Research Article

Electrographic Seizures in Pediatric Systemic Cancer Patients with acute Unexplained Encephalopathy: Bedside Emergent ≥ 30min EEG

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Abstract

Purpose: In comatose children, the definite association between electroencephalographic (EEG) paroxysmal activities and clinical seizures remains uncertain. We aimed prospectively to evaluate EEG patterns and subclinical seizures among systemic cancer pediatric patients who underwent unexplained acute deterioration of consciousness during admission in ICUs and Neuro-ICUs.

Study design: Multicenter prospective observational study describing sub-clinical seizures and EEG features of pediatric systemic cancer patients (1-16 years) with acute unexplained medical coma who underwent emergent bedside EEG ≥ 30 minutes monitoring.

Material and methods: We conducted a prospective longitudinal observational study design and EEG assessment of 40 systemic cancer patients age ≤ 16 years, consecutively diagnosed and admitted in intensive care units (ICUs) and neurointensive care units (Neuro-ICUs) of different cancer hospitals with unexplained acute impaired consciousness (GCS ≤ 8) within ≤ 6 hours of such deterioration. Bed-side EEG recordings of ≥ 30minutes were done according to the clinical scenario and the requirements of the treating neurologist/intensivist. Patients with brain tumor, brain metastasis, seizures or those with known cause of coma were excluded. Data surrounding clinical, electrographic, and treatment factors were collected via a prospective systematic review of medical records and EEGs for correlation with diagnosis, change in the diagnosis and management.

Results: Over a period of 2 year, 40 children (22.5% 1-5 years, 37.5% 6-10 years, 40% 11-16 years); boys 65% and girls 35%, with systemic cancer patients with a median age of 9.8 years with unexplained acute deterioration of conscious level (GCS ≤ 8) were studied. This cohort underwent bed-side EEG of ≥ 30 minutes, which was abnormal in 100% of the records. The main reasons for EEG requests were: 1) unexplained impaired consciousness 22(55%) and 2) impaired consciousness and subtle convulsions 18(45%). The most common EEG abnormalities were invariant mixed theta-delta slowing (27.5%), followed by low-amplitude delta pattern plus epileptiform discharges (20%) and there was electrographic evidence of EEG seizures in 17(42.5%) of the cohort. These electrographic seizures were present in 55.5% of 18 patients with subtle convulsions, whereas were documented only in 20% of the 22 patients without such movements. Electrographic seizures among patients with subtle convulsions responded to anticonvulsant drugs in 75% cases as compared 50% such response among patients without such convulsions.

Conclusion: Emergent bed-side EEG record of ≥ 30 minutes is useful in systemic cancer patients admitted in ICUs, Neuro-ICUs with acutely impaired consciousness with or without abnormal body movements. Neurology consultation and EEG studies in these comatose patients provide useful diagnostic information.

ABBREVIATIONS

EEG: Electroencephalography; ESz: Electrographic Seizures; ESE: Electrographic Status Epilepticus; NCSE: Coma-Nonconvulsive Status Epilepticus; coma-LPDs: Coma-Laterialized Periodic Discharges; Coma- GPDs: Coma with Generalized Periodic Discharges Coma; BS: Burst Suppression; ICUs: Intensive Care Units; Neuro ICUs: Neurointensive Care Units; IV AEDs: Intravenous Anticonvulsants

INTRODUCTION

Systemic cancer pediatric patients are prone to become critically ill and are at high risk for a variety of neurologic insults, including seizures and encephalopathy, which can result in permanent neurologic disability if remain untreated [1]. Despite these risks, there are few techniques for monitoring brain function during sudden deterioration of consciousness in these patients, especially in resource-poor settings. An EEG measures the brain's...
METHODS

This is a prospective observational study of emergency EEGs obtained from systemic pediatric cancer patients from 1st January 2015 to 31st December 2016 submitted to urgent EEG examinations in intensive care units ICUs or in neurointensive care units (Neuro ICUs) of different cancer hospitals in Lahore, Pakistan. These entire urgent EEG requests were received at the Brain Associates, a neurophysiology laboratory located in the center of this cosmopolitan city, Lahore – Pakistan. The laboratory records approximately 60 emergent EEG recordings per month.

Patient identification

The patients with the diagnosis of systemic cancer who had unexplained sudden impaired consciousness GCS ≤ 8 or ≤ 6 hours duration were assessed by an emergent bedside EEG of ≥ 30 minutes. We abstracted the clinical information written when the EEG was recorded and recorded the following parameters: etiology, age, sex, acuity of illness, clinical examination findings, presence of recent clinical seizures, and history of epilepsy. We reviewed the neuroimaging findings and recorded the presence or absence of brain space occupying lesion. The health records of study patients were reviewed on their bed side, discussed with on call resident, and inclusion determined based on the criteria below. Patients with normal movements but not definite convulsions due to seizures were included in the study cohort. Pre-treatment and follow-up treatment plans after EEG reports were discussed with the treating neurologist/intensivist and were documented accordingly.

Inclusion and exclusion criteria

Inclusion criteria consisted of: 1 age ≥ 1 year to 16 years, 2 diagnosis of systemic cancer, 3 encephalopathy with GCS ≤ 8 of ≤ 6 hours duration and 4 availability of EEG records and neuroimaging CT or MRI at the time of analysis. All neuroimaging features were ascertained from radiology reports, or when unclear, by review of neuroimaging films by the study neurologists. All of the original EEGs studies were personally reviewed by Dr. Malik and Dr. Choudhary. The acuity of the patient's disease relative to the timing of the EEG recording was classified as emergent ≤ 6 hours after documentation of deterioration of consciousness, as these are admitted patients. Exclusion criteria consisted of: 1 Patients with brain tumor or brain metastasis, 2 diagnosis of epilepsy in the past history, 3 status epilepticus preceding encephalopathy, 4 identifiable causes for encephalopathy were also excluded, 5 All patients who presented with generalized tonic-clonic SE or over seizure activity were excluded and the patients who had seizures and/or were being treated with anti-seizure drugs and 6 patients with incomplete records and those in which EEG record was performed after ≥ 6 hours of deterioration of the condition.

Data collection

Clinical features: The records of the patients which contain their background characteristics such as age, sex, clinical, radiologic and pathological variables were analyzed. Pre-treatment and follow up treatment plan after EEG report and neurologist’s consultation were reviewed. Clinical features assessed from medical records included: time of deterioration of consciousness and seizure/abnormal movements and their duration. Other clinical features included neurological examination and requirement for anti-epileptic agents single or multiple agents, however, EEGs were done before starting anticonvulsant drugs.

EEG features: The emergency EEGs were performed by the laboratory of neurophysiology at the bedside in the corresponding health facility, majority were in Neuro-ICUs. EEGs were obtained in all of these patients within the first 06 hours of making the diagnosis of coma and were obtained to evaluate the level of brain function and to evaluate seizure activity. We maintained electrode impedance at less than 5 KΩ. We categorized EEG amplitudes into three bands: low <100 μV, medium 100–300 μV and ‘high >300μV amplitudes. Background frequencies were grouped into three categories: delta, mixed theta and delta, and predominantly theta or greater frequency. We defined an EEG seizure as a distinct episode of epileptiform activity sharp waves, spikes, sharp-slow waves, spike-slow waves and poly-spike-slow waves over a minimum duration of 5 seconds. Only the first emergency proper EEG examination of each patient studied between was included in this work. The results were interpreted by two experienced neurophysiologists Malik and Choudhary assisted by three EEG technologists, with the final decision being made by consensus. For the study purposes, only the most significant alteration, whether related to the baseline rhythm or paroxysmal disorders, was considered in each EEG; some examinations had more than one evident alteration. The EEG background abnormalities were categorized into background type normal or abnormal and background asymmetry. The background activity
was considered abnormal if the EEG demonstrated low voltage, discontinuity. The background asymmetry was defined as more than 50% difference in amplitude between each hemisphere. Lateralized EEG findings were defined as the presence of positive or negative sharp or slow waves originating from one hemisphere. The patients were categorized as having possible NCSE if they had at least one of the following criteria: 1EDs > 2.5 Hz i.e., > 25 EDs in “worst” 10-second epoch; 2 typical ictal spatiotemporal evolution of EDs or rhythmic activity > 0.5 Hz; and 3 subtle ictal clinical phenomena with: EDs or rhythmic activity > 0.5 Hz. Coma-nonconvulsive status epilepticus (coma -NCSE), coma-periodic discharges lateralized periodic discharges coma- LPDs or coma with generalized periodic discharges (coma- GPDs), burst suppression patterns and evolution ictal EEG pattern were used according to Beniczky et al. [11].

RESULTS
Study cohort
During the study period of 2 years, 200 systemic cancer patients with acute medical coma GCS ≤ 8 within ≤ 6 hours of deterioration of consciousness were screened in this study. We excluded 160 patients, as study inclusion criteria were not met, primarily as ages were more than 16 years. All of these pediatric systemic cancer patients had emergent bedside EEG at least one record of ≥ 30 minutes duration. Complete clinical information and neuroimaging were available on 40 (20%) of the total patients monitored, comprising the study cohort. All of these the total 40 patients had abnormal EEG records: clinically 2255% cases had coma without any abnormal movements and 18 45% cases had coma with subtle convulsions- possible seizures. The mean age of the enrolled cohort was 9.8 years range 2 to 16 years. Of the total, boys were 26 (65%) and girls were 14 (35%). The demographic characteristics and clinical presentation are shown in Table 1.

EEG findings
At least one bed-side EEG of ≥ 30 minutes was monitored on each of these patients, which was abnormal with invariant and nonresponsive to internal and external stimuli indicating severe encephalopathic EEG background in all of the records, in agreement with clinical severity of coma GCS ≤ 8: with asymmetry in 37.5%. Seventeen (42.5%) of the EEGs of patients in coma demonstrated predominant background of mixture of delta and theta waves but of age appropriate amplitude for EEG background, and a predominant low amplitude delta activities, invariant to internal and external stimuli, consistent with an electrographic diagnosis of severe encephalopathy were found in 18 (45%) EEG records. Electroencephalographic inactivity pattern flat EEG-5% was documented only among the group with no abnormal movements, whereas, theta and alpha coma were found in one case each, Table 2. Electrographic seizures were recorded in 7 (31.8%) of the 22 patients without subtle convulsions, whereas electrographic seizures were in 10 (55.5%) of the 18 such patients with abnormal movements in our study, which is statistically significant, Table 3.

We found 17 (42.5%) patients in our EEG database had paroxysmal periodic discharges GPDs in addition to the severe encephalopathic EEG background. Among these total 17 (100%) EEGs, highest percentage of paroxysmal discharges were found in the records with features of low-amplitude for age delta background 64.7%, as compared to paroxysmal discharges 35.3% interspersed with mixed theta-delta age appropriate background, Table 4.

Information relevant to short term clinical and/or EEG findings in response to intravenous anticonvulsant drugs IV AEDs were available on 30 (75%) of the total patients. Follow-up EEG records 24-48 hours after IV AEDs were available in 1482.4% of

Table 1: Characteristics of 40 medically comatose pediatric systemic cancer patients.

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>No of Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>26</td>
<td>65%</td>
</tr>
<tr>
<td>Girls</td>
<td>14</td>
<td>35%</td>
</tr>
<tr>
<td>Age i ≥ 1-5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. ≥ 5-10 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. ≥ 10-16 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coma GCS ≤ 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coma GCS ≤ 8 and abnormal movements</td>
<td>18</td>
<td>45%</td>
</tr>
</tbody>
</table>

GCS- Glasgow Coma Scale

Table 2: Predominant EEG patterns in unexplained acutely comatose systemic cancer pediatric patients n=40.

<table>
<thead>
<tr>
<th>Predominant EEG Patterns</th>
<th>No of patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Invariant mixed theta-delta slowing</td>
<td>11</td>
<td>27.5%</td>
</tr>
<tr>
<td>b. Mixed theta-delta slowing plus epileptiform discharges</td>
<td>6</td>
<td>15%</td>
</tr>
<tr>
<td>a. Invariant low-amplitude delta pattern</td>
<td>8</td>
<td>20%</td>
</tr>
<tr>
<td>b. Low-amplitude delta pattern plus epileptiform discharges</td>
<td>3</td>
<td>07.5%</td>
</tr>
<tr>
<td>Continuous spike-wave discharges NCSE superadded to low amplitude delta background</td>
<td>6</td>
<td>15%</td>
</tr>
<tr>
<td>Intermittent burst-suppression pattern superadded to low amplitude delta background</td>
<td>2</td>
<td>05%</td>
</tr>
<tr>
<td>Electroencephalographic inactivity pattern</td>
<td>2</td>
<td>05%</td>
</tr>
<tr>
<td>Theta coma</td>
<td>1</td>
<td>02.5%</td>
</tr>
<tr>
<td>Alpha coma</td>
<td>1</td>
<td>02.5%</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 3: Prevalence of electrographic seizures among comatose children without and with abnormal movements n=40.

<table>
<thead>
<tr>
<th>Patients category</th>
<th>Electrographic seizures</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients without abnormal movements</td>
<td>22</td>
<td>31.8%</td>
</tr>
<tr>
<td>Patients with abnormal movements</td>
<td>18</td>
<td>55.5%</td>
</tr>
<tr>
<td>Total 40 (100%)</td>
<td>40</td>
<td>17 (42.5%)</td>
</tr>
</tbody>
</table>
the 17 patients with possible electrographic seizures. Of these 14 patients, 9 (64.3%) patients, EEG records after IV AEDs showed improvement electrographic seizures decreased ≥ 75% ± clinical improvement within 48 hours, usually after 24 hours, of the initial EEG records as recorded by the same set standards. The electrographic response to IV AEDs was documented among 50% and 75% of the patients without abnormal movements and with abnormal movements, respectively statistically significant, Table 5.

**DISCUSSION**

This multicentre prospective observational study demonstrates electrographic seizures ESz and electrographic status epilepticus ESE among 40 children with systemic cancer undergoing bedside emergent ≥ 30 minute EEG, who had unexplained acute medical coma GCS ≤ 8 of children with systemic cancer are at increased risk for life-threatening complications like sudden deterioration of consciousness or seizures either due to their malignancy or its treatment and sometimes no cause could be found for such complications [12]. We documented male predominance 65% with male: female ratio of 1.8:1. Almost similar to our study, Jabeen et al. [13], reported that among 1250 pediatric cancer patients, the frequency of cancer was higher among boys 62% than girls 38% with a ratio of 1.6:1.

Seizures in comatose children may manifest as overt convulsions, subtle or electrographic seizures [14], but we excluded patients with overt convulsions. In a prospective study of 204 comatose children, the seizures were observed in 54% before commencing EEG recording [15]. Similarly, we documented subtle seizures in 18 45% and 22 55% of the children were comatose without any clinical evidence of subtle seizures/abnormal movements. Other studies have documented electrographic seizures in 7-65% of comatose children [4,16-20]. Most of these studies have included children of different age groups, varied aetiology including epilepsy, but none has studied nonconvulsive seizures in acute medical coma among children with systemic cancer. One of the lowest percentage 7% of electroclinical seizures has been reported from Australia [4], which included children only with GCS≤8, the same GCS as in our cohort. In this study, all epileptic seizures were documented in first 3 hours of video–EEG monitoring, pointing the importance of initial EEG record, but these were not systemic cancer patients.

EEG background was abnormal in all 100% of all the patients with GCS ≤ 8 in our study. This is in agreement with the fact that various EEG patterns in coma correlate with the degree of impairment of consciousness and the depth of coma [21-23]. Our study confirms that an EEG reflects cerebral cortical activity, as modulated by brainstem and diencephalic inputs. In 28 (70%) children of our study cohort, the background EEG activity was characterized by mixtures of theta-delta and low-amplitude delta activities, 6 (15%) children had continuous spike-wave discharges NCSE superadded to delta background, intermittent burst-suppression pattern superadded to low amplitude delta background was documented in 2 (5%) of the records. Electroencephalacity pattern was obvious in 5%, whereas theta and alpha coma were in one patient each. Similarly, Gwer et al. [14], has reported EEG in a prospective study of 92 acutely comatose children: 71 (87%) initial background EEG activity was characterized by delta activity < 4 Hz and only 11 13% had predominant frequencies of 4 Hz or greater and 39 (48%) children had low background wave amplitude. These small variations are most likely due the different study cohorts. Electroclinical seizures refer to EEG seizures with a clinical correlate, whereas nonconvulsive seizures refer to seizures without any clinical correlate identified by bedside caregivers or video review by encephalographers [23,24]. We documented electrographic seizures in 45% and electrographic status epilepticus occurred in 15% of our cohort. In comparison, Claassen et al. [25], in a retrospective study of 570 hospitalized patients documented electrographic seizures in 19% but seizures were most frequent in younger patients as 36% of children under age 18 had seizures. Almost similar to our results, in a prospective study of 100 critically ill children, electrographic seizures are reported in 46% and electrographic status epilepticus in 19% [26]. Of interest, all these studies, including ours, indicate that various EEG patterns in coma correlate with the degree of impairment of consciousness and the depth of coma [21-23]. Our study confirms that an EEG reflects cerebral cortical activity, as modulated by brainstem and diencephalic inputs. In 28 (70%) children of our study cohort, the background EEG activity was characterized by mixtures of theta-delta and low-amplitude delta activities, 6 (15%) children had continuous spike-wave discharges NCSE superadded to delta background, intermittent burst-suppression pattern superadded to low amplitude delta background was documented in 2 (5%) of the records. Electroencephalacity pattern was obvious in 5%, whereas theta and alpha coma were in one patient each. Similarly, Gwer et al. [14], has reported EEG in a prospective study of 92 acutely comatose children: 71 (87%) initial background EEG activity was characterized by delta activity < 4 Hz and only 11 13% had predominant frequencies of 4 Hz or greater and 39 (48%) children had low background wave amplitude. These small variations are most likely due the different study cohorts. Electroclinical seizures refer to EEG seizures with a clinical correlate, whereas nonconvulsive seizures refer to seizures without any clinical correlate identified by bedside caregivers or video review by encephalographers [23,24]. We documented electrographic seizures in 45% and electrographic status epilepticus occurred in 15% of our cohort. In comparison, Claassen et al. [25], in a retrospective study of 570 hospitalized patients documented electrographic seizures in 19% but seizures were most frequent in younger patients as 36% of children under age 18 had seizures. Almost similar to our results, in a prospective study of 100 critically ill children, electrographic seizures are reported in 46% and electrographic status epilepticus in 19% [26]. Of interest, all these studies, including ours, indicate that although there are significant differences in the acute neurologic categories epilepsy-related, acute structural, acute nonstructural monitored across institutions, within each acute neurologic diagnosis category there is hardly any significant difference in electrographic seizure occurrence. In agreement with our study, in a single center observational study of 200 children with acute encephalopathy undergoing continuous EEG demonstrated that electrographic seizures (ESz) occurred in 21% and electrographic status epilepticus ESE occurred in 22% [27]. Most electrographic seizures in critically ill children are nonconvulsive seizures, but in our prospective study of 40 children, electrographic seizures only were recorded in 42.5% of the children who had no previous neurological disorders.

Importantly, neither electrographic seizures nor electrographic status epilepticus is 100% clinical seizures [28,29]. Patients experiencing some seizures with a clinical

<table>
<thead>
<tr>
<th>Electrographic seizures' pattern</th>
<th>No of patients</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Mixed theta-delta slowing interspersed with epileptiform discharges</td>
<td>6</td>
<td>35.3%</td>
</tr>
<tr>
<td>Low-amplitude delta pattern interspersed epileptiform discharges</td>
<td>3</td>
<td>17.6%</td>
</tr>
<tr>
<td>Low-amplitude delta interspersed with continuous spike-wave discharges NCSE</td>
<td>6</td>
<td>35.3%</td>
</tr>
<tr>
<td>Low-amplitude delta with intermittent Burst-suppression pattern</td>
<td>2</td>
<td>11.8%</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patients category</th>
<th>Responsive to anticonvulsant drugs</th>
<th>Percentage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrographic seizures in patients with abnormal movements</td>
<td>6</td>
<td>75%</td>
</tr>
<tr>
<td>Electrographic seizures Patients without abnormal movements</td>
<td>3</td>
<td>50%</td>
</tr>
<tr>
<td>Total 14 100</td>
<td>9 64.3%</td>
<td></td>
</tr>
</tbody>
</table>
correlate might be identified by close observation, while
patients with exclusively electrographic-only seizures cannot be
identified without EEG monitoring. To validate this, we analyzed
the dataset for the patients whose follow-up bedside EEG ≥ 30
minute was available after 24-48 hours of IV AEDs. Data was
available on 14 patients, of these 9 (64.3%) patients showed the
significant electrographic ± clinical response. In comparison in
a study of 200 children, ES terminated after administration of
the first IV AED in 74% of children while ESE terminated after
administration of the first IV AED in only 21% of children [23].
We observed the maximum response in children with subtle
convulsions 75% as compared with children with no convulsions
50%. These data demonstrated that 42.5% of the children
with systemic cancer who present with acute unexplained
cencephalopathy have evidence of electrographic seizures, and
of these, about 64% have electroclinical seizures.

This observational study has limitations. First, this was a
single disease cohort which limits generalizability for different
etiologies causing encephalopathy in children. Second, this
was a snap-shot EEG study, whereas continuous or video-
EEG monitoring is superior to snap-shot EEG of ≥ 30 minute.
Thirdly, different centers may have different treatment practices
regarding the speed of seizure identification, overall management
approach, and specific AED choices. Clinical descriptions may
have underestimated the frequency of convulsive activity, and
outcome data were incomplete. Treatment delays have been
associated with lower response rates in children with convulsive
status epilepticus [30]. In spite of these limitations, our study
highlights the significance of potential utility of emergent bedside
EEG in resource-poor settings, for detection of electrographic
seizures, which may be missed by clinical observations alone.

CONCLUSION

Nonconvulsive seizures are common among critically ill
children with acute encephalopathy of diverse causes, including
systemic cancer: would go unnoticed even with careful clinical
observation, and therefore require emergent EEG for their
identification. The research looking at the reliability EEG
monitoring devices in diagnosing NCS is required for the better
management of children with acute encephalopathy. Additionally,
it is not known whether management of electrographic seizures
leads to improved outcomes or not. Further prospective studies
are needed to establish whether electrographic seizures are an
epiphenomenon and simply reflect brain injury or whether they
cause neuronal injury and worsen outcomes.

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Terminology and Categorization for the Description of Continuous


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