Brain imaging abnormalities that changed management:* Used in questions 1 to 4. The criterion for a change in clinical management included the discovery of a new structural lesion, or performing surgery based on the abnormal imaging findings. Some reports clearly stated how many patients were taken to surgery following the imaging study due to findings discovered on the imaging study, such as for a depressed skull fracture. In studies wherein it was not stated how many subjects were taken to surgery, the authors determined, as far as possible in the reports meeting inclusion criteria, in how many subjects neuroimaging disclosed a new structural lesion that would likely lead to surgery or an urgent change in management, such as the finding of a brain tumor in a patient with first seizure, a finding which would reasonably be expected to prompt an urgent intervention, either by ER physicians or a consultant. The list of specific abnormalities that were included as leading to a change in acute or urgent management were as follows: traumatic brain injury including depressed skull fracture, subdural hematomas, nontraumatic bleeding including from arteriovenous malformations and other types of cerebral hemorrhages, cerebrovascular accidents, tumors, brain abscesses, cysticercosis, obstructive hydrocephalus and shunt malfunction, Aicardi syndrome, Miller-Diecker syndrome, tuberous sclerosis, and CNS toxoplasmosis.

Since questions 1 to 4 are related to patient care, rather than detecting seizure etiology, the authors did not exclude structural lesions that may have been unrelated to the seizure, although the abnormalities listed above can potentially cause seizures. In contrast, potentially epileptogenic lesions such as hippocampal sclerosis or dysembryoplastic neuroepithelial tumors that would likely cause seizures but not lead to an acute or urgent change in management were not included in this list of conditions leading to an urgent change in management. However, no arti-

cles reported these types of abnormalities on the neuroimaging studies performed in the emergency department, which were overwhelmingly CTT studies. Questions 1 to 4 of this clinical practice guideline are aimed not at assessing that a specific lesion is related to the seizures, but that performing the imaging study had a particular clinical outcome, leading to an acute or urgent change in management.

Further, hospital admission did not meet criteria for change in management since it cannot be clearly known if admission was related to neuroimaging findings. In the absence of any masked data, the authors determined neuroimaging findings that appeared to prompt important clinical decisions, either possibly related to identification of a possible cause for the seizures, or an abnormality such as hydrocephalus that might require surgical intervention. Other clinical decisions influenced indirectly by positive or negative imaging findings may be harder to track. The authors acknowledge the difficulties in establishing whether a detected lesion indeed led to an acute or urgent change in management. Even the articles meeting inclusion criteria did not include uniformly data on the number of patients taken to surgery, leading to some degree of unavoidable interpretative subjectivity. It is important to keep in mind the range of such neuroimaging abnormalities found in independent reports.

Factors associated with abnormal CT in patients presenting with seizure in the emergency department: Used in question 5. This question is aimed at the clinical and historical features associated with an abnormal CT in the emergency department, and therefore, do not focus on imaging abnormalities that changed management. The aim was to determine the association of clinical features, such as focal seizure onset, with an abnormal CTT. Therefore, any abnormality on CTT, even if it did not acutely or urgently change management, would be accounted for in this analysis. It is likely that the CTT findings that acutely or urgently changed management would be captured in this analysis, but other abnormalities that did not change management were also included.

ANALYSIS OF EVIDENCE **General comment.** Due to the overlap of ages and clinical situations in many studies, we subgrouped studies into general age group categories and clinically relevant situations. Further, there were only a few studies for specific clinical situations of interest. Therefore, the availability of information dictated the categorization of studies to some degree rather than an a priori categorization plan.

Classification. The first four questions are for the utility of an imaging procedure to detect information that would change patient management, and the reports were rated using criteria for a screening article. All 15 studies were Class III since a higher level of classification for a screening procedure requires an assessment masked to the clinical presentation. In all of these studies, the interpreters of the neuroimaging studies were not blinded to the clinical condition.

The fifth question addresses clinical or historical factors that are associated with an abnormal imaging study, and therefore was not confined to imaging abnormalities that led to a change in patient management. There were 9 articles out of the 15 that included information to answer this question and they were rated according to the criteria for a diagnostic article. Two of the studies were prospective and well designed to answer the clinical question using a representative population of interest. However, none of these studies included blinding to the clinical presentation and therefore, none was rated as Class I. However, given that an abnormal imaging study, specifically a CT scan, is a reasonably objective finding, many of the studies met criteria for Class II for this question.

The strength of the recommendations for the answer to each question is based upon the quality of the articles, not upon the rate or severity of imaging abnormalities reported.

Age categorization. The 15 selected articles were divided into general pediatric and adult categories. However, the ages included in each category have some overlap since the articles did not include sufficient detail to stratify neuroimaging results by age. Therefore, separate pediatric and adult neuroimaging outcomes are not available within any article. One study included all ages since birth.² Seven articles³⁻⁹ included ages above 5 years, which is the age above which febrile seizures would not generally be expected to occur, and these studies primarily included adults. The pediatric category includes ages below 22 years in one article,¹⁰ below 16 to 19 years in five,¹¹⁻¹⁵ and below 6 months in one article.¹⁶

Predominantly adult age group. Five studies evaluated neuroimaging for first seizure excluding age groups with a high incidence of febrile seizure.^{3,4,7-9} One of these studies included ages above 5 years,⁴ one included adults and children down to age 14,⁸ but generally subjects were older than 14.^{3,7-9} One study included subjects over age 17 with both first seizure and chronic seizures.⁶

Table 1 Cranial CT results on adults and nonfebrile first seizure patients in the emergency room

Adult and nonfebrile first seizure/design: retro- or prospective	Ages included, y	% Male	Type of CT – = noncontrast, + = contrast	No. of CT scans performed/ no. of subjects	No. abnormal (%)	No. that changed management (%)
Henneman et al. ³ /retrospective	>15	61	CT+/- not specified	325/333	169 (52)	133 (41)*
Mower et al. ⁴ /retrospective	>5	63	CT+/- not specified	875/875	306 (35)	81 (9)*
Schoenenberger et al. ⁷ /prospective	>15	64	CT+/-, unless - showed cerebral hemorrhage	119/119	40 (34)	20 (17%)†
Sempere et al. ⁸ /prospective	>14	71	CT-, then + if normal	98/98	33 (34)‡	Not available
Tardy et al. ⁹ /retrospective	>15	67	CT+	247/247	130 (56)¶	38 (15)¶

*Admitted or diagnosed etiology of seizures.

†39 were traumatic brain injury, 23 were nontraumatic bleeding, 18 were cerebrovascular accidents, 7 were brain abscess, 36 were "other."

‡Findings resulted in craniotomy in 8, high dose corticosteroids in 7, radiotherapy in 2, treatment for toxoplasmosis in 2, anticoagulation for embolic stroke in 1.

§Structural lesions found on CT scan.

¶Focal cerebral lesions in 85 and diffuse atrophy in 45.

||Surgical intervention for tumors, arteriovenous malformations, subdural hematomas.

None of these five studies reported febrile seizures as an etiology for seizure.^{3,4,7-9}

One study included all ages, but 88% of the 180 subjects were older than 18 years; febrile seizures were not excluded.² In this study, which included both first and chronic seizures, febrile seizures accounted for 4% of all seizures.

Pediatric age group including febrile seizures. One study included pediatric subjects of all ages including since birth with first seizure¹³ and one study included first seizure and chronic seizures in the pediatric age group.¹⁵

Pediatric age group excluding febrile seizures. Three studies excluded simple febrile seizures in their study of neuroimaging in first seizure.^{10,11,14}

Chronic seizures and first seizures within the same study. Three studies included chronic and first seizures.^{2,6,15} One consisted of pediatric age group and included febrile seizures¹⁵ with chronic seizures in 32% of subjects, one included all ages² with chronic seizures in 85% of subjects, and one was predominantly adult⁶ with chronic seizures in 52% of subjects.

Special cases. One study evaluated neuroimaging in children less than 6 months old with first seizure¹⁶; one study evaluated children less than 18 years old with blunt head trauma and seizure¹²; one study reported the neuroimaging findings on persons with AIDS and first seizure.⁵

Questions. The tables present data answering the following questions.

Question 1: What is the likelihood that acute management, for the adult emergency patient presenting with a first seizure, is changed because of the

results of a neuroimaging study?

Evidence. Five Class III studies addressed this question (table 1).^{3,4,7-9} These studies included 98 to 875 patients, and 34 to 56% had abnormal CT scans including brain atrophy. Overall, CT scans in the emergency department for adult presenting with seizure resulted in a change of acute management in 9 to 17% of patients. Frequent CT abnormalities that changed acute management were traumatic brain injury, subdural hematomas, nontraumatic bleeding, cerebrovascular accidents, tumors, and brain abscesses. The 41% rate cited as changing management based on CT results in one study³ included prompting hospital admission. It was not included in this summary statement since it is not clear that admission alone actually changed management beyond further patient observation.

Conclusion. An emergency CT in adults with first seizure is possibly useful for acute management of the patient (Class III).

Recommendation. An emergency CT may be considered in adults with first seizure (Level C).

Question 2: What is the likelihood that acute management for the pediatric emergency patient presenting with a first seizure (not excluding complex febrile seizures) will change based on the results of a neuroimaging study?

Evidence. Four Class III studies^{10,11,13,14} addressed this question (table 2). These studies included 25 to 475 patients, and 0 to 21% had abnormal CT scans; patients thought to have simple febrile seizure were excluded in three out of the four studies (648 out of 673 patients combined) and complex febrile seizures were included in all four studies. Overall, CT scans in the emer-

Table 2 CT results on children with first seizure in the emergency department (not excluding complex febrile seizures)

Seizure setting/design: retro- or prospective	Ages included, y	% Male	Type of CT - = noncontrast + = contrast	No. of CT scans performed/no. of subjects	No. abnormal (%)	No. that changed management (%)	
First seizure including febrile	Landfish et al. ¹³ /retro	<17	63	CT+/- not specified	25/56	0 (0)	0 (0)
First seizure excluding simple febrile	Sharma et al. ¹⁰ /retro	<22	53	CT+/- not specified	475/500	80 (17)	38 (8) 5 patients required surgery (1)
	Garvey et al. ¹¹ /retro	Pediatric		CT-, then CT+ performed for evaluation of possible encephalitis in 12/107 and for better definition in 5/107	107/107	19 (18)	At least 7 (7)*
	Maytal et al. ¹⁴ /retro	<16	52	CT-, then CT+ in 4/66 due to radiologist's judgment	66/66	14 (21)	2 required surgery (3)

*Cerebral hemorrhages, tumors, cysticercosis, and obstructive hydrocephalus.

gency room for children presenting with seizure resulted in a change in acute management in approximately 3 to 8% of patients (excluding a study in which only 25 out of 56 subjects underwent CT and none had CT abnormalities). Frequent CT abnormalities that resulted in a change in acute management were cerebral hemorrhages, tumors, cysticercosis, and obstructive hydrocephalus.

Complex febrile seizures, which were included in these analyses, are defined as having one of these associated factors: seizure duration longer than 15 minutes, focal seizure manifestations, seizure recurrence within 24 hours, abnormal neurologic status, or afebrile seizures in a parent or sibling.¹⁷

Conclusion. An emergency CT in children with a first seizure is possibly useful for acute management of the patient (Class III).

Recommendation. An emergency CT may be considered in children with a first seizure (Level C).

Question 3: What is the likelihood that acute management for the emergency patient presenting with a chronic seizure will be changed by the results of a neuroimaging study?

Evidence. Three Class III studies addressed this question (table 3).^{2,6,15} All three studies included

patients with either chronic or first seizures and imaging results on both types of patients within each study are shown in table 3. These studies included 60 to 139 patients with chronic seizures, and 24 to 138 patients with first seizure; 12 to 25% overall had abnormal CT scans. The rates of abnormal CT findings in patients with chronic seizures vs a first seizure in the emergency setting are not different, and approximately 7 to 21% of patients with chronic seizures have abnormal imaging studies. Frequent CT abnormalities were cerebral hemorrhages and shunt malfunctions. However, evidence for the likelihood of an imaging study changing management for emergency patients with chronic seizures is not available.

Conclusion. The evidence is inadequate to support or refute the usefulness of emergency CT in persons with chronic seizures.

Recommendation. There is no recommendation regarding an emergency CT in persons with chronic seizures (Level U).

Question 4: What is the likelihood that the results of a neuroimaging study will lead to a change in acute management in special populations presenting with seizure (age <6 months, AIDS, children

Table 3 CT results on cohorts of chronic seizure or first seizure presenting to the emergency department

Study/design: retro- or prospective	Ages included, y	% Male	No. chronic (%) / no. first (%)	Type of CT - = noncontrast + = contrast	No. of CT scans performed / no. of subjects	No. abnormal (%)	No. abnormal (%) chronic/first	No. that changed management (%) chronic/first
Warden et al. ¹⁵ includes febrile seizures/retro	Pediatric	53	65 (32)/138 (68)	CT+/- not specified	203/203	25 (12)	5 (7)/20 (14) NS by chi-square $p = 0.169$	Not specified/for entire population, at least 10 (5)*
Eisner et al. ² /pro	All ages	68	139 (85)/24 (15)	CT+/- not specified	19/163	5 (25)	0 (0)/5 (21)	Not specified/for entire population, 2 (10)*
Reinus et al. ⁶ /retro	>17	56	60 (52)/38 (33) possible first seizure = 17 (15)	CT-	115/115	23 (20)	13 (21)/7 (18) possible first seizure = 3(18) NS by chi-square $p = 0.89$	Not specified

*Eight cerebral hemorrhages and two shunt malfunctions.

*Subdural hematoma and CNS mass of unknown etiology.

Table 4 CT results on special populations presenting with seizure in the emergency department

Special population/design: retro- or prospective	Ages included, y	% Male	Type of CT – = noncontrast + = contrast	No. of CT scans performed/ no. of subjects	No. abnormal (%)	No. that changed management (%)
<6 mo old: Bui et al. ¹⁶ /retro	<6 mo	61	CT+/- not specified	22/31	12 (55)	12 (55)* (see findings in footnote)
Children with immediate posttraumatic seizures: Holmes et al. ¹² /pro	<18	64	CT+/- not specified	62/63	10 (16) [†]	3 (5) [‡]
AIDS and first seizure: Pesola and Westfal ⁵ /retro	>15	71	CT+/- not specified	26/26	25 (96) 18 showed atrophy	7 (28) [§]

*Aicardi syndrome, Miller-Diecker syndrome, tuberous sclerosis, an infarct, and a depressed skull fracture.

[†]All had traumatic abnormalities on CT and all were hospitalized.

[‡]Had surgery.

[§]Seven had mass lesions, five of which were CNS toxoplasmosis; PML found on 2 patients with follow-up MRI scan where CT showed only atrophy.

with immediate posttraumatic seizures)?

Evidence. Three Class III studies addressed this question (table 4).^{5,12,16} Of these special populations, children less than 6 months of age with seizure will be very likely to have significant abnormalities on CT scans.¹⁶ Fifty-five percent of the 22 children less than 6 months of age studied had significantly abnormal CT scans that changed management; findings included Aicardi syndrome, Miller-Diecker syndrome, tuberous sclerosis, an infarct, and a depressed skull fracture.¹⁶ Further, persons with AIDS and first seizure have very high rates of CT abnormalities; of 26 patients studied, 18 had atrophy on CT and 7 (28%) had CT findings that changed management.⁵ Seven had mass lesions, five of which were CNS toxoplasmosis; PML was found on 2 patients who were followed up with an MRI scan where CT showed only atrophy.⁵ Children with immediate posttraumatic seizures had a very low rate of CT abnormalities that led to a change in management; in the 62 patients studied, 16% had abnormal CT scans and 3 patients, about 5%, had abnormalities that led to a surgical intervention.¹²

Conclusions. An emergency CT in children less than 6 months of age and in patients with AIDS is possibly useful for acute management (Class III).

Recommendations. An emergency CT may be considered in children less than 6 months of age and in patients with AIDS (Level C).

Question 5: What factors are associated with an abnormal neuroimaging study for patients presenting with seizure in the emergency department?

Evidence. Nine out of 15 studies reported information regarding the clinical and historical features associated with an abnormal CT result. Unlike the previous four questions, this question sought to answer the factors that were associated

with detection of any imaging abnormality, not just those that prompted a change in management. Of these nine studies, eight were Class II^{4,6-8,10,11,14,15} and one was Class III.⁹ Several studies had important exclusion criteria regarding previous neurologic history or clinical situations^{7-9,11}; these are listed in table 5.

Five^{4,6-9} of these nine studies showed that a focal abnormality on neurologic examination was associated with an abnormal CT scan; these studies included both adult and pediatric age groups. Factors associated with an abnormal CT scan in ages up to and including 21 years were as follows: 1) a predisposing history in three reports,^{10,14,15} including one where pre-existing patient characteristics associated with an abnormal CT were specifically age <6 months, closed head injury, recent CSF shunt revision, malignancy, or neurocutaneous disorder¹⁵; and 2) focal onset of seizure in two reports.^{10,11} Therefore, each of these clinical or historical features is associated with abnormal results in at least two Class II studies.

Features found in only single studies that were associated with an abnormal CT were the absence of a history of alcohol abuse,⁷ presumably due to selection against patients with withdrawal seizures, patients with a history of cysticercosis,⁴ altered mentation,⁴ or age greater than 65 years,⁴ and seizure duration greater than 15 minutes.¹⁵

Conclusion. The clinical and historical features of an abnormal neurologic examination, a predisposing history, or a focal seizure onset are probably predictive of an abnormal CT study for patients presenting with seizures in the emergency department (Class II).

Recommendation. An emergency CT should be considered in patients presenting with seizure in the emergency department who have an abnormal neurologic examination, predisposing history, or focal seizure onset (Level B).

GAPS IN THE EVIDENCE The evidence available does not support strong recommendations because of methodologic limitations of the studies. The available studies from which evidence was derived for using CTT as a screening procedure for altering acute management in the emergency patient presenting with seizure were Class III. A higher class of evidence requires masking of the clinical presentation. However, emergent seizure treatment does not lend itself easily to a study design including masking to the clinical presentation.

One of the main limitations of available data is the variation in patient population among studies. Most had nonsystematic inclusion criteria and limited numbers of subjects. For example, one factor that likely increased the possibility that an abnormal CT scan would be detected is by including only patients who had both a seizure and a CT scan^{4,6,7,14,15}; the number of patients with seizures who did not undergo CT scan was not reported in these studies. Therefore, in these studies, it is possible that CT was performed more often in patients whose clinical presentation and history would yield an abnormal result, and the more benign patients with seizure did not un-

dergo CT and were not included in the analysis. One study excluded patients with previously identified neurologic disorders,¹¹ and another excluded patients with acute head trauma, hypoglycemia, and alcohol or drug-related seizures.³ Further, the data available do not allow us to comment on the systematic use of contrast CT vs noncontrast CT.

None of the available studies included more than very limited, nonsystematic data on MRI. In one study,⁸ brain MRI was performed in 27 out of 33 cases where CT was unrevealing, MRI study did not detect additional cases of glioma or cavernous malformation, but did detect two cases of more diffuse cerebral pathology likely related to seizures (cyclosporine toxicity with white matter abnormalities and cytomegalovirus encephalitis). Therefore, recommendations on emergent use of MRI cannot be made.

RECOMMENDATIONS FOR FUTURE RESEARCH Future research should address the use of brain MRI in this clinical setting. At present, insufficient data are available to make any recommendations regarding the emergent or semi-

Table 5 Factors associated with abnormal CT in patients presenting with seizure in the emergency department

Study	Seizure setting/inclusion	Ages included, y	Exclusion criteria relevant to CT results	Significant factors for abnormal CT
Mower et al. ⁴ Class II	Adult and nonfebrile first seizure only with CT	>5		For emergent lesions: age >65 y RR = 2.38 (95% CI 1.50-3.78); lateralized neurologic findings: RR = 3.47 (2.38-5.07); altered mentation: RR = 1.72 (1.43-2.07); history of cysticercosis: RR = 1.18 (0.43-3.25)
Schoenenberger et al. ⁷ Class II	Adult and nonfebrile first seizure with CT	>15	Patients >1 hour after seizure, status epilepticus, Glasgow Coma Scale <14 for more than 1 h	From logistic regression: focal neurologic deficit OR = 4.9 (1.7-13.7); no reported alcohol abuse OR = 6.0 (1.9-19.5)
Sempere et al. ⁹ Class II	Adult and nonfebrile first seizure	>14	Excluded known brain tumors	Focal neurologic findings increased risk of abnormal CT scan; RR = 2.80 (1.62-4.83)
Tardy et al. ⁹ Class III	Adult and nonfebrile first seizure	>15	Excluded seizures >24 hours before, history of known brain tumors or hemorrhage	Focal neurologic findings increased risk of focal abnormalities on CT; RR = 4.83 (3.41-6.82)
Sharma et al. ¹⁰ Class II	First seizure	<22	Simple febrile	Predisposing condition* RR = 4.34 (2.12-8.90); focal vs nonfocal seizure: 29% abnormal vs 0%
Garvey et al. ¹¹ Class II	First seizure	Pediatric	Excluded patients with previously identified neurologic disorders or simple febrile	Focal onset or postictal focal findings increased odds of abnormal CT; OR = 6.41 (1.03-39.7)
Maytal et al. ¹⁴ Class II	First seizure with CT	<16	Simple febrile	Symptomatic seizure (predisposing history*) RR = 13.8 (2.6-73.7)
Warden et al. ¹⁵ Class II	Chronic seizure or first seizure including febrile seizures with CT	Pediatric		Pre-existing patient characteristics (age < 6 mo, closed head injury, recent CSF shunt revision, malignancy or neurocutaneous disorder) RR = 5.27 (2.54-10.91); seizure >15 min where there were no pre-existing patient characteristics; RR = 6.53 (1.43-29.7)
Reinus et al. ⁶ Class II	Chronic or first seizure and CT	>17		For new and chronic seizures, any neurologic abnormality predicted 95% of abnormal CTs; RR = 10.78 (1.50-77.1)

*Sickle cell disease, bleeding disorders, cerebral vascular disease, malignancy, HIV infection, hemihypertrophy, hydrocephalus, travel to an area endemic for cysticercosis, closed-head injury.

*Trauma, infection, metabolic, drug intoxication, hydrocephalus, mental retardation.

RR = relative risk ratio (95% CI); OR = odds ratio (95% CI).

emergent use of MRI, which may potentially have greater sensitivity than CT for detecting brain pathology underlying seizure disorders. Moreover, many of the studies reviewed were performed on older CT scanners, which might have lower sensitivity than later models. The role of contrast administration for both modalities needs to be assessed. Important unanswered questions include, particularly for MRI, consideration of risks in scanning potentially unstable patients. As emergency MRI use becomes more prevalent, but CT technology improves, multicenter studies, ideally including both imaging modalities, with a second set of blinded readers will be necessary to achieve adequate statistical power, particularly to investigate the predictive value of clinical data. Further studies should also include better outcome and follow-up data, such as information on patients starting antiseizure medicines or changing antiseizure medicine doses in the emergency department, and on patients presenting with seizures who have normal imaging. However, given the expense of these approaches, it might be possible to use electronic medical records to obtain prospective data on the usefulness of neuroimaging in the emergency department for patients presenting with seizures. It will be particularly useful to segregate results by age, including pediatric and elderly patients. New analytic methods will have to be developed to make optimal use of data acquired in a clinical, rather than research, context.

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APPENDIX 1

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APPENDIX 2

AAN classification of evidence for rating of screening articles

Class I: A statistical, population-based sample of patients studied at a uniform point in time (usually early) during the course of the condition. All patients undergo the intervention of interest. The outcome, if not objective, is determined in an evaluation that is masked to the patients' clinical presentation.

Class II: A statistical, non-referral-clinic-based sample of patients studied at a uniform point in time (usually early) during the course of the condition. Most patients undergo the intervention of interest. The outcome, if not objective, is determined in an evaluation that is masked to the patients'

clinical presentations.

Class III: A sample of patients studied during the course of the condition. Some patients undergo the intervention of interest. The outcome, if not objective, is determined in an evaluation by someone other than the treating physician.

Class IV: Expert opinion, case reports, or any study not meeting criteria for Class I to III.

APPENDIX 3

Classification of recommendations

A = Established as effective, ineffective, or harmful (or established as useful/predictive or not useful/predictive) for the given condition in the specified population. (Level A rating requires at least two consistent Class I studies.)*

B = Probably effective, ineffective, or harmful (or probably useful/predictive or not useful/predictive) for the given condition in the specified population. (Level B rating requires at least one Class I study or at least two consistent Class II studies.)

C = Possibly effective, ineffective, or harmful (or possibly useful/predictive or not useful/predictive) for the given condition in the specified population. (Level C rating requires at least one Class II study or two consistent Class III studies.)

U = Data inadequate or conflicting; given current knowledge, treatment (test, predictor) is unproven. (Studies not meeting criteria for Class I–Class III).

*In exceptional cases, one convincing Class I study may suffice for an “A” recommendation if 1) all criteria are met, 2) the magnitude of effect is large (relative rate improved outcome > 5 and the lower limit of the confidence interval is > 2).

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