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ORIGINAL RESEARCH

Using an in-situ Simulation Model to Identify Deviations from Guideline-Based Management of Pediatric Status Epilepticus in Community Emergency Departments

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Background: Children with epilepsy are often presented to Community Emergency Departments (CEDs) for acute treatment of status epilepticus (SE). Timely medical management is imperative to prevent morbidity and mortality, and adherence to evidence-based guidelines improves outcomes for high stakes/low frequency events. Barriers to guideline adherent management in the CED setting are understudied; in-situ simulation (ISS) can be used to identify gaps in care for events such as pediatric SE.

Objective: The primary objective was to assess for deviations from evidence-based guidelines in the management of pediatric SE. A secondary objective was to explore potential barriers to practice within the evidence-based guidelines.

Methods: We conducted a prospective observational ISS pilot study examining representative CED teams caring for a simulated child in SE. The primary outcome was overall adherence to the pediatric SE guidelines as measured by 12 metrics: 5 non-pharmacologic (for example: delays in vital sign assessment, failure to time seizure) and 7 pharmacologic (for example: incorrect benzodiazepine dose, delay in benzodiazepine administration or escalation to antiseizure medication). Additional metrics including provider knowledge (recognition of status epilepticus) and resources (antiseizure medications stocked) were analyzed as process measures. We enrolled 4 interprofessional teams at 4 participating ED sites.

Results: Overall, 0 of the 4 teams adhered to all 12 metrics. A barrier to timely administration of benzodiazepines for two of the sites came from attempting IV access repeatedly. No team referenced an up-to-date treatment algorithm based on current evidence-based guidelines.

Conclusion: Standardized ISS scenarios identified variability in adherence to the pediatric SE guideline across a pilot sample of local CEDs. Barriers to guideline-adherent care occurred at both individual and systems levels. The study was limited in scope to 4 pilot sites.

Keywords: simulation, pediatric, status epilepticus

Introduction

Persons with epilepsy (PWE) visit the Emergency Department (ED) more often than the general population, with 22% of children with epilepsy seeking ED care each year.[1] The incidence of pediatric status epilepticus (SE), an abnormally prolonged seizure or multiple seizures without returning to the neurologic baseline in-between, is approximately 20 per 100,000 per year.[2,3] Early recognition and treatment of SE with standardized treatment algorithms reduces downstream morbidity and mortality (pediatric SE is associated with overall 3% mortality).[4,5] Despite increased acute care utilization, only 33% of the PWE who seek acute care will receive ED care that meets evidence-based guidelines, a problem exacerbated in community hospital settings.[6,7] Long term, children receiving care that is not adherent to recommended management are at greater risk of hospital readmission, morbidity, and death.[7]

Received: 21 November 2024
Accepted: 23 April 2025
Published: 7 May 2025

Factors contributing to this problem are lack of exposure and preparation of the community emergency care team. While SE is a high-acuity event, it is encountered at a low frequency, accounting for only 1–2% of ED visits and hospital admissions.[8] Importantly, the majority of children seeking emergency care (including those with complex, chronic conditions) present to community EDs, where pediatric volume is low.[9] Lower pediatric volume is negatively associated with a pediatric readiness.[10] The relative infrequency of critically ill pediatric patients in community settings has correlated with lower quality of resuscitative care.[11] Previous collaborative simulation studies have evaluated the quality of care across a spectrum of EDs including adherence to pediatric sepsis and cardiac arrest guidelines as well as seizure care in the setting of hypoglycemia.[12,13] There is limited data on the use of ISS to measure care of pediatric SE, and on what barriers impact SE guideline adherence in community EDs. Despite a growing body of literature investigating simulation as tool to both assess and improve competency in managing neurologic emergencies, such studies are often carried out in academic hospitals large enough to support trainees, and may not generalize to the community setting.

An innovative approach to bridging gaps within pediatric acute care is through mobile, in-situ simulation training (ISS), a validated investigative and educational methodology that is performed in the clinical setting. The Community Outreach Mobile Education Training (COMET) program is one academic-community partnership based at our institution that is uniquely suited for sharing best practices and systems testing via community outreach simulation scenarios.[14] Building on existing infrastructure within the COMET program, we piloted an ISS curriculum focused on acute pediatric seizure care. The primary aim of the study was to identify deviations from the 2016 Evidence-Based Guideline on the Treatment of Convulsive Status Epilepticus in Adults and Children by the American Epilepsy Society.[15] A secondary objective was to explore barriers to practice within the evidence-based guidelines.

Materials and Methods

We conducted a prospective observational ISS pilot study. This study measured the performance of interprofessional Emergency Medicine healthcare teams caring for a simulated pediatric patient with convulsive SE. Four community city-based EDs were enrolled in this study. Recruitment of community ED sites was limited to four based on allotted funding. Institutional Review Board (IRB) approval was obtained from Boston University Chobanian & Avedisian School of Medicine. When applicable, additional consent from the internal research committee for our city's Health Net affiliated centers was also obtained and submitted to the IRB. Participants provided consent to be audio/video recorded.

Teams were composed of one or two physicians, one to two nurse practitioners, two to five registered nurses, one paramedic, one physician assistant and one student. One site had two pediatric-trained personnel that participated, the remainder had adult-trained medical backgrounds. Team sizes were representative of the in-vivo institutional resuscitation team (range of 4–7 members). Recruitment of participating staff was performed by a designated liaison at each site through snowball sampling.

The teams were enrolled during a 6-month period (June 2022 – November 2022). Sessions took place in each institution's ED resuscitation room using each department's actual equipment. Each simulation case was conducted in the exact same manner across each of the four sites to ensure standardization. The scenarios varied in length, averaging about 20 minutes per topic followed by a 20-minute structured debriefing session. Case scenarios were pre-scripted by an interdisciplinary team of simulation and content-experts (two seasoned epileptologists, a pediatric emergency medicine physician and director of COMET program and a senior pediatric neurology fellow). Cases were initially trialed at our home institution and refined based on observation and participant feedback to optimize desired patient physiology, learning objectives, and case flow.

Sessions began with an introduction to the research team and a brief orientation to the manikin's functionality, including demonstrating how to assess physical exam findings, what a seizure looked like, and how to administer medications. After each case, the research team facilitated a structured debrief. This allowed for reflection on team performance, analysis of clinical decision-making, as well as education to address questions from participants. Sessions were audio/video recorded for post-simulation transcription and qualitative analysis, the results of which will be discussed in a separate paper.

Twelve metrics were measured that included pharmacologic and non-pharmacologic components, as defined in Table 1. Teams were also given a summative composite score (reported as a percent) based on the number of metrics met out of twelve. Although the primary focus of the study was to identify deviations from practicing within evidence-based guidelines, the simulation allowed us to assess for barriers (eg, equipment problems, lack of medication access) that impacted evidence-based care. These issues categorized

Table 1 SE Guideline Metrics Across the 4 Participating Sites

Metrics	Site 1	Site 2	Site 3	Site 4
Stabilization Phase (0–5 min)				
1. Vitals and oxygenation assessed	Y	Y	Y	Y
2. Supplementary O2 initiated (facemask or nonrebreather)	N	N	N	Y
3. Placed on continuous ECG monitor	Y	Y	Y	Y
4. Collect finger stick blood glucose	N	N	N	Y
5. Started timing seizure from onset	N	N	N	N
Initial Therapy Phase (5–20 min)				
6. Time of 1st BZD administration	10:15	6:32	2:40	2:15
7. BZD given	Ativan; Diazepam	Ativan	Ativan	Ativan
BZD route	Intravenous; Rectal	Intravenous	Intramuscular	Intramuscular
BZD dose (mg/kg)	0.1; 0.5	0.1	0.2	0.1
8. Proper weight-based BZD dose	Y	Y	N	Y
9. Repeat BZD dose × 1 if seizure continued after 3–5 minutes	Y	Y	Y	Y
Second Therapy Phase (20–40 min)				
10. Use of recommended 2nd line agent	Y	Y	Y	Y
Second-line agent given	Levetiracetam	Levetiracetam	Fosphenytoin	Phenobarbital
Agent route	Intravenous	Intravenous	Intravenous	Intravenous
Agent dose (mg/kg)	50	10	20	20
11. Proper weight-based ASM dose	Y	N	Y	Y
Third Therapy Phase				
12. Team recognized need for anesthetic infusion, transfer to higher level of care	Y	Y	Y	Y
Composite score (/12)	9/12 (75%)	8/12 (67%)	8/12 (67%)	11/12 (92%)

Notes: Actions either were or were not performed, denoted Y = yes and N = no. Composite score calculated as a sum of completed process measures out of 12 reported as a %.

as either knowledge based or structural process measures and recorded in Tables 2 and 3. Data were manually entered in Microsoft Excel and analyzed using descriptive statistics. ISS participating sites were given tailored reports with target areas for improvement, as well as copies of SE guidelines for future use and dissemination to other colleagues. This report serves both as feedback for mitigating latent safety threats and as a means for ongoing knowledge sharing.

Results

Deviations from adherence to the SE treatment algorithm are summarized in Table 1. All four teams chose a benzodiazepine for initial therapy, and all teams re-dosed when the seizure continued prior to giving a second-line agent. Time to first benzodiazepine administration varied, as did the interval between the two administrations. All teams gave a recommended agent during second therapy phase, although not all gave the recommended dose.

https://doi.org/10.2147/OAEM.S507770

Table 2 Process Measures Across All Four Sites Assessing the Accurate Identification and Timing of SE, Plus the Appropriate Reference to Cognitive Aids and Treatment Algorithms to Administer Medications Correctly

Knowledge Process Measures	Site 1	Site 2	Site 3	Site 4
Recognition of seizure	Y	Y	Y	Y
Recognition of SE	N	Y	N	Y
Accurate record of time points meds given	N	N	N	N
Use of cognitive aid	Y	Y	Y	Y
Team referencing SE guideline	N	Y (outdated)	N	N
Medications given at appropriate rate	Y	N	N	N

Notes: Each measure was (Y = yes) or was not (N = no) performed.

Table 3 Process Measures Pertaining to the Appropriate Stock of Critical Medications, Easy Medication and Pharmacy Access, as Well as Stocking Pediatric Equipment

Structural Process Measures	Site 1	Site 2	Site 3	Site 4
Antiseizure medications stocked:	Phenytoin, Levetiracetam	Levetiracetam, Fosphenytoin, Phenobarbital,	Levetiracetam, Fosphenytoin, phenobarbital	Levetiracetam, Phenobarbital, Fosphenytoin
Access to Intra-nasal Midazolam	Y	Y	Y	Y
Benzos available in Pixis	Lorazepam, Diazepam	Lorazepam, midazolam	Midazolam, lorazepam, diazepam	Midazolam, lorazepam, diazepam
Use of pediatric equipment	Team initially grabbed adult airway cart	Incorrect blood pressure cuff used	Team skipped use of non-rebreather and began bagging patient (incorrect hold of bag-valve mask)	No pediatric nasal trumpets stocked; MD could not find pediatric intubation supplies
Immediate access to pharmacist	N	Y (via phone)	Y (via phone)	Limited hours (not overnight)

Notes: Measures either were or were not present at each site (Y = yes, N = no).

The case concluded with the team's recognition of need for anesthetic infusion (third therapy phase) necessitating transfer to a facility with pediatric ICU level care, which all teams recognized.

Barriers included a lack of provider knowledge or use of cognitive aid, as well as resource limitation (ie availability of medications/personnel, access to appropriate equipment etc). Barriers that impacted a team's ability to perform guideline adherent care were categorized as knowledge and/or structural process measures and reported in Tables 2 and 3.

Discussion

We found that deviations from the guidelines occurred at all four participating sites, including both pharmacologic and non-pharmacologic metrics. We observed delays in initial stabilization maneuvers. Three of the four teams failed to check an initial blood glucose level. While the etiology of SE in this case simulation was not hypoglycemia, it is notable that this was a repeatedly omitted task as hypoglycemia is a reversible cause for seizure. Though teams were quick to initiate the patient assessment and examination, none of the teams delegated a role for timing the seizure from the onset. This led to uncertainty of the timing of medication administration. Time-keeping was further skewed when two teams did not immediately recognize a seizure at its onset. Three of the four teams did not apply supplemental oxygen via appropriate respiratory support within the initial stabilization window. Two teams gave oxygen via nasal cannula and one team did not initiate respiratory support within 5 minutes.

AES guidelines recommend treatment with a benzodiazepine if a seizure is longer than 5 minutes. Ultimately, an ED team would be expected to administer a benzodiazepine at that 5-minute mark regardless of intravenous access. While all teams did administer an initial benzodiazepine dose within the goal timeframe based on existing guidelines,[15–17] only two teams successfully administered a benzodiazepine within the 5-minute timeframe. The two teams that did so gave the dose by a non-intravenous route, supporting the observation that first-line treatment may be delayed by waiting to obtain intravenous access. Studies have shown that delayed time to administration of a benzodiazepine leads to both longer convulsive seizure duration and that benzodiazepine responsiveness decreases with longer seizure duration.[18,19] Notably, the time interval in between repeat benzodiazepine administrations for all teams was quite short, with no team waiting more than two minutes in between doses. This could cause unintended adverse medication effects such as further respiratory compromise.

Regarding the second phase of therapy, all four teams chose a recommended antiseizure medication; however, we noticed several latent safety threats. One team gave a sub-therapeutic dose of Levetiracetam (10 mg/kg), likely an inadequate dose to stop SE. One team chose to give Phenobarbital as second-line medication despite having Levetiracetam available (more preferable side effect profile) and was given as a push over 2 minutes. This complicated the scenario for the team by causing significant hypotension in the simulated patient. One site administered IV Levetiracetam infusion via pump rather than as an IV push; this delayed the time to dose completion. Another team gave an infusion of Fosphenytoin on a pump at a higher than recommended rate (3 mg/kg/min). While rates of AED infusions are not explicitly delineated in the guidelines, improper administration leads to unintended cardiopulmonary consequences and compromises standard of care.[20]

We found knowledge gaps in antiseizure medication dosing to be a barrier to guideline adherent care. All teams endorsed the use of a cognitive aid (eg Broselow tape, PediStat mobile App) to assist with medication dosing; however, aids were not linked to an SE treatment algorithm. No team referenced an *up-to-date* SE guideline during the simulation and all teams acknowledged that there was no physical copy of the algorithm posted in their trauma bay/ED. These findings are consistent with one study's findings that compared the impact of simulation vs standardized patients on trainee knowledge and confidence in the management of neurologic emergencies, including SE. The authors also assessed for trainee deviations from guidelines and noted variability in benzodiazepine and antiseizure medication administered.[21]

It is worth noting that while the composite scores depict the guideline adherence rates, they also reveal areas where the algorithm does not provide concrete guidance, ie, rate of anti-seizure medication infusion, or optimal intervals between benzodiazepine administration. Teams could attain a 100% composite score following the algorithm and still have latent safety threats. This underscores the importance of CEDs supplementing guideline adoption with institutional pharmacy policy for maximal clarity and safety. Guidelines should recommend seeking pharmacist consultation for proper administration of infusions.

Regarding additional process measures that served as barriers to optimal management, there was variability in the available antiseizure medications between sites. There was also variability in which benzodiazepines were available in the automated medication dispensing machine. Importantly, all sites had access to intranasal midazolam; however, no site gave it in that form. This may have been due to lack of awareness of its availability, and/or preference for giving alternative routes based on provider knowledge and comfort. Although access to a pharmacist during pediatric resuscitations is a critical resource, half of the teams acknowledged that they often are required to proceed without pharmacy input given lack of staffing. Another barrier was related to equipment. At multiple sites, team members required extra time to find pediatric-sized equipment, and at times proceeded with equipment that was the incorrect size (eg blood pressure cuff). This delayed initiation and escalation of respiratory support when equipment location was not known. Barriers were further explored and analyzed through the structured debrief, when team members reflected on performance and discussed challenges they encountered during the case. Analysis of the qualitative data from debrief sessions will be published in a subsequent write-up.

Use of evidence-based protocols and care pathways improves patient care, yet deviation from guideline recommendation remains multifactorial.[22,23] ISS is uniquely suited for community reach owing to its mobility and flexibility to meet clinicians in their clinical milieu. And if team performance improves after simulation training sessions, for how long is

information transfer sustainable (teams change, guidelines get updated, etc)? By identifying barriers across multiple domains of care delivery, our preliminary findings emphasize the investigative promise of ISS as a tool for performing needs assessments, a key initial step in implementation project design.

Limitations

This study was limited in scope, with funding allowing for the participation of only four pilot sites. ED sites were community-based although predominantly more urban with a high annual volume of patients. Inclusion of more centers, especially those in more rural settings, would provide useful insight to barriers to SE guideline adherence that are pervasive versus those that are unique to more resource-limited settings. We acknowledge that assessing for deviations from guideline management assumes a degree of provider familiarity with guidelines, and we would not expect providers to adhere to guidelines they are not familiar with.

While the pilot sample was small, the implementation of ISS for acute seizure management supports prior reports of deviations in care observed in larger studies of community sites and pediatric referral hospitals alike.[6,24] This includes delays in medication administration and incorrect dosing. ISS allowed for the observation of interdisciplinary teams in real time, identifying deviations from AES guidelines as well as barriers to optimal care delivery – barriers that shared commonality among community sites, and that would not otherwise be easily identified by retrospective data extrapolation.

Conclusions

There was variable adherence to pediatric SE guidelines during simulated care of SE, with no participating ED fully adhering to guidelines. Barriers to guideline-adherent care occurred at both individual and systems levels. Future studies with a larger multi-center design should seek to capture urban and rural hospitals to more robustly assess where deviations most frequently occur and tailor intervention, accordingly. Subsequent implementation projects that mitigate barriers to guideline adherence should focus on sustainability. Future studies should also build off insights from pilot data to measure the impact of ISS by assessing for improvement in guideline adherence and patient outcomes.

Funding

ETF reports grant funding to Boston University to conduct research conceived and written by ETF received from the Joel and Barbara Alpert Endowment for the Center for the Urban Child and Health Family.

Disclosure

The authors report no conflicts of interest in this work.

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