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Case Report

Train of four stimulation artifact mimicking a seizure during computerized automated ICU EEG monitoring☆,☆☆,★

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ABSTRACT

A 54-year-old man was admitted to the intensive care unit with an aneurysmal subarachnoid hemorrhage and subsequently underwent mechanical ventilation and received neuromuscular blocking drugs to control refractory elevated intracranial pressure. During quantitative EEG monitoring, an automated alert was triggered by the train of four peripheral nerve stimulation artifacts. Real-time feedback was made possible due to remote monitoring. This case illustrates how computerized, automated artificial intelligence algorithms can be used beyond typical seizure detection in the intensive care unit for remote monitoring to benefit patient care.

1. Introduction

Since the introduction of digital electroencephalogram (EEG) and computer-based microprocessing, methods of EEG recording have evolved from paper records to dedicated EEG digital servers that can be accessed remotely, similar to telemedicine in the intensive care unit (ICU) [1,2]. Further, raw EEG data can now be processed via computerized software by Fast Fourier transform techniques into condensed quantitative EEG (QEEG) displays with numerous mathematical derivatives for seizure detection and even surrogate cerebral blood flow inferences. The technology for EEG data analysis has advanced rapidly in the last decade, using an array of sophisticated software and artificial intelligence algorithms for seizure detection based on the EEG waveform morphology (i.e., spike detection) combined with spike frequency (>2–3 Hz), or on a combination of amplitude, morphology, and frequency (seizure detection and artifact rejection).

EEG with QEEG trend analysis panels are increasingly used in the ICU setting to remotely monitor for nonconvulsive seizures and status epilepticus, as well as to provide potential prognostic information after brain injury (e.g., cardiac arrest) and monitor vasospasm in subarachnoid hemorrhage [3]. Remote monitoring technological advancements can now send encrypted electronic alerts via email to a subspecialist's mobile phone (iPhone or Android platforms) for near-real-time ICU monitoring. Despite these advances in computer technology, they are not immune to numerous ICU artifacts. This is because they sample various frequencies, amplitudes, and sharp/spike morphology, which can generate erroneous “artifacts” in attempts to detect seizure. The ICU also has many types of electrical interference and 60 Hz artifact from mechanical ventilators and enteral feeding machines, which contaminate the EEG recording [4]. Therefore, ICU EEG monitoring still requires human review of the raw EEG, despite automated technology alerts, to distinguish clinically significant seizures from other ICU-generated artifacts.

We report a patient undergoing EEG monitoring with automated seizure detection who had peripheral nerve stimulation (PNS) artifact detected by QEEG algorithms that lead to an immediate bedside ICU management change. This change involved a location change of the stimulator applied over the facial nerve region to the limb in addition to reduction in neuromuscular blockade (NMB) dosing. This case provides insight into future remote ICU monitoring techniques in the digital age.

Abbreviations: EEG, electroencephalogram; ICP, intracranial pressure; ICU, intensive care unit; NMB, neuromuscular blockade; PNS, peripheral nerve stimulation; QEEG, quantitative EEG; TOF, train of four.

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2. Case report

A 54-year-old man suffered an aneurysmal subarachnoid hemorrhage (Fisher 4, Hunt Hess 5) with coma from a ruptured anterior communicating artery aneurysm. He subsequently underwent continuous 21-channel ICU EEG monitoring with artificial seizure detection and quantitative fast-Fourier transform algorithms (QEEG) to make inferences about cerebral blood flow (alpha-delta ratio) (Persyst 11 software, Persyst Development Corporation, San Diego, CA) [3]. The ICU EEG data is monitored on a bedside EEG machine, which is hardwired via an Ethernet data jack to the hospital's EEG network and secure servers. The ICU EEG machine also has different programmable software thresholds that can send an automated email alert via an encrypted and de-identified message through an internal network. Essentially, the message is a screen shot of the raw EEG pattern (10 second epoch) as well as the QEEG image. This technology is also compliant with the Health Insurance Portability and Accountability Act because there are no patient identifiers. An on-call neurologist receives the message and has to decode which EEG machine sent the alert based on an internal key-code system.

The patient developed refractory elevated intracranial pressure (ICP) despite external ventricular drainage of cerebrospinal fluid, sedation with propofol, and mild induced hypothermia (34 °C) and required NMB with cis-atracurium infusion. Later, the patient underwent a right hemicraniectomy for refractory ICP. PNS was used to assess the degree of NMB with a goal of two out of four train of four (TOF) responses at the ulnar nerve wrist location. On ICU day 5, PNS at the ulnar and tibial nerves was absent, and the facial nerve near the craniectomy site was subsequently stimulated. Stimulation at the facial nerve did not result in observable or palpable facial muscle twitch. Electrical stimulation using a PNS, model 100A (Anesthesia Associates, Inc., San Marcos, CA, USA) was used to deliver the TOF. This monitor has both 2/second and tetanic stimulation (100/50 Hz) options. An automated alert was sent to the iPhone of the reading faculty on call (WDF). The regular EEG clip and QEEG color display immediately and then formally reviewed the EEG and QEEG on a dedicated EEG workstation using Microsoft Remote Desktop™ (Microsoft Corp., Redmond, WA). This pattern was interpreted as a potential seizure alert by the machine due to the frequency, amplitude and morphology shown. Upon review, it was identified as an artifact generated by tetanic stimulation followed by a 2/second stimulation for 2.5 s (Figs. 1 and 2) and not a true electrographic seizure. While facial nerve stimulation is an accepted form of TOF monitoring in the critical care unit, we called the nurse and asked to move this away from the facial nerve and craniectomy site due to a theoretical risk of intracranial electrical transduction causing seizures. No seizures were observed on the EEG in this case. Therefore, this "artifact" led to repositioning of the PNS. Since there was no visible or palpable twitch with PNS, we decreased the dose of

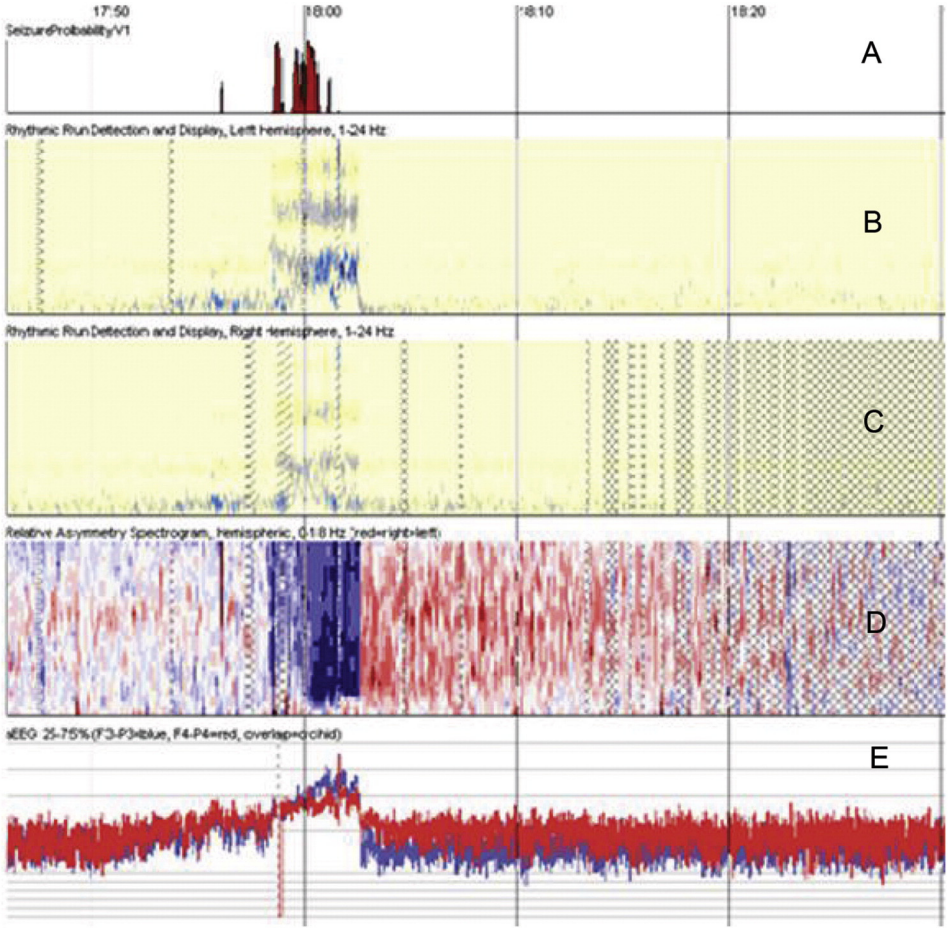

Fig. 1. Displays a QEEG color display showing the seizure detection and high rhythmic run detection on the left hemisphere over approximately 30 minutes of EEG recording. The upper line is the "seizure probability" panel (A), which detects high-frequency events suspicious for seizures. The event triggered the EEG screenshot (see Fig. 2), which was then sent with this accompanying image. The "R2D2"-rhythmic run detection (label B/C) and display showed a similar seizure detection in the QEEG panel. The left hemisphere R2D2 (B) shows a higher frequency and density of activity compared to the right (C) and coincides with the electrical stimulation artifact. A rhythmic asymmetry spectrogram (D) shows dominance of one side vs. the other side in terms of frequency (left = blue, right = red). The final panel (E) at the bottom is an amplitude EEG (aEEG), which trends the averaged amplitude (in microvolts) of each hemisphere (red = right, blue left) which also increases simultaneously. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)