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Neuroimaging in the emergency patient presenting with seizure

Michael K. Greenberg, MD; William G. Barsan, MD; and Sidney Starkman, MD

Neuroimaging (NI) can help determine whether a patient's symptom (i.e., seizure) results from a structural abnormality of the brain or its surroundings, and it is useful in a variety of clinical settings. Patients may report seizure-related symptoms (e.g., simple partial or complex partial seizures) to their primary care provider prompting neurologic evaluation, or a sudden convulsive episode may hasten medical care through an emergency department (ED).

In an ED, the medical staff evaluates the patient to determine the nature of the event, performs diagnostic studies, begins treatment when appropriate, and arranges disposition or follow-up care. The nature of the event is best determined by historical observations from the patient or witnesses. Diagnosis is determined primarily from history and physical examination findings but may be supported by ancillary studies. Treatment decisions and disposition depend on the cumulative results of the evaluation.

The practitioner's decision to order a test must include an assessment of available resources. In the case of NI, this may include limited NI availability in the ED or other limited resources. The decision for emergency NI may result in retriage or reprioritizing patients for available scan time and, in some locations, may lead to a mobilization of equipment or personnel. The patient's clinical status and stability must be ensured before referral for imaging. Assuming that NI is useful in the evaluation of a patient with seizures, critical review of the role and timing of this test in the spectrum of emergency care is the subject of this report.

A panel representing the American Academy of Neurology, American College of Emergency Physicians, and the American Association of Neurological Surgeons convened to examine the available evidence concerning the use of NI in the ED setting. The panelists chosen were recommended by their organizations' practice parameters development group. The panel decided by consensus to consider the clinical circumstances for which NI would most likely result in a change in treatment. To facilitate this report, the panel developed the following consensus definitions to indicate the need (appropriateness) and urgency of NI scanning:

- **Emergent (scan immediately):** Essential for timely decision regarding potential life-threatening or severe disabling entities;
- **Urgent (scan appointment is included in the disposition or performed before disposition when follow-up cannot be ensured):** Essential to enable the timely appropriate clinical disposition or discharge of acute condition;
- **Routine:** Indicated for management and diagnosis but not for immediate disposition;
- **Not indicated:** Not indicated for the routine management of the presenting condition.

Description of the Process. We performed a MEDLINE search for articles published between 1980 and 1993 using the key words "computerized tomography," "seizure," "emergency," and "emergency care." CT literature was chosen because of the more universal availability of this technology in an emergency setting compared with other imaging modalities (e.g., MRI). Terms were exploded as appropriate. Text word searches were also performed using these terms. A titles search produced 502 references. Titles were reviewed for clinical studies, reviews, or articles dealing with NI findings in seizure patients or use of NI in the emergency department. From this list, the panel reviewed 58 abstracts. Additionally, we did a secondary search of the bibliographies of these articles to identify articles published before 1980. Studies dealing solely with status epilepticus were not included. Using this strategy, we found 82 articles. After excluding case reports, letters, and reviews without original data, 51 articles remained. These articles were reviewed in their entirety. Two panelists reviewed each paper, scored them for level of evidence, and

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From the Department of Neurology (Dr. Greenberg), Uniformed Services University of the Health Sciences, Bethesda, MD; Section of Emergency Medicine (Dr. Barsan), University of Michigan, Ann Arbor, MI; and Departments of Emergency Medicine and Neurology (Dr. Starkman), UCLA Medical Center, Los Angeles, CA.

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Address correspondence and reprint requests to Dr. M.K. Greenberg, Department of Neurology, 89 MDOS/SGOMU, 1050 West Perimeter Road, Andrews AFB, MD 20762.

abstracted information on a data collection form. Data tables were then generated from the raw data and combined where possible. By consensus, elements for evaluation included age stratification, likelihood of abnormal NI, types of NI lesions or abnormalities, and outcome data. In addition, any of the following covariables were sought: first seizure, seizure type, signs of CNS infection, persistent altered mental status, recent trauma, meningismus, new focal abnormality, history of anticoagulation/coagulopathy, immunosuppression, malignancy, systemic disease, and headache.

Literature classification criteria. In general terms, a test may be considered clinically useful more than competing modalities if it effectively (i.e., with greater sensitivity or specificity) or efficiently (i.e., with less cost in terms of risk or finances) separates patients into distinct diagnostic groups with prognostic or therapeutic implications. With this in mind, the authors reviewed the literature on "CT, seizure and emergency care" against the following literature classification:

- **Class I:** Evidence provided by one or more well-designed randomized controlled clinical trials, including overviews (meta-analysis) of such trials (we found no class I articles);
- **Class II:** Evidence provided by well-designed observational studies with concurrent controls (e.g., case control and cohort studies) (18 articles);
- **Class III:** Evidence provided by expert opinion, case series, case reports, and studies with historical control subjects (33 articles).

Results. *Data review.* The articles reviewed were divided into four groups based on the clinical setting in which the study was performed; the principal focus of the study; methods of determining etiology, relevance of findings, and cataloging results; and studies of specific clinical entities in which seizure may be part of the clinical picture and NI may be part of the evaluation. Group 1 consists of 11 articles[1-11] in which the authors studied how seizures were evaluated or managed in emergency departments and NI was used in the assessment of a subpopulation of the patients. Group 2 is a collection of 21 studies[12-32] focusing on NI findings in patients with seizures or epilepsy. Group 3 contains eight articles[33-40] that examine the epidemiology of seizures and include NI findings in the data set. Group 4 is made up of nine articles[41-49] that examine single clinical entities where seizures may be present, management in an ED is likely, and NI data are available. Data from each group were collated, combined, or compared with an emphasis on clinical features of seizure patients studied and the nature of their NI findings.

Emergency department studies (group 1). The panel initially identified 13 articles for this group. One paper[50] was excluded for lack of definitive NI data. Another paper[51] was deleted from analysis because the subgroup of seizure patients appeared to be nearly identical to another study published by the same authors.[1] Thus, 11 articles were included in Group 1.[1-11]

There were 1,935 patients in this group, 343 with abnormal NI (17.7%). In some of the papers, the authors failed to identify how many of their patients had NI performed. In five studies,[1,3-6] the total number of patients who had NI was indicated with 766 patients undergoing NI of which 204 were abnormal (26.6%) (table 1).

Table 1 *Emergency department studies*[1-11]

Total patients in group	1,935
Patients with abnormal CTs	343
Patients with abnormal CTs (%)	17.7
Total patients with CT performed (as specified by authors)[1,3-6]	766
Abnormal CTs in this subgroup	204
Abnormal CTs (%)	26.6

Number of abnormal CTs in total patient group and in subgroup where CT was specifically designated by the authors.

In only 161 patients (table 2), the type of lesion found was specifically attributable to the results of NI[1,3,4,6,8,11] (46.9% of all abnormal scans and 8.3% of all patients in group 1; table 2). Most of these lesions were classified as cerebrovascular disease (in 61 patients, 37.8%) and neoplasms (in 32 patients, 19.9%). The temporal relationship of the stroke to the seizure was not specified except that three of the strokes were defined as acute. In addition, there were 10 patients with intracerebral hemorrhage. Six other patients were reported to have subdural hematoma.

For 205 patients (table 3), structural lesions were reported that *might* have been found by NI, but the authors did not specify the method of diagnosis.[6,7,9,11] Again, stroke was the most frequent diagnosis (78 patients, 38.0%), but

Table 2 *Types of lesions found on CT* (ED STUDIES)*[1,3,4,6,8,11]

Stroke (acute vs. chronic not specified in all but three cases with acute stroke)	61 (37.8%)
Neoplasm	32 (19.9%)
Subdural hematoma	6 (3.7%)
Intracerebral hemorrhage	10 (6.2%)
Calcifications	11 (6.8%)
Atrophy	30 (18.6%)
Miscellaneous	11 (6.8%)

* One hundred sixty-one scan results specifically reported (46.9% of all abnormal scans and 8.3% of patients in ED studies group).

Table 3 *Final diagnosis by lesion* type (ED studies)*[6,7,9,11]

Stroke (acute vs. chronic not specified except in 11 cases with prior stroke)	78 (38.0%)
Neoplasm	32 (15.6%)
Trauma	55 (26.8%)
Infection	25 (12.1%)
AVM	10 (4.9%)
Subdural hematoma	4 (2.0%)
Cerebral malformation	1 (0.4%)

* Lesions that might be found by CT but method of diagnosis not specified—205 patients (10.5% of total patient group).

ED = emergency department; AVM = arteriovenous malformation.

Table 4 *Cofactors identified*[1,3,6,11]

Cofactor	No. of patients	No. of abnormal CTs	% Abnormal
Focal examination	158	65	41.1
Normal examination	161	21	13.0
History of cancer	8	5	62.5
Altered mental status	67	20	29.9
Intoxication	11	3	27.3
New seizure	180	47	26.1
Headache	115	12	10.4

Note: In reference 9, 28 of 32 patients with focal exam had an identified etiology with lesions potentially identifiable by CT but method of diagnosis not specified.

patients with trauma-related diagnoses made up a large number (55 patients, 26.8%). Again, the temporal relationship of the stroke or traumatic ictus was not specified except in 11 patients with prior stroke. Other potentially acute cases included 25 with infection and four with subdural hematomas.

Clinical cofactors were reported in few patients (table 4). A total of 41.1% of patients with a focal neurologic finding had abnormal NI, but only 21 of 161 patients (13%) with a normal examination did. One study[1] reported that five of eight patients (62.5%) with known cancer had abnormal scans. In the new onset seizure subgroup, 26.1% (47/180 patients) had abnormal scans, the same percentage of abnormal scans for the entire group known to have been scanned (26.6%; table 1). Age stratification was reported in three studies (table 5). Sempere et al[9] divided their patients into two groups, older and younger than age 45. Those who were older than 45 years had a greater likelihood of NI abnormality related to stroke (37.9%) and neoplasm (12%). The largest subgroup was stroke in patients older than 60 years; 60.6% had NI evidence of stroke. Wood et al[6] reported that 45% of patients older than 50 had abnormal scans, whereas only 16% of patients under 50 did. In a report of new onset seizures in children, no abnormalities were found in 23 patients studied.

Non-ED studies: NI finding in seizure patients (group 2). We identified 21 articles for this group. Of the 21, we excluded 8: 6 papers discuss only patients with transient postictal NI abnormalities,[12-17] 1 reference was published only in abstract form,[18] and 1 paper was a meta-analysis of new onset seizures with tumor diagnosis as the only end point.[19] Five studies were prospective.[20,21,24,27,30] Evidence tables relative to this section are available from the National Auxiliary Publications Service (NAPS).

There were 4,314 patients in group 2 with 1,697 having abnormal NI (39.3%). The principal focus of these papers was NI findings in seizure patients; therefore, all patients had NI performed. The total group was skewed toward the younger age groups with over half the subjects being children, primarily because of two large retrospective studies (2,350 patients)[26,31] and another 101 patients in a prospective study.[30]

NI findings were specified in 12 studies.[20,21,23-32] One paper[22] only reported the number of abnormal scans (34/99 patients), but the lesion types could not be subdivided. This resulted in 4,215 patients, and abnormal scan findings were reported in 1,463 (34.7%). When data from all studies are examined together, the most prevalent findings were atrophy (diffuse and focal), neoplasms, hydrocephalus, and congenital abnormalities and stroke (in declining order). We can divide out those studies that deal specifically with children[26,30,31] from the total group. Then we find that in the children-only studies, 36.6% had abnormalities, with the most prevalent findings being atrophy, diffuse and focal (16.8%); hydrocephalus (5.8%); congenital abnormalities (4.6%); neoplasm (3.7%); and infection (2.4%). In the remainder of the studies (age 5 to 86), 32.1% of the subjects had abnormal NI with the most prevalent findings being neoplasm (7.5%), stroke (4.7%), and diffuse atrophy (6.2%). When prospective studies[20,21,24,27,30] are examined, the total frequency of abnormalities (27.6%) is nearly identical to the frequency in the total group. Similarly, the most prevalent lesions found include neoplasms, stroke, atrophy, and congenital abnormalities, as was demonstrated in the total group.

Three of the studies gave specific NI data on patients in the new onset seizure subgroup.[27,28,30] The most prevalent lesion found was stroke-related seizure (12.5% overall, 18.6% in patients >15 years old), followed by neoplasm (5.1%), atrophy, diffuse and focal (4.8%), and trauma (2.9%). Strokes specifically classified as acute made up 9.0% of the new onset seizure subgroup. Other acute disorders (e.g., infection, subdural hematoma) made up less than 1%.

Data were available for age stratification in four studies.[20,26-28,31] Age groupings were 0 to 10 years, 10 to 30, 30 to 50, and over 50. The frequency of abnormal scans in these groups were 57%, 37%, 32%, and 58%, respectively. However, the data are skewed to the younger age group by a single study[26] reporting 1,134 abnormal scans in 2,094 children. Of these scans, 855 demonstrated congenital, hereditary, or other nonemergent lesions. Deleting that study adjusts the frequency in the under 30-year group to 31%.

Covariables that could be extracted from these studies[20,22-28,31] were analyzed. However, insufficient data were available to correlate any of the covariables to specific lesion types. Focal neurologic findings were associated with 52% abnormal scans. In the study by Ramirez-Lassepas et al,[28] 34 patients are described with normal examinations, of which 9 had abnormal scans (7 atrophy, 2

Table 5 *Age stratification*

Reference	Age group	Findings
10	0–16	No abnormal CTs in 23 children studied
9	>45	Stroke, 37.9% (60.6% of patients >60); tumor, 12%; SDH, 3.4%, AVM, 5.2%; trauma, 1.7%
	<45	Stroke, 2.5%; tumor, 2.5%; SDH, 0%; AVM, 7.5%; trauma, 7.5%
6	>50	Abnormal CT, 45%
	<50	Abnormal CT, 16%

SDH = subdural hematoma; AVM = arteriovenous malformation.

old trauma). Partial seizures or partial seizures with secondary generalization were associated with 37% abnormal scans, whereas patients with generalized seizures had a frequency of 20% abnormal scans.

Finally, transient NI abnormalities are described in six reports (single case reports or case series).[12-17] In all, there were 84 patients, both children and adults, with CTs performed as early as 1 hour after seizure. The abnormalities described include hypodensities, some with enhancement, gyral enhancement, or vascular engorgement. In all, the CT abnormality resolved in days (earliest, 5 days) to weeks (latest, 75 weeks) with no treatment other than anticonvulsants. There is no pathologic confirmation in any of these patients, and the authors speculate about the cause(s) for the changes.

Seizure epidemiology studies (group 3). We identified eight articles for this group.[33-40] Four studies[36,37,39,40] were prospective and four studies[33,35,37,38] were concerned with the elderly. Evidence tables relative to this section are available from NAPS.

There were 1,595 patients in group 3. In some of the papers, the authors failed to identify how many patients had NI performed. In four studies,[34-36,39] the total number of patients who had NI was indicated, with 735 patients undergoing NI of which 235 were abnormal.

For the total group, 488 (29.6%) subjects were given an etiologic diagnosis; however, the method of diagnosis was not specified in many of the papers (i.e., diagnosis may have been by means other than NI). The leading findings were neoplasm (9.3%), stroke (9.0%), atrophy (7.8%), and trauma (1.1%). In the prospective studies, there were 747 patients with etiologic diagnosis in 147 (19.7%). The leading findings were the same. Patients with stroke were not specified into acute or chronic subgroups. Other acute disorders (e.g., hemorrhage, subdural hematoma) were <1.0% of the total group. When the author specified NI findings,[34,36,39] the most prevalent finding was atrophy in 17.4% of all NI performed and 5.4% of NI in the prospective studies. This was followed by neoplasm 7.3% and stroke 3.9% of all NI (3.4% and 1.3%, respectively, in prospective studies).

Five studies characterized the diagnosis of patients in the first seizure subgroup.[35-37,39,40] The most prevalent diagnosis found was stroke-related seizure (10.4%, 6.6% for prospective studies), followed by neoplasm (7.8%, 6.3% for prospective studies). Trauma related was 1.5% of first seizures, and hemorrhage and subdural hematoma accounted for another 1.0%.

Covariables were available in some studies but were catalogued by diagnosis and not specifically to NI findings. Neurologic examination as a covariable was listed for specific diagnoses, with 61.4% of neoplasms and 77.4% of strokes having focal findings. Age stratification[33,35,37,38,40] was provided, with the most data available in the elderly patient population. Over age 60, stroke (35.9%) is the leading diagnosis followed by neoplasia (13.7%). With more limited data, neoplasia was the most frequent symptomatic diagnosis in the 40 to 49 and 50 to 59 age groups (20% and 26.7%, respectively). Other clinical studies of seizure in the elderly (age > 60) were summarized[35,37] for 817 patients with stroke accounting for 49.2% and neoplasia in 20%. Of 271 patients with partial or secondarily generalized seizures,[33,34,37] tumors were present in 28.4% and stroke in 19.9%. Alcohol-related seizures were 4.0% of the generalized seizure group and, surprisingly, 13.7% of the partial seizure group. This may reflect complications of alcohol abuse and not just alcohol withdrawal.

Specific clinical entities (group 4). This is a collection of articles[41-49] where seizure can accompany a neurologic disorder or herald neurologic involvement in a systemic disorder. In each of the studies, NI was performed on some or all of the patients.

Different aspects of stroke and seizure were evaluated in separate studies. Kilpatrick et al[41] prospectively evaluated 1,000 consecutive patients with stroke. Early seizures were defined as occurring within 2 weeks of stroke onset. Seizures occurred in 44 (4.4%), including 10 (15.4%) of lobar or extensive hemorrhage, 6 (8.5%) of 71 with subarachnoid hemorrhage (SAH), 24 (6.5%) of 370 with cortical infarction, and 4 (3.7%) of 109 with hemispheric TIA. In 43 patients, seizure occurred within 48 hours of onset and 26 occurred at or shortly after stroke onset. In the six patients with SAH, all seizures occurred at the onset and all were generalized. Seizures were not associated with higher mortality or worse functional outcome. Arteriovenous malformation (AVM) as a cause for lobar hemorrhage was present in 4 of 10 patients with early seizure and only 2 of 55 without seizure. In cortical infarction, there was no association between seizure occurrence and pathogenesis.

Weisberg et al[42] defined seizures in relationship to parenchymal brain hemorrhage (PBH). Two hundred twenty-two patients were included with a positive CT for PBH, and seizures occurred in 33: 23 immediate (<24 hours), 4 early (24 to 72 hours), and 6 delayed (>72 hours). As in the Kilpatrick et al study, seizure with PBH was most common if the hemorrhage was due to an aneurysm, angioma, or neoplasm. Fontanarosa[43] retrospectively evaluated patients with an ED diagnosis of SAH. In his series, 8 of 129 patients had a seizure, but the paper does not correlate clinical findings to those patients with seizures.

In their study of childhood stroke, Lanska et al[44] reported four neonates and one child who presented only with seizure at stroke onset. Gupta et al[45] retrospectively evaluated 90 consecutive patients with seizure after stroke and found 30% occurred within 24 hours of the stroke onset with early onset seizures more likely to be partial onset and associated with large strokes. Other than the few cases in the childhood group, all patients in these studies had clinical evidence for stroke preceding the seizure or simultaneous to the seizure.

Patients presenting with alcohol withdrawal seizures were evaluated by CT in two studies. The first by Feussner et al[46] found 51% had abnormal CTs, with most, 52 (34.4%), being diffuse atrophy. Of the focal lesions found, 11 were old strokes and another 11 were considered potentially reversible (7 subdural hematomas, 2 hygromas, 2 intracranial hemorrhages) and 6 went to surgery. Thirty percent of patients with focal deficits had abnormal CTs, whereas only 6% without such deficits did. Only one seizure patient without focal deficits was treated surgically. A cohort of alcoholics without seizures yielded similar CT results. Earnest et al[47] evaluated 259 patients with first-time generalized convulsions with no etiology other than recent alcohol withdrawal. Abnormalities were reported in 151 patients (58.3%); however, most had diffuse atrophy,

old injuries, and cerebellar atrophy. Sixteen patients had "clinically significant CT findings." These included eight patients with subdural hematomas or hygromas, two AVM, two cysticercosis, and one each of aneurysm, possible tumor, skull fracture, and probable cerebral infarction. In this study, history or signs of minor head trauma, headache, level of consciousness, and focal neurologic signs did not significantly correlate with CT abnormalities.

One study was concerned with early seizures after mild closed-head injury.[48] In this study, 100 of 4,232 head-injured patients had a seizure within the first week after injury, 43 with seizures in the first 24 hours. Of the 100 seizure patients, 53 had normal scans and the remainder demonstrated intracranial bleeding (3 epidural hematomas, 3 SAH, 24 intracerebral hemorrhages, and 17 subdural and intracerebral hematomas). Surgical management followed in seven patients (three with epidural hematoma and four with subdural/intracerebral hematoma), three in the first 24 hours.

Finally, the paper by Holtzman et al[49] analyzed the evaluation of 100 patients with new onset seizure with known HIV infection (all patients had AIDS). There were 32 mass lesions (toxoplasmosis in 28, lymphoma in 4), 3 strokes, and 1 progressive multifocal leukoencephalopathy. Of 25 patients with focal neurologic examination findings, 16 had mass lesions, and of 76 patients with altered mental status, 31 had mass lesions.

Summary. We reviewed 49 articles for data elements on the role of NI in the evaluation of seizure patients. The goal was then to use this data to help define the role and timing of this test in the spectrum of emergency care. The prevalence of abnormal NI (in patients known to have been studied) was comparable in the groups analyzed. The types of structural lesions found in these groups were likewise similar with most due to stroke and neoplasm. Cerebral atrophy was described in groups 2 and 3 where the NI findings and epidemiology was the focus of the studies. The number of patients with subdural hematomas, intracerebral hematoma, and infection was small in all groups. In contrast, the studies on alcohol-related and head injury-related seizures demonstrated a disproportionate number of patients with intracranial bleeding.

Only two studies were designed to examine the ability of clinicians to predict the likelihood of abnormal CT. Reinus and Zwemer[2] used a data entry form that included the practitioners' assessment of the likelihood of finding an abnormality on the patients' CTs. The likelihood of finding an abnormality was rated from "remote" to "certain" in six levels of certainty. Fifty-six of their patients had seizures; of these, 26 had chronic lesions, 14 had acute lesions, and 17 had normal scans. There were 20 patients assessed in the remote or "low" likelihood groups. Of these, only one patient had an acute abnormality, a 61-year-old woman with a known seizure disorder who suffered a head injury that provoked a seizure. CT demonstrated a small subdural hematoma that was treated without surgery (Reinus, personal communication). Schoenenberger and Heim[11] studied only patients with generalized seizures; however, they do not disclose whether these were primary and secondarily generalized seizures. They were able to show from their data that focal findings on the neurologic examination had a sensitivity of 50% and specificity of 89% for focal brain lesions on CT. From data in groups 1 and 3 above, the neurologic examination has a positive predictive value of 48% and negative predictive value of 84% for focal findings on CT (sensitivity 76%, specificity 60%, prevalence of abnormalities on CT, 32.4%).

Data were available regarding some of the covariables. As above, patients with focal neurologic examination findings were found to have a much higher likelihood of abnormal CT (41.1% in group 1 and 45.3% in group 2) than patients with a normal examination, but the type of lesions found could not be extracted from the papers. Among group 3 patients found to have stroke or tumor, the proportion with focal neurologic findings by examination was high but well below 100%. There was a small increase in the likelihood of finding an abnormality with partial-onset seizures when compared with generalized seizures. However, there was a greater percentage of tumor and stroke in the partial-onset seizure subgroup. Lesions found in the new onset seizure subgroups were mainly represented by stroke, neoplasm, and trauma-related lesions. The combination of infection, subdural hematoma, and intracerebral hematoma made up about 1% of the new onset seizure patients. The likelihood for stroke or tumor increased with advancing age. Patients over 40 years old had a conspicuous increase in the likelihood of having an abnormal CT, with an increase in tumor prevalence beginning at age 40, and stroke in the over 60 year age group. Seizures in the immunosuppressed, as was demonstrated in AIDS patients,[49] are frequently due to mass lesions and most frequently infections.

Recommendations. Data are available that can help predict the likelihood of NI abnormalities in selected seizure patients. The focus of this report was the usefulness and timing of NI in the emergency patient with seizure and not the overall utility of NI in the evaluation of patients with seizures or epilepsy. These recommendations are based on literature review (classes II and III) and panel consensus (class III).

A provider should first ensure stabilization of the emergency patient before pursuing an imaging study. The decision to obtain an imaging study in the ED must take into consideration clinical findings, the likelihood of confirming a specific clinical entity based on those findings or excluding an alternate or serious cause, the natural history of the suspected disorder or alternative diagnoses in the differential, and the availability of adequate follow-up for the patient. Knowledge of the patient's prior condition may favor performance of an emergent NI (e.g., immunosuppression, anticoagulation therapy, history of cancer) or militate against the study (e.g., prior history of epilepsy, previous trauma, or stroke with no change in neurologic findings). Chronic lesions found in the ED usually will not lead to acute changes in management but may change disposition. In the absence of increased intracranial pressure, delay of diagnosis of a brain tumor by referral for urgent or routine NI is unlikely to change patient outcome. Patients with seizure associated with acute stroke (including intracerebral and subarachnoid hemorrhage) will be managed based on the underly-

ing clinical condition and usually includes NI. Although there is very little evidence showing that the emergency management of patients presenting to the ED with a seizure is changed by NI (except in those where infection or intracranial hemorrhage are suspected), the decisions for patient management, disposition, or both may be dependent on the NI findings.

For patients presenting with seizure(s), NI may be performed in their evaluation. Because most life-threatening conditions associated with seizures are related to hemorrhage, brain swelling, or mass effect, an unenhanced (noncontrast) CT may be all that is necessary on an emergent basis. A decision for an enhanced (contrast) CT or an MRI may be subsequently determined. The priority for performance should consider the following clinical circumstances.

For patients with first time seizure:

Emergent NI (scan immediately) should be performed when a provider suspects a serious structural lesion. Clinical studies have shown a higher frequency of life-threatening lesions in patients with new focal deficits, persistent altered mental status (with or without intoxication), fever, recent trauma, persistent headache, history of cancer, history of anticoagulation, or suspicion of AIDS **(guideline)**.

Urgent NI (scan appointment is included in the disposition or performed before disposition when follow-up of the patient's neurologic problem cannot be ensured) should be considered for patients who have completely recovered from their seizure and for whom no clear-cut cause has been identified (e.g., hypoglycemia, hyponatremia, tricyclic overdose) to help identify a possible structural cause. Because adequate follow-up is needed to ensure a patient's neurologic health, urgent NI may be obtained before disposition when timely follow-up cannot be ensured **(option)**.

Additionally, for patients with first-time seizure, **emergent NI** should be considered if any of the following are present **(option)**: age >40 years and partial-onset seizure.

For patients known to have epilepsy with recurrent seizure(s):

Emergent NI (scan immediately) should be performed when a provider suspects a serious structural lesion. Clinical studies have shown a higher frequency of life-threatening lesions in patients with new focal deficits, persistent altered mental status (with or without intoxication), fever, recent trauma, persistent headache, history of cancer, history of anticoagulation, or suspicion of AIDS **(guideline)**.

Urgent NI (scan appointment is included in the disposition or performed before disposition when follow-up of the patient's neurologic problem cannot be assured) should be performed for patients who have completely recovered from their seizure and for whom no clear-cut cause has been identified (e.g., hypoglycemia, hyponatremia, tricyclic overdose) to help identify a possible structural cause. Because adequate follow-up is needed to ensure a patient's neurologic health, urgent NI may be obtained before disposition when timely follow-up cannot be ensured **(option)**.

Additionally, for patients with **recurrent seizure** (prior history of seizures), **emergent NI** should be considered if any of the following are present **(option):** new seizure pattern or new seizure type and prolonged postictal confusion or worsening mental status.

Patients with typical febrile seizures or patients with typical recurrent seizures related to previously treated epilepsy are unlikely to have life-threatening structural lesions. **These patients do not require emergent or urgent NI (guideline).**

Recommendations for future research. Areas of research that will improve clinical decision-making include studies that measure therapeutic impact or patient outcome as they are affected by the timing of NI performance. Patient preference data would help to determine how NI studies might be used to meet their clinical needs and expectations. How NI is used in the sequence of diagnostic modalities and NI's changing role in the era of advancing technologies (i.e., MRI, functional MRI) are also vital topics for study.

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