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Improved access to rapid electroencephalography at a community hospital reduces inter-hospital transfers for suspected non-convulsive seizures

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ABSTRACT

Objective. Patients with suspected non-convulsive seizures are optimally evaluated with EEG. However, limited EEG infrastructure at community hospitals often necessitates transfer for long-term EEG monitoring (LTM). Novel point-of-care EEG systems could expedite management of non-convulsive seizures and reduce unnecessary transfers. We aimed to describe the impact of rapid access to EEG using a novel EEG device with remote expert interpretation (tele-EEG) on rates of transfer for LTM.

Methods. We retrospectively identified a cohort of patients who underwent Rapid-EEG (Ceribell Inc., Mountain View, CA) monitoring as part of a new standard-of-care at a community hospital. Rapid-EEGs were initially reviewed on-site by a community hospital neurologist before transitioning to tele-EEG review by epileptologists at an affiliated academic hospital. We compared the rate of transfer for LTM after Rapid-EEG/tele-EEG implementation to the expected rate if rapid access to EEG was unavailable.

Results. Seventy-four patients underwent a total of 118 Rapid-EEG studies (10 with seizure, 18 with highly epileptiform patterns, 90 with slow/normal activity). Eighty-one studies (69%), including 9 of 10 studies that detected seizures, occurred after-hours when EEG was previously unavailable. Based on historical practice patterns, we estimated that Rapid-EEG potentially obviated transfer for LTM in 31 of 33 patients (94%); both completed transfers occurred before the transition to tele-EEG review.

Significance. Rapid access to EEG led to the detection of seizures that would otherwise have been missed and reduced inter-hospital transfers for LTM. We estimate that the reduction in inter-hospital transportation costs alone would be in excess of $39,000 ($1,274 per patient). Point-of-care EEG systems may support a hub-and-spoke model for managing non-convulsive seizures (similar to that utilized in this study and analogous to existing acute stroke infrastructures), with increased EEG capacity at community hospitals and tele-EEG interpretation by specialists at academic hospitals that can accept transfers for LTM.

Key words: hub-and-spoke model, tele-neurology, electroencephalography, rapid response electroencephalography, non-convulsive seizures, status epilepticus

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The capacity to acquire and interpret electroencephalography (EEG) is extremely limited at most community hospitals, and even at some academic medical centers, despite evidence suggesting that utilization of EEG monitoring is associated with better patient outcomes [1, 2]. Prior surveys of inpatient EEG services underrepresent community hospitals, which are less likely to have EEG capability and tend to rely on intermittent routine EEG studies; however, access to even routine EEG is limited outside regular business hours [1, 3, 4]. Even hospitals that have EEG monitoring on-site often experience dramatic delays in acquisition that force providers to manage patients empirically without EEG data [5]. These limitations represent critical gaps in the conventional EEG infrastructure that hinder optimal management of patients with suspected non-convulsive seizures and non-convulsive status epilepticus (NCSE), who are at risk of empiric over-treatment or under-treatment with anti-seizure medications (ASMs) in the absence of early EEG data and who may require inter-hospital transfer for EEG monitoring.

Studies of conventional EEG system implementation at community hospitals are rare, but expanded access to EEG infrastructure has been shown to improve detection and control of status epilepticus, prevent transfers to affiliated academic medical centers solely for EEG monitoring, and decrease healthcare costs [6]. However, these approaches are resource-intensive and do not address the delays inherent in acquiring conventional EEG recordings. In addition, an often-overlooked aspect of implementing EEG monitoring is treating neurologists' comfort and expertise in interpreting these recordings and using them to guide management of non-convulsive seizures. Akin to the tele-stroke networks that have emerged in the last decade, EEG monitoring may benefit from the development of hub-and-spoke models to improve the detection and management of suspected non-convulsive seizures. In such a system, community hospitals would be empowered to rapidly obtain EEG data that can be interpreted remotely by experts at affiliated academic medical centers, initiate appropriate clinical management of patients with suspected non-convulsive seizures, and appropriately triage more complex patients to be transferred for EEG monitoring [7, 8].

Novel point-of-care EEG devices, such as the Rapid Response EEG System (Rapid-EEG; Ceribell Inc., Mountain View, CA), may help address this gap. Rapid-EEG consists of a 10-electrode headband that records EEG data and an attached device, which includes a visual display of EEG waveforms in a reduced eight-channel bipolar montage and a sonification tool that converts the EEG waveforms into an audible tone that can be interpreted by non-experts. EEG data can also be reviewed remotely through a cloud portal, and the device generates an automated real-time quantification and trend of the burden of seizures and highly epileptiform patterns (HEP) using an artificial intelligence algorithm (Clarity, Ceribell Inc., Mountain View, CA). Rapid-EEG can be quickly set up by any healthcare provider (*e.g.*, nurses, respiratory therapists, technicians, physicians) within five minutes, and each available modality of EEG interpretation – reduced hairline montage, EEG sonification, and automated seizure burden trend – has been shown to have excellent diagnostic accuracy, especially for detecting generalized seizures and highly epileptiform rhythmic and periodic patterns seen in critically ill patients with encephalopathy (*figure 1*) [9-12].

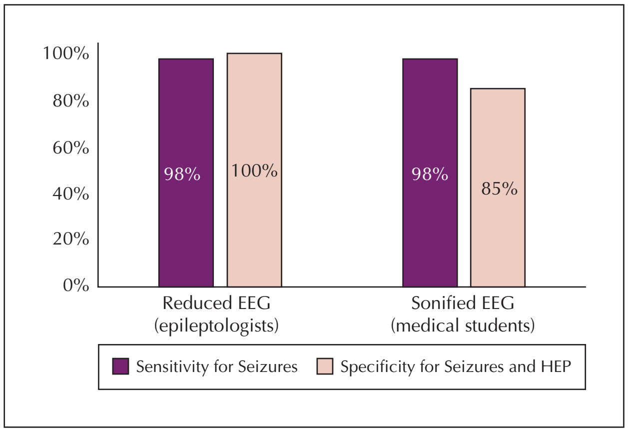
The DECIDE multicenter clinical study demonstrated that use of Rapid-EEG improved the speed and accuracy of physicians' assessments of suspected NCSE in the critical care setting at five major academic centers in the United States [13]. While this study did not entirely reflect real-world outcomes of the device, especially in community hospitals, several pilot studies have described the impact of the device in academic and community hospital intensive care unit (ICU) and emergency department (ED) settings [14-16]. In particular, a pilot study of 10 patients in a community hospital ICU showed that Rapid-EEG could be deployed in this setting and prevented over-treatment [15]. However, this study did not consider the EEG expertise of the treating neurologist or take advantage of the device's capability to wirelessly transmit EEG data to a cloud server (accessible via a web portal) for remote tele-EEG review. The small size of the study also did not capture the potential utility of Rapid-EEG in reducing inter-hospital transfers for EEG monitoring.

We designed the current study to expand upon the aforementioned observations with Rapid-EEG to further describe its real-world value in the management of patients with suspected NCSE at a community hospital both before and after the implementation of a hub-and-spoke model utilizing tele-EEG interpretation. Our outcomes of interest were: (1) the frequency of seizures and highly epileptiform patterns detected after-hours that would otherwise have been missed without Rapid-EEG; and (2) the number of potential inter-hospital transfers for EEG monitoring that were avoided because of access to Rapid-EEG.

Materials and methods

Standard protocol approval, registration, and patient consent

This study was conducted according to the principles expressed in the Declaration of Helsinki, and the study protocol was reviewed by the Stanford University



■ **Figure 1.** Rapid review of diagnostic accuracy measures for Rapid-EEG interpretation modalities. Results from prior studies validating the two Rapid-EEG interpretation modalities utilized by neurologists in this study (visual review of reduced montage EEG and audio review of sonified EEG) are summarized; automated detection of seizure burden using the Clarityγ algorithm was not available during the study period. Visual review by epileptologists was 98% sensitive for generalized seizures and 100% specific for generalized seizures and HEP; even neurology residents and medical students demonstrated significantly greater specificity for generalized HEP when reviewing reduced montage EEG (86-90%) compared to full montage EEG (69-80%) [9]. Audio review by medical students and nurses was 95-98% sensitive for seizures and 82-85% specific for seizures and HEP, comparable to neurologists' visual review (88% sensitive for seizures, 88% specific for seizures and HEP) [11]. EEG: electroencephalography; HEP: highly epileptiform pattern.

Institutional Review Board and considered exempt from review as a quality improvement project. Individual patient consent was not required due to retrospective collection of data. Use of Rapid-EEG and subsequent treatments were directed by standard-of-care at the discretion of the treating physician.

Patient cohort

We retrospectively identified a cohort of patients who underwent Rapid-EEG monitoring in either emergency or critical care settings between December 1st, 2018 and March 31st, 2020 at Stanford Health Care (SHC) ValleyCare. Device usage predominantly focused on adult patients; however, we did not exclude the one pediatric patient (age <18 years) who underwent Rapid-EEG monitoring during the study period to reflect the real-world experience of smaller community hospitals that do not have dedicated pediatric neurology services. Participants with facial trauma, open head wounds, or craniotomies were excluded, as these conditions would preclude the use of the Ceribell headband.

EEG infrastructure and development of a hub-and-spoke tele-EEG model

SHC ValleyCare is a community hospital in the San Francisco Bay Area affiliated with Stanford University Hospital (SUH), SHC's flagship quaternary medical center. Prior to this study, SHC ValleyCare only had access to conventional EEG for spot or routine studies during typical business hours and interpretation by general neurologists, whereas SUH had 24/7 access to EEG monitoring and interpretation by EEG-trained neurologists (epileptologists or clinical neurophysiologists). Patients with suspected non-convulsive seizures after-hours had to either wait until business hours (when conventional EEG became available) or be transferred to SUH for EEG monitoring. In either case, empiric management was guided by clinical suspicion alone in the absence of EEG data. Implementing Rapid-EEG at SHC ValleyCare on December 1st, 2018 enabled 24/7 access to EEG monitoring (for up to around 12 hours per study) in addition to the extant capacity for routine conventional EEG during business hours. SHC ValleyCare neurologists could decide to monitor patients with either conventional EEG during business hours, or Rapid-EEG at any time. If a patient needed EEG monitoring, Rapid-EEG would be utilized, and spot conventional EEG could be obtained following Rapid-EEG monitoring at the discretion of the treating neurologist to verify Rapid-EEG findings.

Initially, the local on-call neurologist (without dedicated fellowship training in EEG) at SHC ValleyCare interpreted Rapid-EEG recordings, and the treating physician made diagnostic assessments and treatment decisions based on their own interpretations of EEG waveforms and sonification (automated detection was not available during the study period and was therefore not used). From October 1st, 2019 onwards, epileptologists at SUH remotely interpreted Rapid-EEG recordings, and these specialists communicated their interpretations and recommendations to the on-site neurologist. This created a hub-and-spoke model for on-site EEG acquisition and remote EEG interpretation (tele-EEG) so that physicians at the community satellite could be empowered to manage patients with suspected non-convulsive seizures appropriately with EEG data interpreted by experts, who could then help triage patients for transfer to the academic hub for EEG monitoring [17].

Data collection

For each patient, we abstracted medical records for patient demographic characteristics, details of Rapid-EEG monitoring (EEG findings, time of day [business hours or after-hours, including weekends], monitoring duration), subsequent conventional EEG monitoring, and patient disposition (transfer to affiliated flagship hospital for EEG monitoring, hospital length of stay [LOS]). Rapid-EEG findings were obtained from the EEG report generated by the neurologist who originally read the study (whether this was the on-site neurologist or the remote epileptologist) since this interpretation guided clinical care; we did not adjudicate these findings by having a blinded reviewer read the EEGs. Findings of Rapid-EEG and conventional EEG monitoring were subsequently classified as either seizure, HEP, or non-epileptiform slow or normal activity. As defined in the DECIDE study of Rapid-EEG, HEP included abnormal epileptiform activity, such as periodic discharges or lateralized rhythmic delta activity, that did not meet the Salzburg criteria for electrographic seizures [13, 18].

Indications for transfer for EEG monitoring and historical practice patterns

Potential candidates for transfer to a higher level of care for EEG monitoring were historically identified based on a stepwise model that considered the clinical indication for EEG monitoring, immediate availability of conventional EEG (typical business hours vs after-hours or weekends), and, if available, conventional EEG findings (*figure 2*). Patients who presented with clinical events concerning for seizures followed by impaired consciousness without recovery were considered high-risk for non-convulsive seizures and were prioritized for EEG monitoring. If these patients presented during typical business hours (Monday to Friday, 8AM to 4PM) when conventional EEG was available, they would undergo a spot EEG for 30 minutes. If this spot EEG showed ongoing seizures or HEP, or if the patient presented outside typical business hours and conventional EEG was unavailable, then the patient would be transferred for EEG monitoring. In cases of unexplained encephalopathy or targeted temperature management (TTM) after cardiac arrest, spot conventional EEG would be performed during typical business hours (either same day or the following day, depending on whether the patient presented after-hours), and the patient would be considered for transfer only if the spot EEG revealed ongoing seizures or HEP. We applied this historical practice pattern to our cohort to identify patients who would have been considered for potential transfer prior to the implementation of Rapid-EEG and compared this estimation to the number of completed transfers during the study period (both before and after implementation of tele-EEG review).

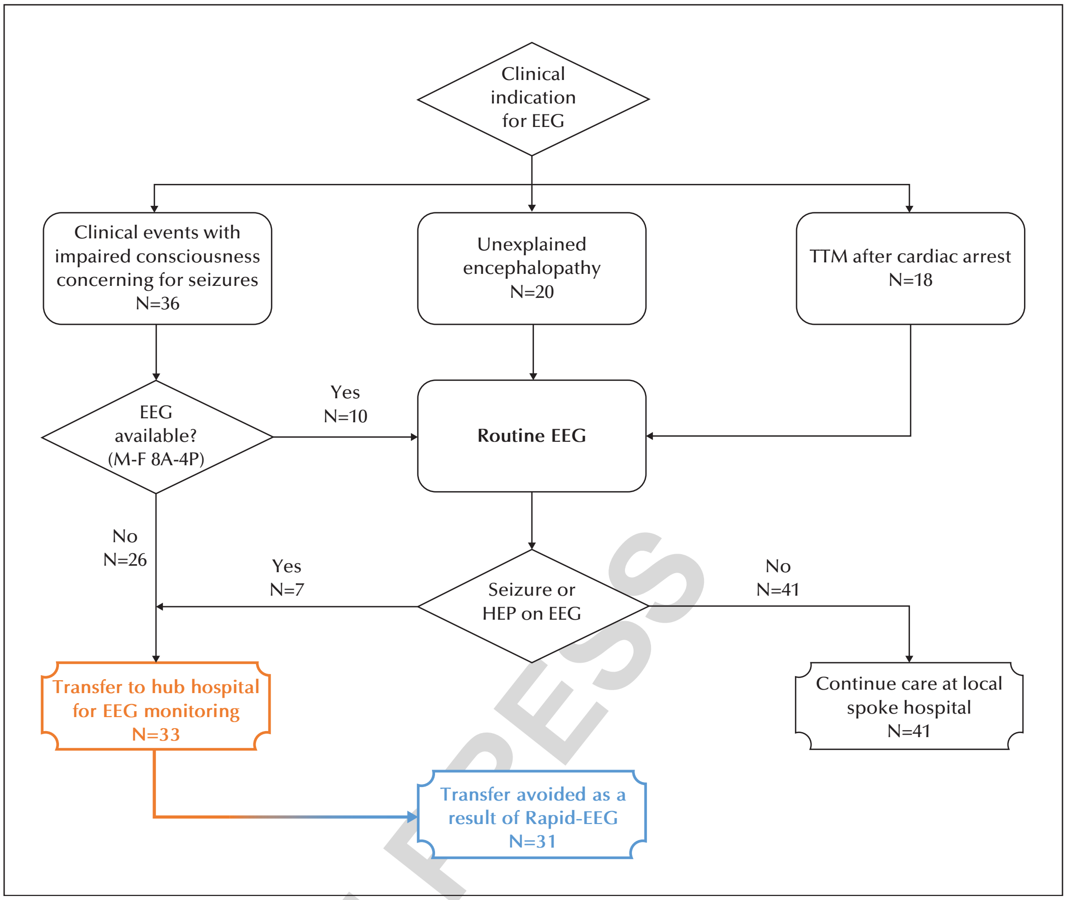
Statistical analysis

We calculated descriptive statistics for categorical (number and percentage) and continuous (mean±SD) variables. We calculated the absolute risk reduction (ARR) of inter-hospital transfers and the corresponding number needed to treat (NNT) associated with the implementation of Rapid-EEG monitoring and tele-EEG review. Comparisons between groups were performed using χ^2 tests for categorical variables and one-way ANOVA for continuous variables; a significance level of α=0.05 was used for omnibus testing with Bonferroni correction for multiple comparisons.

Results

In total, 74 patients underwent 118 individual episodes of Rapid-EEG monitoring during the study period. Patient and EEG monitoring characteristics are shown in *table 1*. Rapid-EEG monitoring occurred in the ICU (72%) or the emergency department (28%). The majority of patients presented with either a clinical event concerning for seizures (49%) or cardiac arrest (24%), while unexplained encephalopathy was the indication for 27% of Rapid-EEG studies. On-site neurologists at SHC ValleyCare interpreted 68 Rapid-EEG studies in 40 patients, and, after the implementation of the hub-and-spoke model for EEG interpretation, epileptologists at SUH remotely interpreted 50 Rapid-EEG studies in 34 patients. Rapid-EEG monitoring detected seizures in seven patients (9%) across 10 recordings (9%), HEP in eight patients (11%) across 18 recordings (15%), and slow or normal activity in 59 patients (80%) across 90 recordings (76%, including four recordings showing burst suppression in two individual patients). Only one Rapid-EEG recording could not be interpreted due to excessive myogenic activity from the patient moving his head restlessly during the entire recording. Although the distribution of Rapid-EEG findings did not significantly differ between different monitoring indications (p=0.64), seizures and HEP were more common among the 36 patients who underwent EEG monitoring to evaluate seizure-like clinical events compared to the 18 patients undergoing EEG monitoring after cardiac arrest. The majority (69%) of Rapid-EEG studies, including 9 of the 10 that detected seizures, were conducted after-hours when conventional EEG would otherwise be unavailable.

By applying historical practice patterns to our patient cohort, 33 patients (45%) would have been considered



■ **Figure 2.** Historical practice patterns of inter-hospital transfer for EEG monitoring. Historically, patients were considered for transfer based on the clinical indication for EEG monitoring (clinical events with impaired awareness concerning for post-convulsive non-convulsive seizures, post-cardiac arrest neuromonitoring while on TTM, and unexplained encephalopathy), the availability of conventional EEG monitoring (limited to typical business hours, weekdays between 8AM and 4PM), and, if available, conventional EEG findings. For patients presenting after-hours with unexplained encephalopathy or TTM after cardiac arrest, transfer decisions would typically wait until the next business day when a routine EEG could be obtained, and these EEG findings would guide the decision to transfer. However, patients presenting with clinical events concerning for seizures were transferred if conventional EEG was unavailable. We applied these historical practice patterns to our study cohort in order to estimate the number of patients who would have been considered for potential transfer prior to the implementation of Rapid-EEG (orange box) and the number of potential transfers that were avoided as a result of access of Rapid-EEG (blue box). EEG: electroencephalography; HEP: highly epileptiform pattern, TTM: targeted temperature management.

as potential transfers for EEG monitoring if Rapid-EEG was unavailable (*figure 2*). Of these, only two patients (3% of all patients, 6% of potential transfers) were transferred to the affiliated academic medical center for the purposes of EEG monitoring (clinical vignettes of transferred patients are provided in the *supplementary material*). All transfers occurred prior to the transition to tele-EEG review, although it is worthwhile to note that no seizures were detected on Rapid-EEG after this transition. Rapid-EEG obviated the need for transfer for EEG monitoring for 31 patients (42% of all patients and 94% of potential transfers), including six of seven patients (86%) found to have seizure activity, seven of eight patients (86%) found to have HEP, and 18 of 59 patients (31%) found to have slow or normal activity. Among the 40 patients included prior to the transition to tele-EEG, 19 patients were considered potential transfers for EEG monitoring, but only two

▼ **Table 1.** Characteristics of 74 patients and 118 individual Rapid-EEG recordings. Seizures and HEP were more common among patients with preceding clinical events compared to patients with recent cardiac arrest. Among patients with a clinical event preceding monitoring, Rapid-EEG revealed seizures in 14%, HEP in 11%, and slow/normal activity in 75%, whereas among post-cardiac arrest patients, Rapid-EEG revealed seizures in 6%, HEP in 6%, and slow/normal activity in 88% (p=0.49). Mean individual Rapid-EEG study duration was longer for seizure and HEP cases compared to slow/normal cases (p<0.001 for omnibus ANOVA using α=0.05; p=0.013 for seizure vs HEP, p<0.001 for seizure vs slow/normal, and p=0.46 for HEP vs slow/normal using Bonferroni-corrected α=0.017). Mean hospital LOS was longer for HEP cases compared to seizure or slow/normal cases, but this did not reach statistical significance (p=0.28 for omnibus ANOVA).

PATIENT LEVEL	All Patients *N*=74	Seizure *N*=7	HEP *N*=8	Slow or normal *N*=59
Age, mean±SD	61.7±19.8	60.7±10.6	59.6±19.6	62.1±20.9
Female gender, *n* (%)	34 (45.9)	1 (14.3)	7 (87.5)	26 (44.1)
Patient location, *n* (%)				
ED	21 (28.4)	2 (28.6)	1 (12.5)	18 (30.5)
ICU	53 (71.6)	5 (71.4)	7 (87.5)	41 (69.5)
Indications for EEG monitoring, *n* (%)				
Clinical event concerning for seizure	36 (48.7)	5 (71.4)	4 (50.0)	27 (45.8)
Cardiac arrest	18 (24.3)	1 (14.3)	1 (12.5)	16 (27.1)
Unexplained encephalopathy	20 (27.0)	1 (14.3)	3 (37.5)	16 (27.1)
Intubated, *n* (%)	39 (52.7)	3 (42.9)	5 (62.5)	31 (52.5)
Rapid-EEG monitoring encounters per patient, mean±SD	1.6±1.2	2.9±1.8	2.3±1.8	1.4±0.9
Length of stay (days), mean±SD				
Total LOS	10.1±9.9	9.1±5.6	15.4±4.8	9.4±10.7
ICU LOS	6.5±7.1	7.0±5.4	9.3±5.0	6.1±7.5
Transferred for EEG monitoring, n (%)	2 (2.7)	1 (14.3)	1 (12.5)	0 (0.0)
EEG ENCOUNTER LEVEL	**All Rapid-EEGs *N*=118**	**Seizure *N*=10**	**HEP *N*=18**	**Slow or normal *N*=90**
After-hours or weekend study, *n* (%)	81 (68.6)	9 (90.0)	9 (50.0)	63 (70.0)
Rapid-EEG monitoring duration (min), mean±SD	277.9±215.8	525.8±284.8	286.2±190.2	248.7±195.8

EEG: electroencephalography; ED: emergency department; HEP: highly epileptiform pattern, ICU: intensive care unit; LOS: length of stay.

patients were actually transferred. Among the 34 patients included after the transition to tele-EEG review, none of the 14 patients who were considered potential transfers were ultimately transferred. As such, the implementation of Rapid-EEG with on-site EEG interpretation resulted in an ARR of 39.6% (NNT 2.5) and the addition of tele-EEG review resulted in an ARR of 44.6% (NNT 2.2) (*table 2*).

Discussion

This study evaluated the impact of expanding access to EEG monitoring at a community hospital in critical care settings using Ceribell's Rapid Response EEG system. Mid-way through the study period, we implemented a hub-and-spoke tele-EEG model, which transitioned EEG interpretation from general neurologists at the community hospital to epileptologists at the academic medical center using Ceribell's web portal.

We found that Rapid-EEG obviated the need for transfer for EEG monitoring in 31 of 33 (94%) patients who would otherwise have likely been transferred to the affiliated academic medical center when Rapid-EEG was not available. The frequency of completed transfers to the affiliated academic medical center for EEG monitoring further decreased after transitioning to a hub-and-spoke model with tele-EEG

▼ **Table 2.** Impact of rapid-EEG and tele-EEG on rates of inter-hospital transfer. Potential transfers from the community hospital (spoke) to the academic hospital (hub) for EEG monitoring prior to Rapid-EEG were estimated by defining historical practice patterns regarding inter-hospital transfer (when Rapid-EEG was unavailable) and applying these transfer criteria to our cohort. The integration of Rapid-EEG into clinical practice was associated with an 89% decrease in rates of completed transfers compared to estimated historical patterns (44.6% to 5.0%). Implementation of a hub-and-spoke tele-EEG model with remote Rapid-EEG review by expert epileptologists at the hub site further reduced the transfer rate; no patients were transferred during this study period.

Access to Rapid-EEG and Tele-EEG	Patients transferred (*n/N*)	Rate of Transfer	ARR (historical–actual)	NNT (1/ARR)
Before Rapid-EEG (historical)	33/74	44.6%	–	–
After Rapid-EEG + Before Tele-EEG (actual)	2/40	5.0%	39.6%	2.5
After Rapid-EEG + After Tele-EEG (actual)	0/34	0.0%	44.6%	2.2

ARR: absolute risk reduction; NNT: number needed to treat.

review. Rapid-EEG either confirmed the absence of ongoing seizure activity or guided appropriate ASM treatment prior to transfer. The indication for the majority of potential transfers was diagnostic uncertainty (*e.g.*, inability to exclude NCSE) rather than ongoing management of confirmed NCSE. Another noteworthy finding of our study is that Rapid-EEG enabled after-hours EEG monitoring, which accounted for 69% of total included studies and 90% of studies that detected seizures, which would have otherwise been available only by inter-hospital transfer.

Our results suggest that general neurologists at community hospitals who are given the necessary diagnostic tools are able to manage a substantial number of potential transfers in-house. Evidence that EEG monitoring improves outcomes has led to a proliferation of long-term monitoring at academic medical centers. However, cost and resource utilization constraints continue to limit accessibility of long-term monitoring in community hospitals and in under-resourced settings [1, 2, 19, 20]. Many hospitals without EEG capability overcome this limitation by either resorting to repeating spot EEGs for intermittent monitoring [21], or transferring patients to a higher level of care, particularly at hospitals affiliated with a tertiary or quaternary medical referral center. Although expanding access to EEG has important implications for improving neurological outcomes and reducing disparities in care, the feasibility of doing so in community hospitals has not been well-studied.

Our study evaluated the real-world use of Rapid-EEG as part of a new standard-of-care using a hub-and-spoke model, as well as its impact on patient disposition according to the treating neurologist. Although such hub-and-spoke models have been well-developed and studied for the treatment of acute ischemic stroke [8], there is limited evidence, to our knowledge, regarding the benefits of specific health-care systems and delivery models for the management of possible NCSE. Based on our findings, we argue that Rapid-EEG, either alone or in combination with routine or long-term monitoring using conventional EEG systems, can enable a hub-and-spoke model. Additionally, tele-EEG review by experts at the hub site may have incremental value towards improving EEG interpretation accuracy and streamlining triage of transfers for EEG monitoring, similar to the benefit of central triage of acute ischemic stroke transfers between primary and comprehensive stroke centers [22]. Our findings have merit in that they capture the impact of rapid EEG access on the clinical decision-making by the neurologist considering transfer for EEG monitoring.

From an economic perspective, Rapid-EEG's ability to provide decision-makers (both clinicians and hospital administrators) with more accurate information regarding the presence or absence of non-convulsive seizures can avoid opportunity costs in the form of delayed care, inappropriate care, or inappropriate transfer of care. The financial impact of Rapid-EEG with regard to avoiding over-treatment (intubation, ventilation, and unnecessary anti-seizure treatment in non-seizing patients) and under-treatment (failure to recognize and abort seizures with first-line medication until conventional EEG can be mustered) was previously modeled in a decision-analytic framework, which found that Rapid-EEG saved $3,971 per patient, largely due to avoiding over-treatment in non-seizing patients [23]. In this study, we highlight the additional impact of EEG resource scarcity, and the resultant absence or delay of electrographic data, on the rate of inter-hospital transfer at community hospitals, and these factors are also associated with a financial impact. Inter-hospital transfer would lead to a reduction in reimbursement for the transferring institution by prorating the reimbursable amount under the Medical Severity-Diagnosis Related Group according to the Center for Medicare and Medicaid Services, and the cost of transfer for emergency ground ambulance services with personnel capable of providing advanced life support to facilities even a few miles away can be in the hundreds or thousands of dollars. In an analysis of inter-facility transfers among 85 community hospitals, the average per-transfer cost of transportation costs for ground ambulance was $1,274, while air ambulance costs per-patient were $6,534 [24]. At the rate of ground ambulance alone, the cost savings in avoided ambulance transfers in our study would exceed $39,000. This figure is likely to significantly underestimate the economic impact of deploying Rapid-EEG in a community hospital, as it does not account for the reduction in over-treatment and length-of-stay, or in changes to staffing as a result of implementing a tele-EEG model, which should be investigated in future studies.

Our study has several limitations. Firstly, we conducted a descriptive retrospective cohort study at a single site without a control group or randomization; as such, future prospective and blinded studies are needed. We acknowledge that the retrospective nature of this study makes the identification of potential transfers subjective. We attempted to eliminate this subjectivity to a great extent, as well as reflect real-world practice at many smaller community hospitals, by implementing the same stepwise model for evaluating potential transfers that has been historically used at our institution. Secondly, our aim was solely to address the issue of access to EEG at community hospitals and its impact on inter-hospital transfers. Our study lacked the statistical power to address patients' clinical outcomes or compare the clinical impact of Rapid-EEG in guiding patient care to that of long-term, continuous video-EEG monitoring with conventional EEG systems at the "spoke" hospital. We did not adjudicate the EEG interpretations of general neurologists who performed EEG interpretations during the first phase of the study (before epileptologists at the academic hub provided EEG interpretations remotely) because we were interested in describing the Rapid-EEG findings that guided clinical management and transfer decisions at the time. Previous studies (including some focused on Rapid-EEG) have described the impact of inter-rater variability or fellowship training in EEG interpretation [9-11, 25-27]. Comparison of electrographic findings from Rapid-EEG and conventional EEG was outside of our study's scope, especially since this has been addressed in prior studies [13, 14]. Lastly, we are mindful that many community hospitals are not affiliated with a medical center equipped to offer 24/7 EEG interpretation. As such, the benefits of the hub-and-spoke model described in this study may not translate to those community hospitals. We hope our findings provide an impetus for more detailed prospective studies in the future to determine the impact of implementing a hub-and-spoke tele-EEG model on patient outcomes, healthcare costs at spoke sites, and additional revenue generation at hub sites associated with providing professional services (*i.e.*, EEG interpretation), and to determine optimal models for expanding access to EEG at community hospitals and reducing disparities in neurological care for patients at hospitals without EEG capability.

Conclusion

Our findings expand the results of the DECIDE multicenter clinical study to the real-world community hospital setting, where management decisions often hinge on whether the patient needs to be transferred to a hub hospital for EEG monitoring. This is especially true outside typical business hours when EEG is unavailable at many spoke hospitals. Our findings will hopefully create an impetus for well-controlled, prospective, and randomized trials where the full clinical and economic impact of tele-EEG systems using Rapid-EEG at community hospitals can be further assessed. ■

Key points

- Most community hospitals lack the EEG capacity to manage patients with non-convulsive seizures, necessitating transfer for EEG monitoring.
- Improving EEG access can guide treatment of patients with non-convulsive seizures and mitigate transfers solely for EEG monitoring.
- The majority of Rapid-EEG studies occurred after-hours, when EEG would have been unavailable and patients would have been transferred.
- Rapid-EEG monitoring with tele-EEG review prevented transfer for 94% of patients who would historically have been transferred.
- Novel EEG devices and tele-EEG review enabled the development of a hub-and-spoke model for managing patients with non-convulsive seizures.

Supplementary material.
Summary slides and supplementary material accompanying the manuscript are available at www.epilepticdisorders.com.

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TEST YOURSELF

(1) What percentage of patients would have been transferred due to EEG unavailability after-hours and what percentage of Rapid-EEG recordings took place after-hours?

(2) How many patients need to be monitored with Rapid-EEG, with or without expert tele-EEG review, in order to prevent one inter-hospital transfer for long-term EEG monitoring?

(3) What are the costs associated with ground or air transportation for inter-hospital transfer?

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com.