Heliyon 10 (2024) e35973

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Intervention time and adverse events in a canadian epilepsy monitoring unit: An updated audit

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ARTICLE INFO

Keywords:
Epilepsy
Monitoring unit
Safety
Intervention time
Adverse events

ABSTRACT

Background: Optimizing patient safety in the epilepsy monitoring unit (EMU) has become a topic of increasing interest. We performed an audit of our center's new single-floor EMU, assessing intervention rate (IR), intervention time (IT), and adverse events (AEs).

Methods: A prospective study was conducted on all clinical seizures of patients admitted over a one-year period at our Canadian academic tertiary care center's new single-floor EMU. This single-floor EMU was supervised by EEG technologists during daytime (similar to the old set-up) and beneficiary attendants during nighttime/weekends (versus live video feed to the central nursing station on the neurology ward previously). Among 153 admissions, 79 were analyzed, and a total of 537 seizures were reviewed to assess IR, IT, and AEs. Univariate comparisons were performed with our double-floor EMU, which we reported in a previous publication.

Results: In our new single-floor EMU, the IR was 61.1 % and overall median IT was 29.0s (19.0s–45.9s). The AE rate was 4.8 %. Compared to previously reported numbers for our old double-floor EMU (IR = 27.8 %; IT = 21.0s; AE = 1.2 %), the IR was significantly higher (($p < 0.001$) but unexpectedly, the median IT was higher ($p < 0.001$) as well as the AE rate ($p < 0.001$).

Conclusion: This prospective evaluation revealed a small but non-negligible rate of complications in our EMU, higher than our prior retrospective audit. Heightened levels of supervision in our new single-floor EMU led to higher IR. This may have led to artificially longer ITs.

1. Introduction

Epilepsy affects approximately 50 million individuals globally, positioning it among the most prevalent neurological disorders worldwide [1]. While many individuals with epilepsy can benefit from a timely, precise diagnosis, there are instances where the diagnosis and management of epilepsy are more complex [2]. In these instances, epilepsy monitoring units (EMUs) have become essential, offering an environment conducive to closely monitoring seizures. These units are equipped with long-term video--electroencephalography (VEEG), the gold-standard diagnostic tool for epilepsy which combines video recording with synchronized real-time EEG monitoring [3,4]. Patients may be admitted to EMUs for different reasons: categorization of seizure types, seizure quantification, medication adjustment, and localization of epileptic foci in presurgical evaluations [4]. Nonetheless, admission to these

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https://doi.org/10.1016/j.heliyon.2024.e35973
Received 3 August 2024; Accepted 7 August 2024
Available online 10 August 2024

Table 1
Characteristics of the old double-floor EMU and the new single-floor EMU.

Aspects	Double-floor EMU	Single-floor EMU
Location	Canadian academic tertiary care center. Comprised of two subunits: EDU and the NWU	Canadian academic tertiary care center on the neurology ward
Rooms	Three private rooms	Four private rooms
Seizure induction strategies	Intermittent photic stimulation, ASM tapering/withdrawal, video games, and sleep deprivation	Same as double-floor EMU
Supervision	Two EPM technologists from 8:00 a.m. to 3:30 p.m.; single EEG technologist from 3:30 p.m. to 8:00 p.m. in EDU. Nursing staff *via* video surveillance at main desk in NWU	Two EEG technologists during weekdays from 8:00 a.m. to 10:00 p.m., and beneficiary attendants during weekends and nighttime
Distance to monitoring station	EDU: 5 m from patients' rooms NWU: 15 m from patients' rooms	Three to 5 m from the patients' rooms
Nurses ratio	One nurse for three EMU patients and two-to-four non-EMU patients.	One nurse for a maximum of four patients
Patient communication	Through bell, push-button system, or verbal/nonverbal communication	Same as double-floor EMU
Data collection	Retrospective (from January 1, 2014, to December 31, 2014)	Prospective (from August 2021 to September 2022)

EDU = epilepsy department subunit; EEG = electroencephalographic; EMU = epilepsy monitoring unit; NWU = neurology ward subunit.

units may entail risks, especially since deliberate measures are routinely employed to induce seizures. Strategies such as the withdrawal of antiseizure medications (ASMs), hyperventilation, photic stimulation, and sleep deprivation may heighten the probability of capturing seizures but can also lead to adverse events (AEs) in patients [5–7].

Optimizing patient safety and the effectiveness of practices in the EMU has become a topic of interest over the years [8]. Over the years, substantial efforts have been devoted to enhancing in safety in the epilepsy monitoring unit (EMU). In 2021, the International League Against Epilepsy (ILAE) and the International Federation of Clinical Neurophysiology (IFCN) published a consensus statement reporting on recommended EMU practices; this marked a significant milestone in standardizing safety practices in these units. A recent study conducted on EMUs across 260 centers in the United States highlights variability in quality and safety practices among different centers [9]. Other research has proposed quality indicators to monitor, evaluate, and enhance safety in EMUs [10]. Despite these efforts, there remain inconsistencies in the safety practices observed in various facilities [5,9,11,12]. Our group published in 2021 a retrospective evaluation of the intervention rate (IR), intervention time (IT), and adverse events (AEs) at our prior double-floor EMU set-up [13]. In the latter set-up, patients spent the day in a three-bed video-EEG unit in the neurophysiological department (watched over by EEG technologists) and nights and weekends on the neurology ward in rooms equipped with video-EEG (with the video fed to a monitor at the central nursing station). In doing so, we highlighted the importance of adequate supervision by trained staff members in ensuring patient safety and favoured a single-floor EMU model versus a double-floor EMU model. From the time this study was conducted, our EMU has been relocated to a newer center, changing from a double-floor to a single-floor unit. While daytime supervision of patients was still ensured by EEG technologists in this new set-up, surveillance during nighttime or weekends was now provided by beneficiary attendants rather than solely relying on a live video feed to the central nursing station. We also hosted educational sessions with our staff with the aim of sensitizing them to recommendations derived from our previous study. The present study is a prospective audit of our newly established EMU, with a primary objective of assessing its IR, IT, and AEs and comparing these measures with those from our old EMU.

Table 2
Patients' characteristics according to EMUs.

Patients' characteristics	Single-floor EMU	Double-floor EMU
Females, n (%)	41 (51.3)	31 (53.5)
Age, median (IQR), years	34.0 (25.0–49.0)	32.5 (23.3–41.5)
Duration of stay, median (IQR), days	10.0 (7.0–12.0)	8.0 (4.3–12.0)
Reason for admission		
Presurgical evaluation, n (%)	50 (63.3)	34 (59.0)
Characterization, n (%)	21 (26.6)	11 (18.8)
Quantification/medication adjustment, n (%)	8 (10.1)	10 (17.2)
Postsurgical evaluation, n (%)	0 (–)	3 (5.0)
Seizure type		
Patients presenting FAS, n (%)	45 (57.0)	16 (28.0)
Patients presenting FIAS, n (%)	41 (51.9)	21 (36.0)
Patients presenting OBMS, n (%)	1 (1.3)	16 (28.0)
Patients presenting BTCS, n (%)	21 (26.6)	19 (33.0)
Patients presenting BNMS, n (%)	2 (2.5)	1 (2.0)
Patients in whom PNES was suspected or confirmed, n (%)	11 (13.9)	9 (15.5)

BNMS = bilateral non-motor seizures (absence seizures); BTCS = bilateral tonic-clonic seizures; FIAS = focal impaired awareness seizure; FAS = focal aware seizure; EMU = epilepsy monitoring unit; IQR = interquartile range; OBMS = other bilateral motor seizures; PNES = psychogenic non-epileptic seizures.

Table 3
Seizure occurrence for different seizure types according to EMUs.

Seizure type	Single-floor EMU	Double-floor EMU	*p*-value
FAS, n (%)	354 (65.9)	245 (19.0)	<0.001
FIAS, n (%)	145 (27.0)	417 (32.3)	0.030
OBMS, n (%)	1(0.2)	562 (43.4)	<0.001
BTCS, n (%)	35 (6.5)	44 (3.4)	0.005
BNMS, n (%)	2 (0.4)	25 (1.9)	0.010
Total, n (%)	537 (100.0)	1293 (100.0)	

BNMS = bilateral non-motor seizures (absence seizures); BTCS = bilateral tonic-clonic seizures; FIAS = focal impaired awareness seizure; FAS = focal aware seizure; EMU = epilepsy monitoring unit; OBMS = other bilateral motor seizures. P-values were calculated using Fisher's exact tests.

2. Methods

2.1. Patients

A prospective study was conducted on all clinical seizures of patients admitted to our single-floor EMU over a one-year period, from August 2021 to September 2022. During this timeframe, our EMU was closed for six weeks (from December 23rd, 2021, to February 7th, 2022) due to the COVID-19 pandemic. Comparatively, our previous study was retrospective, encompassing all clinical seizures of patients admitted over a one-year period, from January 1st, 2014, to December 31st, 2014 [13]. In Table 1, we summarize the characteristics of the different EMUs. To ensure a meaningful comparison with the previous study, we maintained the same inclusion and exclusion criteria. As such, the following text was directly sourced from our previous study: *"Purely electrical seizures were excluded. Purely clinical events with no electrical correlation on EEG, such as psychogenic non-epileptic seizures (PNES) and certain auras, were excluded. Clinical seizures with deep foci (e.g., frontal and insular) generating no clear electrical correlation on EEG were however included. The decision to include seizures with deep foci, including those in the frontal and insular regions, was based on the patients' history. Some patients were already known retrospectively to have deep foci in these regions or were found to have deep foci during their hospitalization using tests other than scalp EEG. Auras were included only if they generated characteristic electrical findings on EEG. Patients who did not present any clinical seizures during their EMU stay were excluded since they required no intervention. Seizures occurring whilst patients underwent tests outside the EMU (e.g. radiology department) could not be analyzed* [13]. All patients provided informed consent to the use of their data for research, this audit did not require ethical approval.

2.2. Work routines and EMU setup

Work routines and EMU setup for the older double-floor EMU were described in depth in our prior study [13]. Table 1 outlines the characteristics of the different EMUs. Our old double-floor EMU was comprised of two subunits: the third-floor epilepsy department subunit (EDU) and the fifth floor neurology ward subunit (NWU). Patients stayed in one of the three-bed in the EDU during weekdays and the rest of the time, the patients would be in the NWU in one of three beds equipped with video-EEG (during weeknights from 8:00 p.m. to 8:00 a.m. and during weekends) [13].

Our new single-floor EMU was situated within a Canadian academic tertiary care center on the neurology ward. Our unit was comprised of four private rooms. These rooms received continuous supervision from two EEG technologists. These technologists operated from a dedicated station equipped with video-EEG, conveniently positioned in front of the patients' rooms. The physical distance between the patients' rooms and the monitoring station was approximately three to 5 m. On weekdays, EEG technologists provided supervision from 8:00 a.m. to 10:00 p.m. Outside of these hours, the responsibility for patient care and monitoring transitioned to beneficiary attendants. Since beneficiary attendants lacked EEG interpretation skills, real-time EEG interpretation was not available during weekends and nighttime hours. Instead, the EEG tracings were retrospectively reviewed by the EEG technologists the subsequent morning [13]. In contrast to the double-floor setup, nurses were dedicated to the EMU patients. One nurse could oversee a maximum of four patients. In our previous setup, one nurse would oversee five to seven patients, including non-EMU patients.

Table 4
Intervention occurrence for different seizure types according to EMUs.

Seizure type	Single-floor EMU	Double-floor EMU	*p*-value
FAS interventions, n (IR %)	204 (57.6)	143 (58.4)	0.867
FIAS interventions, n (IR %)	92 (63.4)	149 (35.7)	<0.001
OBMS interventions, n (IR %)	1 (100.0)	34 (6.0)	0.062
BTCS interventions, n (IR %)	29 (82.9)	33 (75.0)	0.426
BNMS interventions, n (IR %)	2(100.0)	1(4.0)	0.009
Total interventions, n (IR %)	328 (61.1)	360 (27.8)	<0.001

BNMS = bilateral non-motor seizures (absence seizures); BTCS = bilateral tonic-clonic seizures; EMU = epilepsy monitoring unit; FIAS = focal impaired awareness seizure; FAS = focal aware seizure; IR = intervention rate; OBMS = other bilateral motor seizures. P-values were calculated using Fisher's exact tests.

Table 5
Intervention times according to EMUs.

Intervention times	Single-floor EMU	Double-floor EMU	*p*-value
Median IT (IQR), s	29.0(19.0–45.8)	21.0 (11.0–40.8)	$<$0.001
Median IT BTCS (IQR), s	29.0(20.0–60.0)	42.0(20.8–90.0)	0.177
Median IT FIAS (IQR), s	32.0(20.8–51.5)	22.5(11.5–50.0)	0.048
Median IT other seizures (IQR), s	28.0(18.0–44.0)	16.0(9.0–27.0)	$<$0.001
Median IT with warning (IQR), s	28.5 (18.0–43.3)	22.0(11.0–38.0)	0.328
Median IT without warning (IQR), s	31.0(20.0–46.0)	17.0(11.0–33.5)	$<$0.001
Median IT daytime (IQR), s	27.0 (17.0–37.0)	18.0(11.0–33.0)	$<$0.001
Median IT nighttime (IQR), s	44.5 (24.5–64.8)	24.0 (12.0–42.8)	0.223
Median IT weekends (IQR), s	38.0 (25.5–64.0)	20.5(8.8–42.8)	$<$0.001

BTCS = bilateral tonic-clonic seizures; EMU = epilepsy monitoring unit; FIAS = focal impaired awareness seizure; IT = intervention time. P-values were calculated using Mann-Whitney U tests.

Consistent with the methodology used in the previous study, various strategies were employed to induce seizures including intermittent photic stimulation, ASM tapering/withdrawal, video games, and sleep deprivation. Patients could communicate with the staff through various means: using a bell, a push-button system, or through verbal/nonverbal communication. Patients could circulate in their rooms unless mobility issues or a major risk of fall indicated otherwise. Patients remained connected to the monitoring equipment while using the washroom connected to their rooms [13].

2.3. Operational definitions

We maintained the same operational definitions as our prior study, with the only exception being the definition of AEs [13]. AEs were defined as undesirable medical complications that manifest during a patient's stay in the EMU. In our prior research, the

Table 6
Adverse event characterization according to seizure type in the single-floor EMU.

ID	AE	Seizure type
29	Fall	FIAS
64	Fall	BNMS
70	Fall minor injury	BTCS
44	Fall from bed head and shoulder injury	FAS
18	Postictal psychosis (severe agitation white code)	BTCS
26	Postictal aggressive behavior	BTCS
41	Psychotic episode (hallucination and screaming)	FIAS
31	SUDEP	BTCS
3	Seizure cluster	FIAS
3	Seizure cluster	FIAS
3	Seizure cluster	FIAS
26	Seizure cluster	FAS
26	Seizure cluster	FAS
23	Seizure cluster	FAS
23	Seizure cluster	FAS
33	Seizure cluster	FAS
40	Seizure cluster	BTCS
40	Seizure cluster	BTCS
41	Seizure cluster	FIAS
55	Seizure cluster	FAS
57	Seizure cluster	FAS
58	Seizure cluster	FAS
61	Seizure cluster	FIAS
67	Seizure cluster	BTCS
67	Seizure cluster	BTCS
72	Seizure cluster	FAS
59	Ictal bradycardia	FIAS
59	Ictal bradycardia	FIAS
72	Ictal bradycardia	FIAS
72	Ictal bradycardia	FAS
72	Atrioventricular blocks	FAS
72	Atrioventricular blocks	FAS
26	Asystole	FAS

AE = adverse event; BTCS = bilateral tonic-clonic seizures; BNMS = bilateral non-motor seizures (absence seizures); EMU = epilepsy monitoring unit; FIAS = focal impaired awareness seizure; FAS = focal aware seizure; ID = identification; SUDEP = sudden unexpected death in epilepsy.

definition of AEs was based on the consensus statement outlined by Sauro et al. regarding quality indicators. In their work, the authors created a non-exhaustive list of AEs that should be documented in EMU safety studies [10]. In the current study, AEs that did not figure in the list from Sauro et al., such as cardiac arrhythmias, were included but analyzed separately. Otherwise, the following text was directly sourced from our previous work: *"A seizure was defined as an uncontrolled electrical disturbance in the brain that may generate various physical and cognitive manifestations. An intervention was defined as staff purposefully interacting with a patient during a seizure or during possible post-ictal disorders. IT was defined as the time separating electrical onset of a seizure, as determined via visual inspection of EEG recordings, and the moment an intervention took place. This moment corresponded to when a staff member entered a patient's room to interact with the patient or when a staff member purposefully communicated with a patient to ensure their wellbeing without entering their room. For the latter case, staff members could communicate with patients using an intercom system or directly outside their door. For cases in which a staff member would first communicate with a patient to ensure their wellbeing and then enter their room to provide assistance, the moment of intervention corresponded to when the staff member entered the room. A subset of seizures occurred whilst a staff member was already by the patient's bedside at seizure onset, either by coincidence or because the patient was experiencing repetitive seizures and enhanced supervision was warranted. In these cases, interventions were considered to have occurred, but no IT nor warning issuance could be attributed to them by definition. Warning signals corresponded to visual cues generated at the main desk by a patient using their push-button, audio cues generated at the main desk when a patient would ring their portable bell, vocal notifications from patients or witnesses, and physical interception of a staff member by a witness. Seizure clusters were defined as seizures occurring in repetition at an unexpectedly high frequency for the patient (at least three times the expected frequency) or without full recuperation between each seizure. Seizures were classified as focal seizures with preserved awareness (FSPA), focal seizures with impaired awareness (FSIA), bilateral tonic-clonic seizures (BTCS, either bilateral at onset or secondarily bilateral), other bilateral motor seizures (OBMS), and bilateral non-motor seizures (BNMS, absence seizures). OBMS included, for instance, tonic seizures, clonic seizures, atonic seizures, and gelastic seizures.* [13]."

In the current study, we have updated the terminology. We have replaced FSIA with FIAS (focal impaired awareness seizures) and FSPA has been revised to FAS (focal aware seizures). Bilateral tonic-clonic seizures (BTCS) were defined as either bilateral at onset or focal to bilateral tonic-clonic seizures.

2.4. Data collection

Data collection for the old double-floor EMU was done retrospectively and is described in depth in our prior work [13]. In the new single-floor EMU, data were collected prospectively by an EEG technologist (JF). Data were systematically recorded using a structured Excel form. Recorded patient data included the following: age, sex, hospitalization duration, reason for admission, type of seizure presented by the patient, presence or absence of staff suspicion of PNES, and presence or absence of confirmed PNES (according to the ILAE classification system). Recorded seizure data included seizure type, seizure occurrence, time of seizure onset, presence or absence of a warning signal, type of warning, presence or absence of seizure clusters, intervention occurrence, type of intervention, IT, presence or absence of a staff member by the patients' bedside at seizure onset, AE occurrence, and a specific description for each AE.

2.5. Data analysis

All statistical analyses were performed using R version 4.3.0 [14]. Results are presented using medians (interquartile ranges) for continuous variables and count (proportions) for binary/categorical variables. To evaluate our new EMU, we performed univariate statistical tests comparing IR, IT, and AE rates between both EMUs. In addition, the IR for each seizure type was compared between EMUs. The ITs for BTCS, FIAS, or other seizures, for when there was a warning or not, for when the intervention took place during the day or the night, and for when it was a weekday or the weekend were also compared between EMUs. The ITs for BTCS versus other seizure types were compared in the single-floor EMU. When comparing AE rates between EMUs, we did not consider arrhythmias, since these were not reported in our previous study. Fisher's exact tests were employed for binary variables, and non-parametric Mann-Whitney U tests were used for continuous variables (since these exhibited a non-normal distribution). Significance level was set at 0.05.

3. Results

3.1. Patients and monitoring data

Out of the 153 admissions to our new single-floor EMU, 49 patients had no seizures or presented only electrical seizures, and 25 patients presented only PNES; thus, 79 patients were included in the analysis. In comparison, among 124 admissions to our previous double-floor EMU, 58 were included in the final analysis. In Table 2, we summarize the demographic and general characteristics of patients in the different EMUs. Table 3 outlines seizure occurrence according to seizure type in the different EMUs.

3.2. Intervention rate and intervention time

In total, 328 interventions occurred in the single-floor EMU and 360 interventions in the double-floor EMU. The IR was 61.1 % in the single-floor EMU and 27.8 % in the double-floor EMU ($p < 0.001$), as shown in Table 4. A total of 290 ITs and 214 ITs were recorded in the single- and double-floor EMUs, respectively. When a staff member was present at the patient's bedside at seizure onset, no IT could be recorded; bedside staff presence rate was 10.8 % in the double-floor EMU and 6.0 % in the single-floor EMU. Table 5 details the ITs recorded in the two EMUs. Overall median IT was 29.0s (19.0s–45.8s) in the single-floor EMU and 21.0s (11.0s–40.8s) in the double-floor EMU ($p < 0.001$).

3.3. Adverse events

A total of 26 AEs were reported in the single-floor EMU and 15 AEs in the double-floor EMU. In the single-floor EMU, AE rate was 4.8 % when cardiac arrhythmias were excluded and 6.2 % when arrhythmias were included. In the double-floor EMU, AE rate was 1.2 %, which was significantly lower than in the single-floor EMU ($p < 0.001$). Further details regarding AEs that occurred within the single-floor EMU are provided in Table 6.

4. Discussion

There was a noteworthy improvement in the IR between the single-floor EMU and the double-floor EMU. This higher IR was explained by FIAS and BNMS, which were the only seizure types that showed a significantly higher IR. A higher IR was expected in the single-floor EMU as supervision levels were heightened. In effect, the presence of EEG technologists was more pronounced in the single-floor EMU (8:00 a.m. to 10:00 p.m.) than in the double-floor EMU (8:00 a.m. to 8:00 p.m.). The expertise of EEG technologists in interpreting real-time EEG data enabled them to detect seizures that might have gone unnoticed by beneficiary attendants. In our prior study, we observed that a substantial proportion of seizures did not benefit from interventions, particularly less clinically impressive seizures. Another study had noted that 11.4 % of their seizures went unnoticed by nursing staff, with a majority of these seizures being FIAS [15]. Our study highlights the role of EEG technologists in detecting more clinically subtle seizures. Also, the IR we report is now much more similar to the IR reported by other authors, which often surpasses 60 % [15,16]. On a related note, there were significantly more OBMS in the double-floor unit (43.4 %) than in the single-floor unit (0.2 %). This discrepancy could largely be explained by one outlier patient who presented 404 OBMS in the double-floor EMU.

ITs in the new single-floor EMU were significantly longer compared to the old double-floor EMU. At first glance, these findings might imply a favorable safety profile for the older double-floor EMU. However, there are several reasons for which the difference in ITs may be biased. Many factors outside of the actual EMU practices may have affected ITs. Variations in patient demographics and in the distribution of seizure types, the temporal context of the studies (pre-COVID versus post-COVID), and even hospital locations may have confounded our analysis of IT. The transition from shared rooms to individual rooms, the increase in the number of monitoring beds (four monitoring beds in the single-floor EMU versus three in the double-floor EMU), and the implementation of heightened hygiene measures before entering the patients' rooms during the pandemic in the new single-floor EMU may also have led to longer ITs. The replacement of sliding glass doors with half-glass doors in the new single-floor EMU may have resulted in longer ITs. We could not have reasonably controlled for all these confounding factors with the way we collected our data. In addition, the higher IR in the single-floor EMU might have artificially rendered interventions slower, since staff members probably intervened more often in less urgent cases, which would not have triggered an intervention in the double-floor EMU. Despite being longer than in the old, double-floor EMU, the overall median IT in the single-floor EMU remains congruent with the existing body of literature. Instances of previously reported ITs in the literature include 142.3s, 23.5s, 31.0s, and 26.0s [17–19]. Our median IT of 29s grossly aligns with this range of ITs. Nevertheless, from a practical standpoint, a longer IT is still a longer IT, and care should be taken to improve this IT in our new EMU.

A few analyses we performed using IT data merit special attention, notably the IT for BTCS and during nightshifts. BTCS were analyzed apart from other seizure types due to their safety profile. BTCS may carry a higher risk of severe injuries when compared to other seizure types; prompt intervention is particularly important [20–22]. For BTCS, the median IT on the single-floor EMU was not significantly different than on the double-floor EMU. Our BTCS IT of 29 s falls within a similar range of ITs as those reported in the literature [18,23]. On a related note, in the previous study, there was a noticeable difference in ITs between BTCS and other seizure types, BTCS being associated to slower interventions. This discrepancy was attributed to the supplementary time needed to prepare interventions for BTCS compared to other seizure types, due to the potential severity and associated risks. Interestingly, in the current study, this distinction is no longer observed; IT for BTCS now mirrors that for other seizure types. This improvement in IT underscores a positive advancement in our overall management of BTCS. As for ITs during the nightshift, we can reconfirm that interventions were significantly slower during the night, despite continuous supervision by a beneficiary attendant compared to a live video feed to the central nursing station. This has been shown by another study, which demonstrated that IT was significantly longer during night shifts (49.0s) when compared to day shifts (22.0s) [24]. This highlights how EEG technologists are best suited for patient surveillance considering they have better knowledge of seizure semiology, epilepsy, and EEG compared to beneficiary attendants or even nurses. As most centers are probably unable to ensure technologist surveillance 24/7, alternatives may need to be explored. Whether automated seizure recognition systems can "make up" for the lack of technologists during the night remains a salient question. There is evidence that automated recognition systems such as Encevis and BESA Epilepsy may detect seizures faster than staff in 65 % of cases with a good sensitivity and low false positive rate [16]. Incorporating such systems could represent a promising tool to enhance patient security throughout their stays in the EMU.

The AE rate was found to be significantly higher in the single-floor EMU than in the double-floor EMU. This was the case even when arrhythmias, which were not reported in the previous study, were analyzed separately [10]. These findings do not necessarily entail that our single-floor EMU was more dangerous than our double-floor EMU. The disparity in AE rates could be due to the prospective nature of the current study, as we may have been able to detect AEs with greater precision. In the single-floor EMU, we observed that seizure clusters were the most frequently reported AE, accounting for 69.2 % of AEs. Similar findings have been reported another study, wherein most AEs were attributed to seizure clusters (58.7 %) [25]. Care should evidently still be taken to lower our AE rate in the future.

Two AE types we recorded in this study merit special attention: cardiac arrhythmias and SUDEP. Cardiac arrhythmias are not on the list of recommended AEs to report in the EMU, but we chose to report them as AEs regardless [10]. Arrhythmias are commonly observed during seizures [26]. Arrhythmias were the second most common AE in our single-floor EMU after seizure clusters. In a recent study conducted in America, cardiac arrests were observed in 0.1 % of admissions, leading to one reported death [9] This finding may weigh in favor of continuous ECG monitoring in the EMU. However, even with continuous ECG monitoring, many staff members may not be trained to adequately detect arrhythmias. Automatic cardiac rhythm abnormality detection systems may prove useful in these circumstances. Perhaps if such a system was used in our EMU, we could have avoided our SUDEP case, which occurred in the interval of time a beneficiary attendant left a patient's bedside during the night to go the bathroom. The patient suffered from a BTCS and was later found unresponsive in his room. Emergency protocols were initiated, but the patient ultimately passed away. SUDEP is relatively rare in the EMU, with an incidence of 5.1 per 1000 patient-years [27]. However, the implications of a SUDEP occurring at the EMU are dire, meriting substantial EMU practice revisions. This case led our group to conduct a survey of EMU safety practices across Canada, which showed that three Canadian EMUs have had cases of SUDEP to date [28].

Our study featured several limitations. Although we aimed to provide descriptive safety data from our single-floor EMU, we also sought to compare these data with those of a previous study investigating our old double-floor EMU. Since the methodology (*e.g.*, prospective vs retrospective) and patient demographics of these studies differed, any comparisons made between the two EMUs must be cautiously interpreted. As previously discussed, in these circumstances, a longer IT and higher AE rate do not necessarily imply a more dangerous EMU. The occurrence of a case of SUDEP during the study period may have inadvertently influenced the staff's vigilance and consequently impacted their responsiveness to seizures. The temporary closure of our new single-floor EMU for six weeks during the study adds another layer of complexity to the interpretation of our findings. How these factors affected IT and AE rate ultimately remains hypothetical. The generalizability of our results might be limited due to the exclusion criteria, such as PNES. Also, our study was conducted seven years after the prior audit, implying notable changes, particularly concerning staffing and system. As various COVID pandemic protocols were still ongoing during the study period, our findings may not be easily generalizable to hospitals operating in a post-pandemic era.

5. Conclusion

In our updated audit, IR was improved, whereas IT was longer and AE rate was higher. We have defended in this article that these findings do not necessarily entail that our new EMU was less safe and may rather be due to numerous biasing factors. In fact, it may be precisely because interventions were more frequent, and staff were more careful that IT and AE rate appeared higher. To substantiate this hypothesis and confirm the causes of the variation between the two EMUs would require more detailed analyses. Nonetheless, we can reassert with our findings that the type of surveillance holds considerable importance for EMU safety. In the current study as in our previous study, we have shown that nighttime ITs were longer than daytime ITs, highlighting the necessity for continuous surveillance. The AE rates observed in both the single- and double-floor EMUs, and particularly the occurrence of arrhythmias and the SUDEP case in the single-floor EMU, emphasize the need for cardiac monitoring. Finally, to address potential areas for improvement in our single-floor EMU, we recommend enhancing the level of supervision as a priority. This can include increasing the availability of EEG technologists, ensuring 24/7 live supervision, and implementing advanced seizure detection systems. The findings of this study may provide benefits to other centers interested in enhancing the safety within their EMUs.

Disclosures

AH has nothing to disclose. JL is supported by the Fonds de recherche du Québec – Santé. DKN reports unrestricted educational grants from UCB, Eisai, Liva Nova, and Paladin Labs; research grants for a UCB-investigator-initiated study as well as from government entities (Canadian Institutes of Health Research, Fonds de Recherche Québec – Santé, Natural Sciences and Engineering Research Council), academic institutions (Centre Hospitalier de l'Université de Montréal), and foundations (TD Bank and Savoy Foundation). DKN's salary is supported by Canada Research Chair Program.

Funding

JL is supported by the Fonds de recherche du Québec – Santé. DKN is supported by Canada Research Chair Program.

Data statement

All relevant data for this study are available upon request addressed to the corresponding author.

CRediT authorship contribution statement

Amal Hagouch: Formal analysis, Writing – original draft, Writing – review & editing. **Jimmy Li:** Formal analysis, Supervision, Writing – review & editing. **Julie Forand:** Data curation. **Dang Khoa Nguyen:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Authors would like to thank all healthcare professionals involved in the care of the CHUM epilepsy monitoring unit, from EEG technologists to beneficiary attendants and nurses.

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