Brain Scientific, Inc.
205 East 42nd Street
New York, NY 10017

Tel. +1-917-388-1578
info@brainscientific.com
www.brainscientific.com

Electroencephalography in the Emergency Department

BY BRAIN SCIENTIFIC

Brain Scientific, Inc.
205 East 42nd Street
New York, NY 10017

Tel. +1-917-388-1578
info@brainscientific.com
www.brainscientific.com

Executive Summary

Emergency department visits have increased sharply over the last two decades and continue to rise. Cases that involve acute neurological conditions have also increased rapidly over that time, driven in large part by mild traumatic brain injury and delirium in dementia patients. CT scans remain the ubiquitous diagnostic tool of first resort among emergency department physicians in the workup of virtually all acute neurological conditions. While head CT and MRI to play a primary role in some forms of traumatic injury and stroke diagnosis, their use far exceeds the clinical indications for which they are ordered. In other words, CT is ordered too frequently, almost reflexively, even for conditions in which there is very low diagnostic yield such as syncope, delirium and vertigo. For as much as CT is overused, EEG is underused in the emergency department. New research demonstrates the primary role that EEG can play in the workup of various neurological conditions. EEG can be instrumental in the initial diagnosis of patients with altered mental status and delirium from whom reliable medical histories cannot be obtained. Likewise, considerable evidence suggests EEG could supplant the use of CT for most non-traumatic cases of neurological compromise and indeed many cases of traumatic brain injury. In non-convulsive status epilepticus, EEG is irreplaceable, and can mean the difference between early detection/treatment and long-term disability/death. Unfortunately, even the largest medical centers are not adequately equipped perform EEG in a timely manner in the emergency department. The size of traditional EEG systems, lack of portability, and inadequate numbers of trained EEG personnel are real barriers to care. Fortunately, portable, wireless, easy to use EEG acquisition devices and disposable electrode caps (EEG headsets) are capable of changing this paradigm. NeuroCap™ and NeuroEEG™ by Brain Scientific provide “easy and anywhere” mobile-wireless deployment of next generation EEG diagnostics at various point-of-care sites, including emergency departments. These solutions promise to finally bring timely and accurate EEG diagnosis of acute neurological conditions to the emergency department.

Emergency department visits continue to increase

Between 1997 and 2007, annual ED visits increased by 37%, which is double what would be expected from population growth alone.[1] While the Affordable Care Act (ACA) includes mandates intended to minimize the burden on emergency department (ED) and divert patients to primary care settings, the number of emergency care visits has remained high and continues to increase. Staff in hospitals across the United States managed over 130 million ED visits in 2013 and over 150 ED million visits in 2016.1 ED visits increased 14.8% between 2006 and 2014 alone.

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Emergency department staff must quickly and correctly triage patients

ED staff face a daunting challenge: to correctly assess the acuity of each patient's condition and properly prioritize care. Patients' access emergency services for a variety of reasons, ranging from sore throat to cardiac arrest. The former patient likely does not need to be in the ED at all, while the latter must be diagnosed quickly and correctly so that life-saving treatments can be administered.

In many cases this triage is rather straightforward: simply ask the patient about the chief complaint, elicit a brief medical history and run a few bedside tests. Experienced ED physicians can usually determine the acuity of the condition, make the right diagnosis, and deliver appropriate, timely treatment. Conditions that affect mental status and neurologic function, however, make diagnostics more challenging and complex. In addition, patients with altered mental status can have difficulties providing a chief complaint or medical history. Making matters worse, some conditions that involve altered mental status can be acutely life-threatening or lead to lifelong disability. In these cases, rapid diagnostic tools are critical.

For neurologic diagnoses, computerized tomography is the default technique

Without question, computerized tomography (CT) is the primary tool for diagnostic workup of neurologic conditions in the ED. Approximately 70 million CT examinations are performed annually in the United States. In 2007, 14% of all patients in the ED underwent CT nationwide, a six-fold increase compared with 1995.2 This is not surprising, since CT scanners are widely available in large and small hospitals, scans can be acquired quickly and noninvasively, and initial results can be obtained within minutes.[2]

Unfortunately, an order for a CT scan of the head is often a reflexive decision in almost every patient with a complaint related to the skull or brain. CT scans are inappropriately ordered for common conditions such as headache, syncope and minor head trauma. Since 1995, CT scan use for head injury has increased at least 21-fold, with 76% of that growth occurring in the ED, without a concomitant increase in positive detection of head injuries.[2,3] Despite their heavy use, CT scans of the head for acute conditions are really only useful for a handful of conditions (e.g. identifying brain hemorrhage, skull fracture, malignancy). Approximately 90% of CT scans for mild traumatic brain injury (mTBI) cases were found to be negative for clinically important outcomes,[4,5] with some reports showing that unnecessary scans for mTBI can range up to 25%.6 The diagnostic yield is even worse for non-traumatic cases of neurologic dysfunction. While greater than 50% of head CT scans in the ED are requested for patients without trauma,[7] the diagnostic yield ranges from 0% to 15% depending on whether the condition is delirium/cogni-

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tive impairment, dizziness/vertigo, or syncope.8,9,10 This overuse of head CT has prompted policymakers to warn about the excessive costs and radiation exposure of CT.[11]

MRI is inferior to CT for most emergent neurological issues

Over the past decade, institutions with greater resources have added MRI as a principle diagnostic tool for ED use. Many large hospitals have a dedicated MRI for use with people presenting to the emergency department (or at least an arrangement where chronic care patients can be bumped from the list). While MRI does provide higher resolution images and greater detail of the brain than CT, it has limited utility as a primary diagnostic tool for triage and ED patients.[12] Its primary use is to diagnose early phase ischemic stroke (diffusion weighted MRI) so that thrombolytic drugs can be administered. It can also be used to rule out hemorrhagic stroke and brain herniation for the same purpose (though CT can serve these purposes as well). While MRI has an expansive role in outpatient and non-acute neurologic diagnosis, its role in the ED is relatively limited. Because acquiring MRI images is relatively slow, costly and logistically burdensome at all but the largest institutions, it is generally not (or should not be) considered a primary diagnostic tool for presumed non-stroke etiologies in emergency departments.

Electroencephalography is an important, underutilized tool in neurocritical care

Electroencephalography (EEG) has potential to fill an important niche in initial triage and early diagnosis of acute neurological conditions. EEG can be used as an adjunct to CT in cases of head trauma since it can detect mild traumatic brain injury. Likewise, EEG may provide ED physicians with a way to assess non-traumatic neurological issues (delirium/cognitive impairment, dizziness/vertigo, or syncope) without resorting to CT or MRI.

Empirical reviews show that EEG is an important tool for diagnosing patients with various acute neurological conditions.[13] EEG has only recently emerged as a routine screening tool for patients in whom the clinical examination is limited due to coma, sedatives, toxic encephalopathy, or primary neurological conditions.13 EEG offers the potential for identification of occult seizures and other electrical abnormalities of the brain that may be interfering with consciousness. Newer quantitative measures even allow for the opportunity to detec regional brain ischemia.[13,14]

EEG in the workup of altered mental status

EEG is particularly useful in cases of delirium and altered mental status where patients are unable to provide a reliable medical history. Bautista and co-authors demonstrated that a 5-minute, abbreviated EEG using a commercial electrode cap allowed emergency department physicians to properly diagnose patients

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with mental status change of unknown cause. The rapid EEG assessment identified cases of nonconvulsive status epilepticus, focal brain abnormality, psychogenic causes and non-neurologic events (DENNE).[15] In a separate study, Ziai's group used an abbreviated, five-minute, full montage EEG to screen 82 patients who presented to the ED with altered mental status. The researchers determined EEG successfully distinguished toxicologic, psychiatric, and metabolic causes of altered mental status from other causes.16 EEG assisted in the diagnosis of 51% of cases in the study.[16]

EEG can reliably distinguish between dementia and delirium

Dementia and delirium are distinct clinical states; the former is a chronic, progressive cognitive decline while the latter is an acute confusional state that is usually reversible. Dementia and delirium commonly co-occur in older individuals, though it can be difficult to assess whether an elderly individual is experiencing acute delirium (and can therefore be treated) or simply suffering from an acute worsening of dementia. Thomas and co-authors demonstrated that while resting EEG showed low accuracy for the diagnosis of delirium, quantitative EEG revealed specific activation patterns that could reliably distinguish dementia with delirium from dementia without delirium.17 By focusing on activated upper alpha and D power density compared to resting EEG, they achieved a diagnostic correctness of 83% in elderly patients, which corresponded to 67% sensitivity and 91% specificity.

In a 2018 report, Shinozaki et al. documented the use of a handheld EEG device employing a 10-minute, bispectral EEG (BSEEG) reading in patients with and without delirium. The authors showed that using a BSEEG index allowed them to successfully distinguish delirium with a sensitivity of 80% and a specificity of 87.7%.18 The authors concluded that bedside EEG is a useful clinical tool for mass screening of suspected delirium patients in a hospital setting.

Non-convulsive status epilepticus can only be diagnosed with EEG

Non-convulsive status epilepticus has long been a widely accepted indicator for "stat" EEG.19 Non-convulsive status epilepticus condition is common, dangerous and treatable. The condition becomes substantially and rapidly worse the longer it remains undiagnosed and untreated. Non-convulsive status epilepticus can only be diagnosed via EEG; it does not appear on CT, MRI, or any other imaging system.[19] In response to this need, hospitals have attempted to create the infrastructure necessary to deploy stat EEG when needed (with varying degrees of success[20]).

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The use of electroencephalography in traumatic brain injury

TBI-related ED visits have been increasing steadily over the past decade due in part to greater public concern about TBI effects.[21] Between 2006 and 2010, ED visits for head injury increased more than 8 times faster than general increases in ED visits (29% vs. 3.6%).[22] Between 2007 and 2013, TBI-related ED visits accounted for about 1 out of every 50 visits, increasing from 1.6 million to 2.5 million over that period.[21]

As mentioned, the diagnostic yield for CT in mild traumatic brain injury is very low (<10%).[4,5] The use of EEG in mTBI, on the other hand, is extremely promising. EEG-based biomarkers can objectively identify the presence of mTBI23 and can be reliably used to assess its severity.[24] EEG results can be used in clinical decision algorithms to help ED physicians properly triage and manage patients who have sustained blunt head trauma.[4] EEG results can also help providers determine whether CT scans are even indicated in particular situations.[25] EEG-based biomarkers can be highly predictive of positive and negative CT-based detection of intracranial injuries (92% sensitivity, 51% sensitivity, 96% negative predictive value), and also show usefulness in predicting CT detection of traumatic hematomas (98% sensitivity, 98% negative predictive value).[4] EEG was shown to effectively discriminate intracranial lesions in mTBI when certain discriminant scores and decision rules were used.[26]

Speed and convenience are the key barriers to EEG use

Despite the important role for EEG in the workup of altered mental status, traumatic brain injury, delirium, and nonconvulsive status epilepticus, the practical use of EEG in emergency departments remains limited. EEG acquisition can take hours, which is simply not feasible in modern emergency department practice. At one large US tertiary care medical center, where EEG availability and usability should be at its greatest, access time to EEG in the ICU was 3.5 hours and 4.8 hours in non-ICU hospital rooms. Patients in the ED fared slightly better, but not substantially so: Average EEG access time in the ED was 2.7 hours.20 The researchers found that access time is not significantly different for stat requests or EEGs for suspected seizure activity. These reports highlight the current poor state of EEG infrastructure in the United States.

Wider use of EEG for emergent neurological care is limited by lack of physical space, insufficient portability of units or difficulty moving acute care patients, relatively high costs, the length of time needed to apply EEG electrodes, and the limited availability of technicians capable of recording and reading EEG data. For-

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tunately, these barriers to access and care can be alleviated by using EEG systems that are small, portable, wireless, easy to apply, and record data that can easily be visualized, often using built-in analytics that do not require trained technicians.

Brain Scientific overcomes barriers to provide practical EEG in the ED

Brain Scientific's subsidiary MemoryMD provides two separate devices, NeuroCap™ and NeuroEEG™, for "easy and anywhere" mobile-wireless deployment of next generation EEG diagnostics at various point-of-care sites including emergency departments, out-of-hospital urgent care, neurology clinics and tele/remote-medicine. NeuroCap™ is an FDA-cleared, wireless, portable system for brief, high-quality, clinical-grade EEG recordings. The Neurocap is low-cost and is easily set up within five minutes by any clinician. The device consists of a disposable plastic array with pre-gelled electrodes arranged according to the international 10-20 system. NeuroEEG™ is a low-cost, miniature EEG amplifier that integrates with NeuroCap and includes recording software, wireless real-time visualization, analytics and API/SDK for developers. The NeuroCap™ also has a universal adapter for plugging into non-NeuroEEG recording systems.

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