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Aetiology and Outcome of Childhood Convulsive Status Epilepticus

A tertiary care experience in Oman

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Abstract

***Objective*:** This study aimed to evaluate the etiology, management, and outcomes of convulsive status epilepticus (CSE) in children highlighting the factors that affect patient outcome. ***Methods*:** In a retrospective study spanning 2020 to 2023, 93 children with convulsive status epilepticus (CSE) treated at Sultan Qaboos University Hospital's emergency department (ED), High Dependency (HD), and intensive care unit (ICU) were analyzed. The Modified Rankin Scale at discharge determined CSE outcome. ***Results*:** Study of 93 children (mean age 4.84 years ± 3.64), predominantly Omani (92.47%). Acute 14 symptomatic (37.7%) and febrile tatus (31.2%) were primary causes. Diazepam used in 67.44% 15 cases as first-line treatment, with median seizure duration of 45 minutes. Successful control achieved in 16 76.34% within 60 minutes. Return to baseline in 55.9%, 5.38% mortality, and 38.7% disability. Etiology and 17 duration significantly impacted outcomes ($p < 0.05$). ***Conclusion*:** Acute symptomatic is the most common etiology of CSE, and a longer duration is associated with higher mortality and neurological disability. Therefore, managing CSE promptly and appropriately is crucial. Furthermore, identifying and treating the underlying cause is essential to reduce the duration of CSE and improve the outcome.

Keywords: Etiology, Outcome, Convulsive Status Epilepticus, Modified Rankin Scale

Advances in Knowledge

- Of the 93 children studied, acute symptomatic etiologies were the primary cause of CSE.

- Prolonged CSE duration correlated with increased mortality and neurological disability.
- First-line antiseizure medications, particularly benzodiazepines like Diazepam, were commonly administered.
- Successful seizure control was achieved in 76.34% of patients within 60 minutes.
- Overall, 55.9% of patients returned to baseline, 5.38% died, and 38.7% experienced disability.
- The study underscores the significance of prompt CSE management and the importance of identifying and addressing underlying causes to improve outcomes in children.

Applications to Patient Care

- This study's outcomes offer valuable insights for enhancing patient care practices in managing childhood convulsive status epilepticus (CSE).
- By identifying acute symptomatic etiologies as the most common cause and linking prolonged CSE duration to poorer outcomes, clinicians can prioritize early intervention and tailored treatments.
- Findings in this study underscore the critical importance of swift and appropriate CSE management, emphasizing the need for multidisciplinary collaboration among healthcare providers.
- Ultimately, these insights will aid in improving patient care protocols, potentially reducing mortality rates and enhancing the quality of life for children with CSE.

Introduction

Convulsive Status Epilepticus (CSE), the most common neurological emergency in children, has a diverse etiology and if prolonged, it can result in unfavorable outcomes, especially in cases of refractory and super-refractory status epilepticus.[1] CSE is characterized by continuous seizures that last longer than 5 minutes or repetitive seizures without regaining consciousness. The condition occurs when mechanisms fail to terminate seizures, resulting in neuronal injury and devastating neurological consequences.[2] The estimated incidence of status epilepticus (SE) in childhood is 20 per 100,000 per year, with the highest incidence occurring in children under the age of five years. This emphasizes the need for increased vigilance in detecting seizures.[3,4]

The ILAE definition of CSE has two operational dimensions. First, the length of seizure and the time point (t_1) beyond which the seizure should be considered as "continuous seizure activity" necessitating the need for treatment. The second time point (t_2) is the time of ongoing seizure activity after which there is a risk of long-term consequences. In the case of convulsive SE, both time points from t-1 at 5 minutes to t-2 at 30 minutes are important in interpreting the short and long-term consequences.[5] It is estimated that 23%–48% of children with convulsive status

epilepticus progress to refractory SE, which can have varying outcomes.[6] Convulsive status epilepticus is usually managed using specific national or local treatment algorithms. First-line treatment is administered when a tonic-clonic or motor clonic seizure lasts more than five minutes (impending or premonitory CSE). Second-line treatment is administered when the CSE persists after two doses of first-line treatment (established CSE).[7] Robust randomised clinical trial (RCT) evidence supports the use of benzodiazepines as a first-line treatment and second-line treatments being phenytoin, levetiracetam and sodium valproate.[8]

Etiology is the most important outcome defining factor in CSE however, it cannot always be easily defined in emergency settings. The causes of CSE can range from febrile, acute symptomatic conditions such as stroke, CNS infections, intoxication, and metabolic disorders to remote symptomatic conditions like post-stroke, post meningitic, postencephalitic, progressive encephalopathies such as electroclinical syndromes, neurodegenerative disorders, CNS tumors, or even cryptogenic/unknown causes.[9] Febrile illnesses are the most common cause of convulsive status epilepticus (CSE) in children, accounting for approximately 33% to 35% of all cases. Some children with genetic epilepsy, specifically Dravet syndrome and PCDH19, may also experience febrile CSE as these syndromes usually present between 3 and 12 months of age with 'febrile seizures'.[10] Meanwhile, acute symptomatic etiology with impaired consciousness right at the outset is frequently related to CSE with high morbidity and costs that increase with disease refractoriness, warranting detailed, exhaustive workup.[11]

Literature suggests that CSE is significantly linked to morbidity. However, there is a lack of sufficient data to determine whether the severe outcomes are solely due to CSE or are influenced by factors such as the patient's age, management guidelines, and timing of arrival at healthcare settings. To swiftly manage and prevent the refractoriness of this condition, which is associated with high-cost profiles and significant morbidity, this study was conducted to identify the causes, management practices, and outcomes of children with CSE. This study will provide evidence for clinicians to assess the early outcomes of CSE patients while considering the impact of predictive factors that significantly influence the prognosis.

Methods

This retrospective cohort study was conducted at Sultan Qaboos University Hospital (SQUH), Oman. The study involved children who were admitted with convulsive status epilepticus (CSE) in the Emergency Department (ED), High Dependency Unit (HDU), and Pediatric Intensive Care Unit of the hospital within three years between June 2020 and June 2023. Ethical approval was obtained from the institutional research ethical committee before conducting the study. The data

were collected using electronic patient records through the TrakCare system available in SQUH. The sampling technique used in the study was a non-probability consecutive technique.

The inclusion criteria for the study were patients of either gender, aged between 1 month and 12 years, who presented with convulsive status epilepticus, regardless of the type of seizure or its cause. We excluded patients with nonconvulsive SE because it was difficult to interpret clinically their seizures duration and response to antiseizure medication. Patients with alternative diagnoses that mimic convulsive status epilepticus, such as status dystonicus and psychogenic nonepileptic attacks, were also excluded. The operational definition for convulsive status epilepticus (CSE) was continuous seizure activity lasting for more than 5 minutes, requiring antiseizure treatment to abort as per the International League Against Epilepsy (ILAE) definition.[12] The information required for this study was gathered from the TrakCare system. The study included 93 patients who met the operational definition of CSE within a specific timeframe. The study documented patient demographics, including age, gender, nationality, seizure type according to ILAE classification, duration, and the cause of CSE. In cases where convulsive SE occurred in a previously normal child within 1 week of acute CNS injury (such as bacterial, viral, or autoimmune encephalitis), acute demyelinating disorders, or acute stroke, it was labeled as an acute symptomatic etiology.[13] Prolonged febrile seizure was defined as CSE in a child aged 6 months to 5 years during an episode of fever without CNS infection.[14] Remote symptomatic etiology is defined as a type of epilepsy that is caused by a known risk factor such as a previous stroke or head injury and occurs at least a week after the CNS insult.[15] Progressive encephalopathy encompasses neurodegenerative, epileptic, and neurometabolic disorders. Static encephalopathy includes cerebral palsy. Idiopathic epilepsy is characterized by a second unprovoked seizure leading to SE and is unclassified when unable to be placed in other categories.[16] The study reviewed various investigations, such as neuroimaging, cerebrospinal fluid analysis (if needed), electroencephalography (EEG), and other relevant tests to determine the cause of CSE. The medical history, previous test results, and treatment details of patients who had experienced previous neurological insult and the management practices for CSE were also recorded. The study assessed outcomes using a modified Rankin score (0–6). The outcomes were classified into three categories: return to baseline (0–1 score), neurological disability (2–5 score), or mortality (6 score). Furthermore, neurological disability was categorized into mild (Rankin score of 2), moderate (Rankin score of 3), and severe disability (Rankin scores of 4–5).[17-18] To determine the outcomes of previously neurologically disabled children, the study also considered the baseline Glasgow Coma Scale with a modified Rankin score.

The data were analyzed using SPSS 25. Numeric variables, such as the age of patients, duration of seizures, and time interval to control seizures, were expressed as mean ± SD. Categorical variables, including gender, demography, seizure type, management options, etiology of CSE, and outcome of patients, were presented by frequency and percentage. The association between outcome and different variables, such as etiology, duration of status epilepticus, and the association between etiology and seizure type and age, was determined using the chi-square test. A p-value of ≤0.05 was considered significant.

Results

The study included 93 children, 52 (55.9%) males and 41 (44.1%) females, resulting in a male-to-female ratio of 1.3:1, as shown in Table 1. The patients' average age was 4.84 ± 3.64 years, most of whom were of Omani ethnicity, comprising 86 (92.47%) and 7 (7.53%) of non-Omani origin. The age distribution in various subgroups revealed that 41 patients (44.1%) were aged between 1 month to 2 years, 35 patients (37.6%) were aged between 2 to 6 years, and 17 patients (18.3%) were aged between 6 to 12 years. Generalized seizures were the most common seizure type, occurring in 49 patients (52.7%), followed by focal seizures in 17 patients (18.3%), and focal to bilateral tonic-clonic seizures in 24 patients (25.8%), as shown in Table 1. A mixed seizure type comprising tonic, clonic, and myoclonic was found in three patients (3.2%), mostly in patients with either static or progressive encephalopathy. Generalized seizures were significantly associated with etiology (p = <0.01) and were most commonly associated with an acute etiology. Acute symptomatic was the most common etiology noted in 35 (37.6%) patients, followed by febrile status in 29 (31.2%) patients, remote symptomatic in 4 (4.3%) patients, progressive encephalopathy in 11 (11.8%) patients, static encephalopathy in 4 (4.3%) patients, idiopathic in 9 (9.7%) patients, and unclassified in 1% of patients. Acute symptomatic etiology and febrile status were noted in the early age groups, whereas progressive encephalopathy was commonly seen in late childhood (p = <0.01).

Eighty-six of the patients received first-line interventions, which account for 92.47%. There were 67.74% of patients who needed second-line antiseizure medications (n = 63) and 36 (38.7%) needed third line medication for seizure control.The most commonly used antiseizure medications for convulsive status epilepticus management were Diazepam, phenytoin, and Levetiracetam, as shown in Table 2. To stop seizures, a significant number of patients received benzodiazepines as first-line measures, including Diazepam (67.44%) and Midazolam (4.65%). Phenytoin (42.86%) and levetiracetam (22.22%) were among the most commonly used second-line antiseizure drugs. Midazolam infusion (30.56%) and phenytoin (27.78%) were this study's most commonly used third-line antiseizure drugs. Out of 86 patients, 23 (26.74%) responded to first-line treatment, and

out of remaining 63 patients, 27 (42.86%) responded to second-line treatment. The median time taken to control the seizures was 45 minutes, with a range of 30–600 minutes. This study showed that 71 cases (76.34%) were successfully controlled within 60 minutes. Prolonged duration of seizures of more than 6 hours was mainly noted in etiologies like progressive encephalopathy and remote symptomatic seizures. The duration of seizure control had a strong association with the etiology of SE, with a p-value of 0.027.

Out of the 52 patients who recovered (returned to baseline), 41 (78.85%) had controlled seizures within 60 minutes, while 11 (21.15%) had uncontrolled seizures for over 60 minutes.

The patients who received Diazepam had a mean age of 4.54 years (range, 0.17–12 years), those who were given phenytoin had a mean age of 4.71 years (range, 0.17–12 years), and those administered with levetiracetam had a mean age of 3.95 years (range, 0.42–12 years).

The mean admission or hospital stay duration was 5.82 days (range, 1–55 days). Among the 91 admitted patients, 54 (58.89%) stayed in the hospital for over two days, while 37 (41.11%) stayed for two days or less.

Patients were admitted to either the pediatric ward, HD, or ICU. 42 patients (46.67%) were admitted to the pediatric ward, 23 (25.56%) to the pediatric HD, 24 (26.67%) to the pediatric ICU, and one patient to both the HD and ICU, as illustrated in Figure 1.

Out of the enrolled patients, 52 (55.9%) returned to baseline with good recovery, while 36 (38.7%) showed no recovery with either disability or recurrence of convulsive status. The mortality rate was 5.38% (n = 5), and 2 (2.1%) cases were lost to follow-up. Neurological disability, according to the modified Rankin score (mRS), was mild in 11 (11.8%) cases, moderate in 12 (12.9%) cases, and severe with persistent vegetative state in 7 (7.5%) cases..

Etiology was associated with morbidity in terms of neurological disability and mortality, with a significant p-value (0.021). Prolongation of CSE was associated with poorer outcomes (p = 0.041). There was no association between age groups, seizure type, and timing of the first benzodiazepine injection and outcome.

Discussion

The overall incidence of childhood status epilepticus is unvaryingly 20 per 100,000 children per year, with overall mortality of 3% therefore SE is a constant challenge for healthcare professionals, in both the pre-hospital and in-hospital settings.[19] Bearing in mind the incidence of this most common neurological emergency, warrants immediate identification and epidemiological

surveillance for etiology to guide adequate management. Our research showed that acute symptomatic seizures were the leading cause of convulsive status, followed by febrile status. This is in accord with the findings of a study conducted in a developing country by Uzair et al., which reported a strong correlation between the cause of CSE and the outcome of patients with SE.[20] One study from KSA found that febrile seizure is the most common cause of convulsive status epilepticus, followed by electrolyte imbalance and hydrocephalus.[21] There is availability of extensive data on the timing, choice, and dosage of antiseizure medication administration. However, in our study group, the most used first-line anticonvulsants were benzodiazepines, specifically Diazepam in 67.44% of cases and midazolam in 4.65% of cases based on constant available options in our institute, this is in accordance with similar study from Oman where also same subgroups of benzodiazepines were used.[22] Becker et al conveyed that if intravenous access is available, IV lorazepam is at least as effective as, or even more effective than, IV diazepam/midazolam. It has also been suggested that IV lorazepam has fewer side effects. If intravenous access is not available, buccal and especially intramuscular midazolam can be used as first-line anticonvulsants for treating convulsive status epilepticus in a hospital setting.[23]Our study found that the most commonly used second-line anti-seizure medications were phenytoin and Levetiracetam, accounting for 42.86% and 22.22%, respectively. This finding is consistent with a previous study published in 2019 that identified these drugs as the most effective second-line antiepileptics. Lyttle et al. reported that Levetiracetam had comparable safety profiles and administration ease to phenytoin, indicating that it could be a suitable alternative as the first-choice, second-line anticonvulsant for treating pediatric convulsive status epilepticus.[24]

In our study, generalized seizure was the predominant seizure type (52.7%) and seizure semiology had significant association with the etiology of CSE ($p=<0.01$) which was acute in majority. The acute etiology typically involves diffuse cortical involvement and could explain why generalized seizures were more common. In contrast, an international study conducted in Italy found focal convulsive seizures to be the most common semiology (50.8%), while generalized seizures were less common (32.3%) and nonconvulsive status (16.9%) was the least common. Similar to our results, they found a statistically significant correlation between their seizure semiology and etiology ($p < 0.001$).[25] Our patients had an average age of 4.84±3.64 based on previous reports that showed a higher prevalence of Convulsive Status Epilepticus (CSE) in preschool children.[26] It has been hypothesized that younger children are more vulnerable to acute factors, such as febrile seizures, due to underdeveloped mechanisms for seizure control and disruption of these mechanisms with minimal abnormalities in neuronal function. Psychomotor development, closely related to nervous system maturity and dependent on genetic and structural factors, was regular in majority of the children. It is essential to understand the clinical profile and factors that predict

morbidity and mortality in children with CSE to improve prognosis and modulate management. Richard's study determined the outcome after the first-ever CSE at the 1-year follow-up and their data suggested that etiology, not duration, is the primary determinant of the outcome. Those who were previously neurologically healthy before CSE had a better outcome.[27] On the contrary our study found etiology as well as duration of CSE to be significant outcome predictive factors. In our current research, the mortality rate was 5.38% which is lower than the mortality rates reported in previous Indian studies, where the mortality rate in children with convulsive status epilepticus (CSE) ranged from 14% to 33%. A recent study from a developing country showed a much higher mortality rate of 26.4% than our study's findings.[28] Our study found that the longer duration of status, acute symptomatic etiology, and progressive encephalopathy are significant risk factors for mortality. Guterman and Vasquez reported that delayed or insufficient treatment with a benzodiazepine (BDZ) can lead to lower efficacy, longer time to seizure cessation, and an increased risk of refractoriness. This, in turn, can result in more intensive care unit admissions, more respiratory and hemodynamic complications, and worse outcomes.[29-30] We also noted significant association between time of first BDZ administration and outcome of CSE in terms of neurological disability and mortality, in case where intravenous benzodiazepine cannot be promptly administered, buccal or intramuscular midazolam should be considered.

STRENGTHS AND LIMITATIONS

In our study, we presented a comprehensive report of varied etiology, management practices and acute outcome as well as outcome predictive factors in children with convulsive status epilepticus from a specialised centre in Oman. As a limitation, this study portrays single centre experience in retrospective manner by analysing medical record with relatively small sample size and did not identify other reported adverse outcomes after status epilepticus including cognitive and sensory impairment, hippocampal injury and subsequent risk of epilepsy as long-term consequences.

Conclusion

Acute symptomatic is the most common etiology of CSE and longer duration of status is associated with higher mortality and neurological disability. Therefore, managing CSE promptly and identifying and addressing the underlying cause is foremost to reduce seizure duration and improve outcomes in children. Optimal care for children with CSE requires collaboration between community pediatricians, neurologists, and emergency medical personnel.

Conflicts of Interest

The authors declare no conflict of interests.

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Author Contributions

AW edited and rewrote the manuscript. SSAM and ASAJ contributed to the data collection, statistical analysis and initial manuscript writing. FAA, FA and AM did the revision and editing of the manuscript. AAF was responsible for the idea, design, supervision of students and editing of the manuscript. All authors approved the final version of the manuscript.

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Availability of Data

The data of this study will be furnished upon a reasonable request from the corresponding author.

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Table 1: Patients' Characteristics, Seizure Type, and Etiology of Convulsive Status Epilepticus (n=93)

Characteristic	Value
Mean age, years (SD)	4.84 ± 3.64
Gender, n (%)	
Male	52 (55.9%)
Female	41 (44.1%)
Seizure Type, n (%)	
Generalized	49 (52.7%)
Focal	17 (18.3%)
Focal with bilateral tonic and clonic	24 (25.8%)
Mixed (clonic, tonic, myoclonic)	3 (3.2%)
Mean time between seizure onset and 1st BZD, min (SD)	25 (± 19)
Etiology, n (%)	
Acute symptoms	35 (37.6%)
	26 (27.9%)
Central Nervous system infection	7 (7.5%)
Acute Demyelinating Encephalomyelitis	2 (2.2%)
Autoimmune encephalitis	
Prolonged febrile seizure	29 (31.2%)
Progressive encephalopathy	11 (11.8%)
Neuro-degenerative disorder	2 (2.2%)
Epileptic encephalopathy	7 (7.5%)
Metabolic disorder	2 (2.2%)
Static encephalopathy	4 (4.3%)
Remote symptomatic	4 (4.3%)
Structural epilepsy	3 (3.2%)
Post meningitic sequelae	1 (1.1%)

Characteristic	Value
Idiopathic epilepsy	9 (9.7%)
Unclassified	1 (1.1%)
SD, standard deviation; BZD, benzodiazepine.	

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392 **Table 2:** Frequency Breakdown of use of antiseizure medication

Medication used	1st line n(%)	2nd line n(%)	3rd line n(%)
Diazepam	58 (67.44%)	3 (4.76%)	0 (0.00%)
Phenytoin	9 (10.47%)	27 (42.86%)	10 (27.78 %)
Levetiracetam	4 (4.65%)	14 (22.22%)	6 (16.67%)
Midazolam	4 (4.65%)	9 (14.29%)	11 (30.56%)
Sodium Valproate	6 (6.98%)	2 (3.17%)	3 (8.33%)
Other medications	5 (5.82%)	8 (12.70%)	6 (16.67%)

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394 **Table 3:** Relationship of Etiology with Age, Seizure Type, and Duration of Status Epilepticus

Etiology	Age in groups (n = 93)			P-value
	One month to 2 years	>2 years–6 years	>6 years–12 years	
Acute symptoms	18 (19.4%)	9 (9.7%)	8 (8.6%)	
Prolonged febrile seizure	17 (18.3%)	12 (12.9%)	0	
Remote symptoms	1 (1.1%)	1 (1.1%)	2 (2.2%)	
Progressive encephalopathy	2 (2.2%)	3 (3.2%)	6 (6.5%)	<0.01
Static encephalopathy	1 (1.1%)	3 (3.2%)	0	
Idiopathic epilepsy	2 (2.2%)	6 (6.5%)	1 (1.1%)	
Unclassified	0	1 (1.1%)	0	
	Seizure type (n = 93)			

	Generalized	Focal	Mixed	Focal with bilateral tonic and clonic	
Acute symptoms	21 (22.6%)	3 (3.2%)	0	11 (11.9%)	
Prolonged febrile seizure	19 (20.4%)	10 (10.8%)	0	0	
Remote symptoms	0	1 (1.1%)	0	3 (3.2%)	
Progressive encephalopathy	4 (4.3%)	3 (3.2%)	2 (2.2%)	2 (2.1%)	<0.01
Static encephalopathy	3 (3.2%)	0	1 (1.1%)	0	
Idiopathic epilepsy	2 (2.2%)	0	0	7 (7.5%)	
Unclassified	0	0	0	1 (1.1%)	
	Duration of status epilepticus (n = 93)				
	<I hour	**1–6 hours**	**>6 hours**		
Acute symptoms	28 (30.1%)	4 (4.3%)	3 (3.2%)		
Prolonged febrile seizure	27 (29.0%)	2 (2.2%)	0		
Remote symptoms	1 (1.1%)	1 (1.1%)	2 (2.2%)		
Progressive encephalopathy	6 (6.5%)	2 (2.2%)	3 (3.2%)		0.027
Static encephalopathy	0	3	1 (1.1%)		
Idiopathic epilepsy	9 (9.7%)	0	0		
Unclassified	0	1	0		

TABLE 4: Relationship between outcomes and predictive factors (n=93)

VARIABLE	**OUTCOME**			**P-value**
	Return to baseline	Neurological disability	Death	

	n = 52 (55.9%)	n = 36 (38.7%)	n = 5 (5.38%)	
Etiology: n (%)				0.021
Acute symptoms	15 (16.1%)	18 (19.4%)	2 (2.2%)	
Prolonged febrile seizure	26 (28.0%)	3 (3.2 %)	0	
Remote symptoms	1 (1.1%)	3 (3.2%)	0	
Progressive encephalopathy	2 (2.2%)	7 (7.5%)	2 (2.2%)	
Static encephalopathy	2 (2.1%)	2 (2.2%)	0	
Idiopathic epilepsy	6 (6.5%)	3 (3.2%)	0	
Unclassified	0	0	1(1.1%)	
Duration of Convulsive Status Epilepticus: n (%)				0.041
<1 h	51 (54.8%)	20 (21.5%)	0	
1–6 hours	0	11 (11.8%)	1 (1.1%)	
>6 hours	1 (1.1%)	5 (5.4%)	4 (4.3%)	
Mean time between onset of seizures to 1st benzodiazepine injection: n (%)				0.00001
<10 minutes	11 (11.8%)	7(7.5%)	0	
10–30 minutes	38 (40.9%)	17 (18.3%)	0	
>30 minutes	3 (3.2%)	12 (13.0%)	5 (5.4%)	

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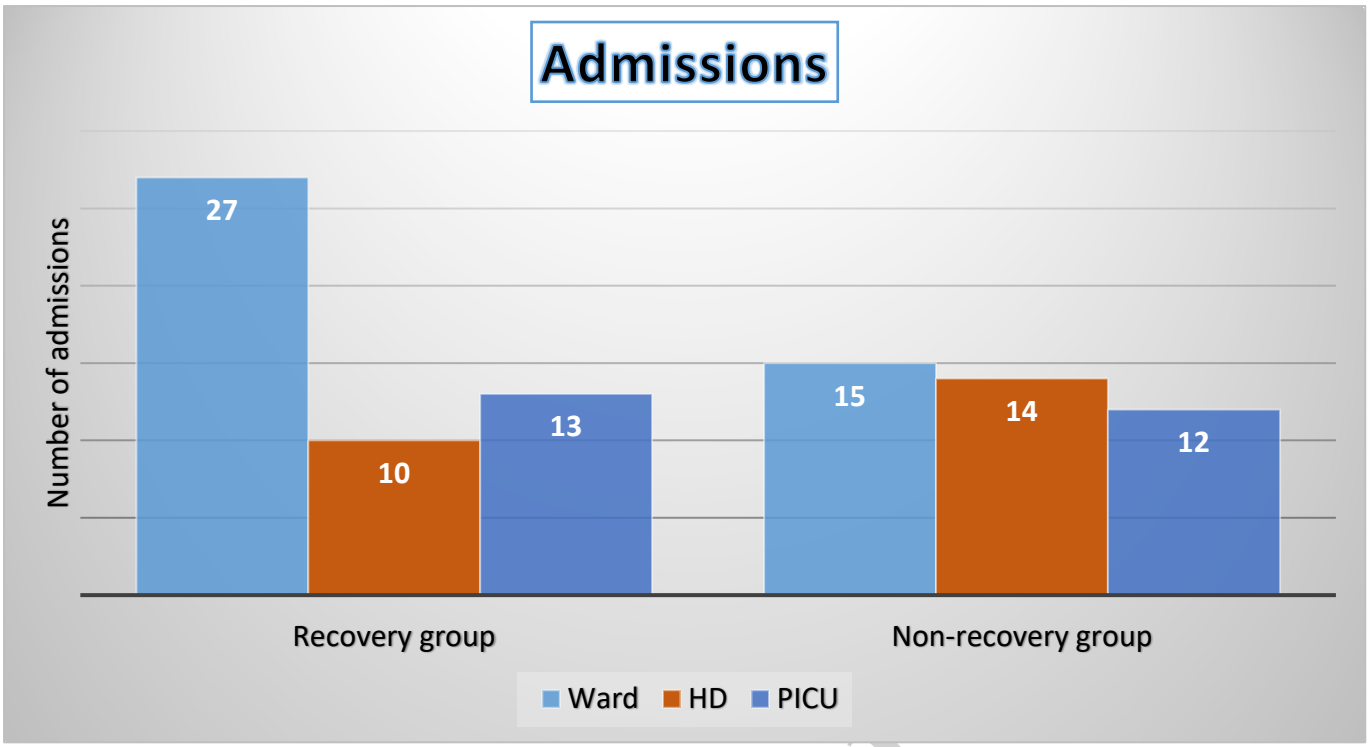

Figure 1: Frequency Breakdown of patients admitted to various divisions depending on seizure duration