

SHORT RESEARCH ARTICLE

Objective outcome assessment in epilepsy surgery using ultralong-term subcutaneous EEG: A case report

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Abstract

Accurate seizure documentation is essential in guiding treatment decisions in epilepsy but still heavily relies on highly subjective and sometimes unreliable patient reports. We report a case of medically refractory mesial temporal lobe epilepsy where subcutaneous EEG revealed persistence of seizures following add-on antiseizure medication despite the patient's self-report of seizure freedom. Thus, ultralong-term EEG subcutaneous monitoring provided valuable information on medical refractoriness and supported the decision to proceed to surgical intervention. Subcutaneous EEG monitoring was continued after resective surgery and has shown no further seizures to this date. To our knowledge, this is the first reported case utilizing subcutaneous EEG for objective seizure documentation both pre- and post-surgery.

Plain Language Summary: Making the right treatment decisions depends on knowing the seizure frequency of a person with epilepsy, but patients' reports are often inaccurate. In our case, we describe a patient in which seizures were only detected because of a small electrode implanted under the skin to record brain activity (subcutaneous EEG). Based on this information, the patient received brain surgery, and the device was left in place after surgery, showing no further seizures. To our knowledge, this is the first reported case where this type of EEG device was used to track seizures both before and after epilepsy surgery.

KEYWORDS

epilepsy surgery, epilepsy treatment, objective seizure documentation, subcutaneous EEG, ultralong-term EEG monitoring

1 | INTRODUCTION

In the treatment of epileptic seizures, assessment of any intervention, including antiseizure medications and epilepsy surgery, relies heavily on patient-reported

seizure documentation. Yet, patient reports are highly unreliable and show only limited correlation with objective seizure documentation obtained both during video-EEG monitoring^{1,2} or long-term invasive EEG recordings.^{3,4}

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Clinical utility of video-EEG monitoring is restricted by the artificial inpatient setting, where antiseizure medications are frequently reduced or stopped and the recording duration is limited to several days.⁵ Therefore, it provides largely inadequate information on long-term seizure frequency in everyday life. Additionally, the resources of video-EEG are limited and can only be offered to a restricted number of patients.^{6,7} Long-term invasive EEG recordings are applied only in patients undergoing responsive brain stimulation, representing a highly selected and small patient group.^{8,9}

For these reasons, biomarkers for objective seizure documentation are urgently needed in clinical epileptology. While available wearable devices measuring motor manifestations (e.g., accelerometry, surface EMG) or autonomic changes (e.g., heart rate, electrodermal activity) can detect generalized onset tonic-clonic and focal to bilateral tonic-clonic seizures with high sensitivity and low false alarm rates, they still fail to reliably detect focal seizures.¹⁰⁻¹²

Therefore, long-term EEG recordings remain the most reliable method to detect both focal and generalized seizures without major motor manifestations. Several types of long-term non-invasive EEG recordings including in- and behind-the-ear electrodes, headband electrodes, and Epilog sensors have been studied.¹³⁻¹⁵ Yet, these approaches still exhibit low sensitivity and high false alarm rates and cannot be used for ultralong-term recordings of several weeks to months.¹⁶⁻¹⁹

Subcutaneous EEG (sqEEG) using the UNEEG system (UNEED SubQ™) offers a minimally invasive approach to document seizure frequencies, primarily of seizures with involvement of the temporal lobe, for several months up to 3 years. It produces EEG recordings with high quality²⁰⁻²³ and has been shown to have high sensitivity.²⁴ While sqEEG has been used to study treatment response following changes in antiseizure medications,^{20,25} so far, no reports on objective outcome documentation following epilepsy surgery using sqEEG recordings have been published to the best of our knowledge.

Here, we report a patient with right-sided mesial temporal lobe epilepsy, who was completely amnesic to her seizures and underwent long-term sqEEG recordings before and after epilepsy surgery, thus facilitating objective epilepsy surgery outcome documentation.

2 | CASE PRESENTATION

2.1 | Patient information

A 53-year-old right-handed woman was referred to our epilepsy center because of medically refractory seizures. The patient was delivered at term following a normal

Key points

- SqEEG offers objective, long-term seizure monitoring beyond patient self-report.
- In our case it revealed ongoing seizures despite the patient reporting seizure freedom supporting the decision for resective surgery.
- This case shows the potential of SqEEG to guide treatment decisions in the perioperative setting.

pregnancy and birth. At the age of 8 months, she suffered from a complex febrile seizure with a prolonged, left-sided postictal hemiparesis. The patient was put on primidone and experienced no further seizures. At age 19 years, primidone was discontinued, and the patient remained seizure-free till the age of 52 years when she started to experience unprovoked seizures.

Seizures were only noticed by the patient's relatives and colleagues at work, while she herself was completely unaware of her seizures. They reported that the patient would become unresponsive, stare, and exhibit oral automatisms consisting of chewing and swallowing movements. Seizures lasted approximately 30–60 seconds and were followed by postictal confusion lasting for several minutes. At least one seizure per month was noticed by others, with the exact frequency being unknown. Notably, the patient did not experience any auras leading up to the seizures, and there were no bilateral tonic-clonic seizures reported.

2.2 | Clinical findings

During 5 days of video-EEG monitoring, interictal EEG showed intermittent right temporal slowing and unilateral right temporal spikes/sharp waves with a maximum at electrodes F8, FT10, and T8 (94% of all spikes/sharp waves occurred over the right temporal lobe according to semi-automatic interictal EEG analysis). Four habitual seizures could be recorded, with impaired consciousness, staring, and oral automatisms. On ictal EEG, a right temporal seizure pattern was observed (Figure 1). Seizure patterns on scalp-EEG were highly stereotypic and similar to each other. High-resolution MRI imaging showed right-sided hippocampal atrophy and sclerosis. FDG-PET-MRI revealed hypometabolism in the right temporomedial and temporobasal regions, predominantly in the anterior hippocampus.

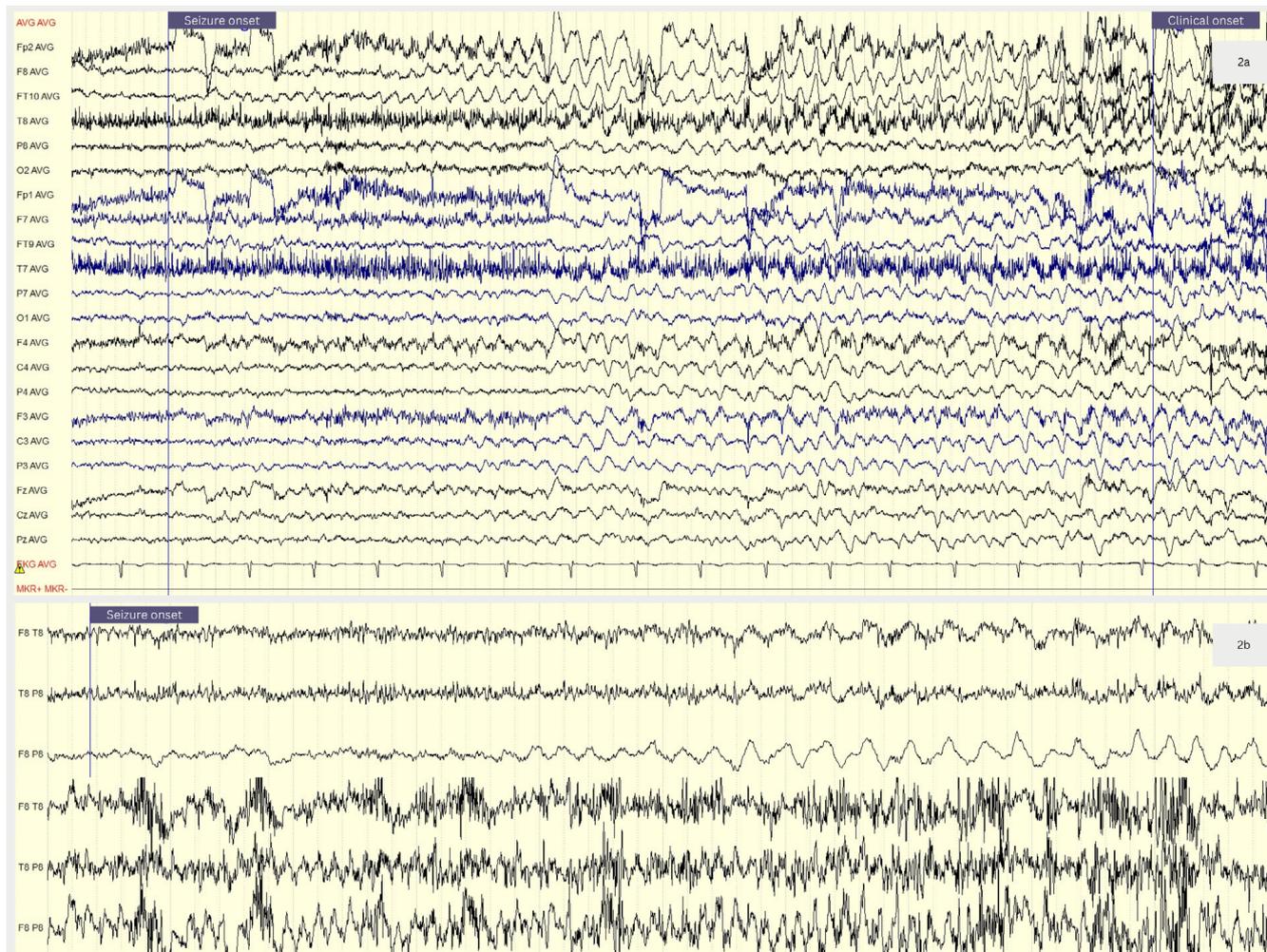


FIGURE 1 Scalp EEG seizure pattern over right temporal lobe registered on average montage (2a) and in a F8-T8, T8-P8, and F8-P8 montage to allow better comparison with sqEEG (2b).

2.3 | Therapeutic intervention and implantation of sqEEG device

Antiseizure medication treatment consisted initially of levetiracetam, and after video-EEG monitoring, cenobamate was added. At a follow-up visit 4 months after starting with add-on treatment with cenobamate, the patient reported that no further seizures had occurred. However, a more detailed history revealed that following a recent breakup with her partner and a change in her work environment, the patient now spent most of her time alone, making accurate seizure documentation impossible.

Therefore, the patient underwent implantation of a UNEEG SubQ™ system consisting of three electrodes (one reference, two active electrodes) covering the right temporal region. Electrographic seizure activity were identified using the UNEEG Episight software via automatic annotations, followed by visual review by two experienced neurophysiologists (CD and JK). During the following 3 months (109 days, average of 15.1 h of

usage per day) of outpatient sqEEG recordings, five distinct EEG seizure patterns originating from the right temporal region were documented (Figure 2). As in the scalp-EEG, seizure patterns on sqEEG were stereotypic and very similar to each other. Moreover, seizure patterns on sqEEG closely resembled the seizure patterns on scalp-EEG recorded during video-EEG monitoring (compare Figures 1 and 2). The patient was unaware of all recorded seizures (Figure 3).

2.4 | Post-surgical outcome assessment using sqEEG

Due to the now documented medically refractory seizures, the patient was offered resective epilepsy surgery. Following informed consent, an anteromesial temporal resection (amTLR) was performed 3.5 months after implantation of the sqEEG device. After consensus discussion during an interdisciplinary epilepsy board, it

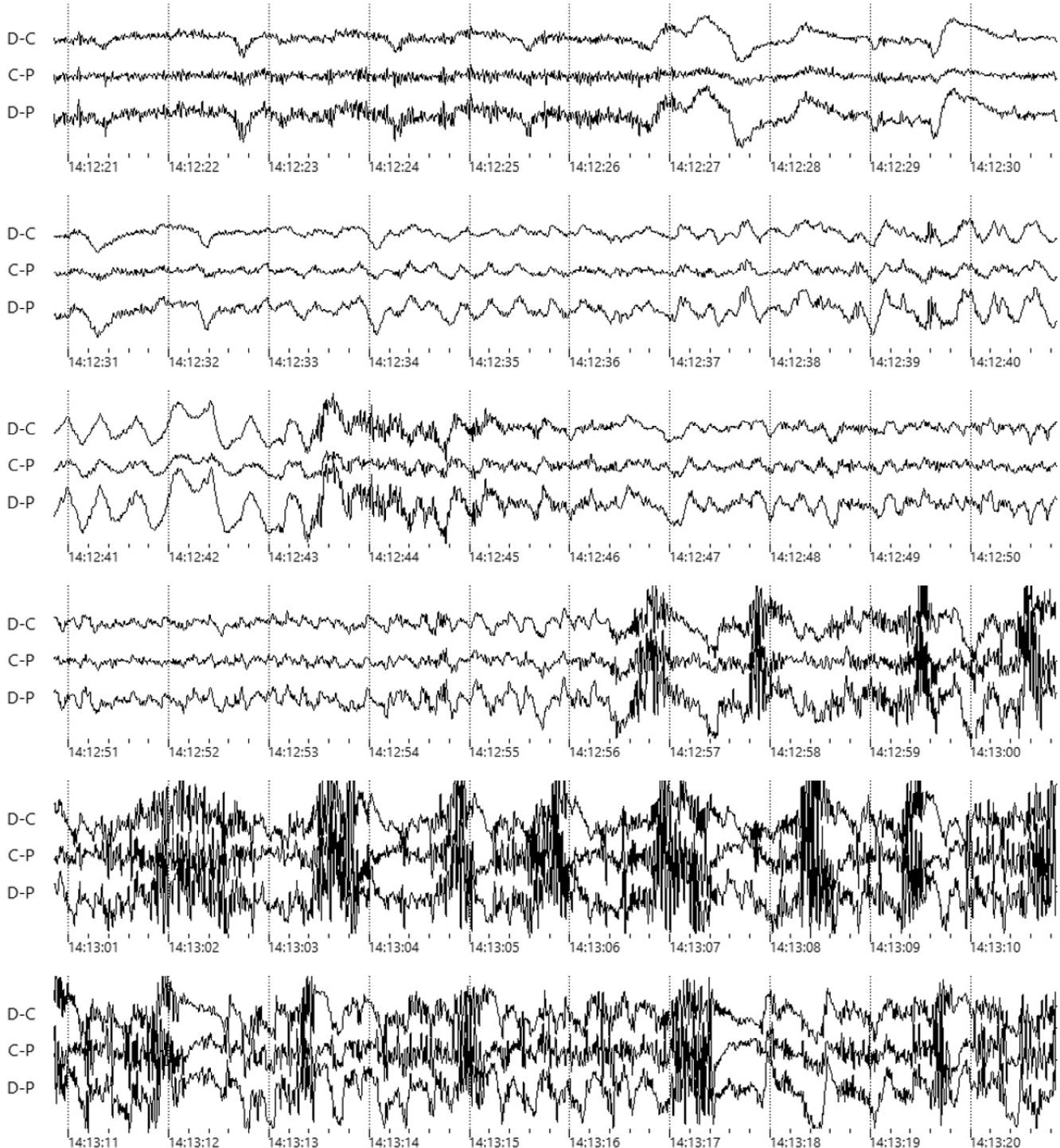


FIGURE 2 Seizure pattern over the right temporal lobe registered on subcutaneous EEG.

was decided to leave the sqEEG device implanted after epilepsy surgery to objectively document surgical seizure outcome. During surgery, the device was safely identified. The electrodes were placed in the same region as preoperatively to maximize comparability. In the 3.5 months (101 days of recording, average of 15 h usage per day) following amTLR, no seizures could be recorded on sqEEG documenting a seizure-free outcome (Figure 3).

3 | DISCUSSION

To the best of our knowledge, this is the first reported case in which subcutaneous ultralong-term EEG monitoring was used to objectively document both pre- and postoperative seizure frequency in resective epilepsy surgery. In this case, this was especially useful since the patient was unaware of her seizures and had resumed living alone.

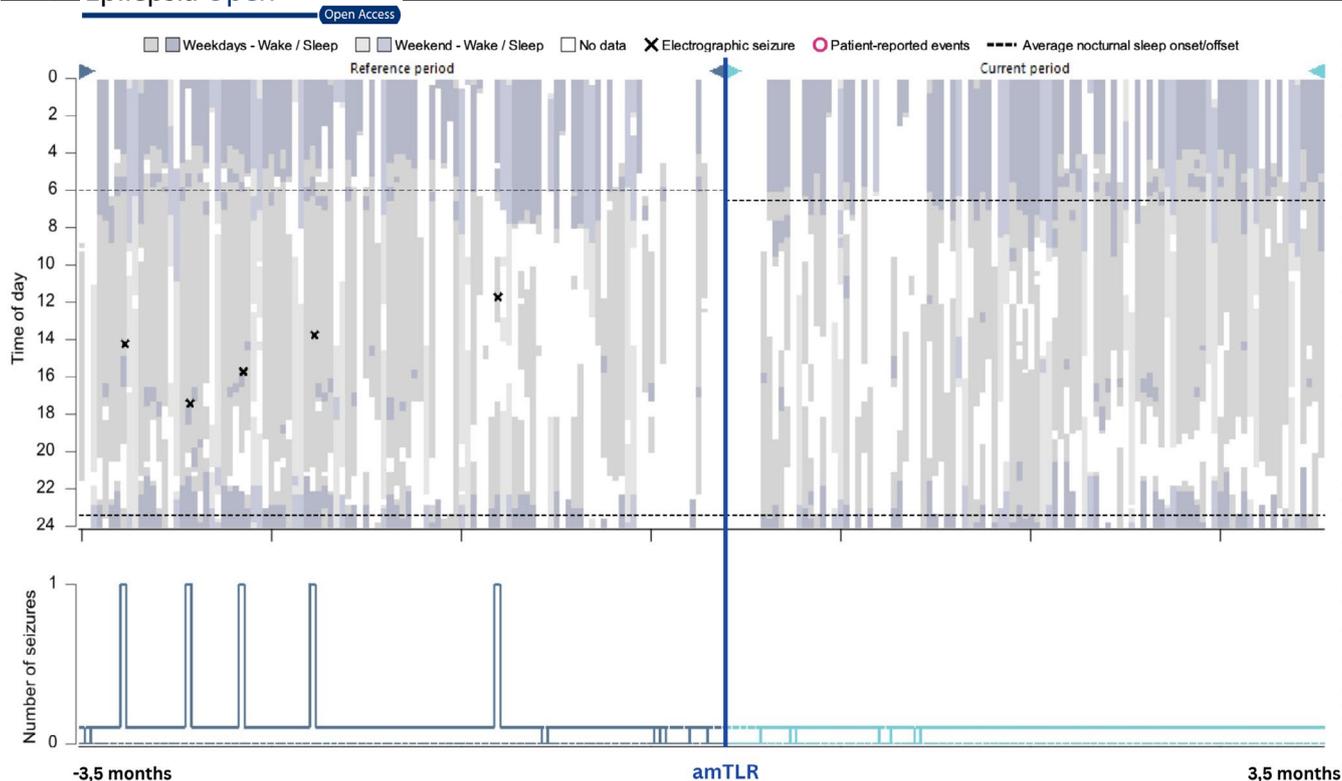


FIGURE 3 Electrographic seizures 3.5 months before (reference period) and 3.5 months after (current period) anteromesial temporal resection (amTLR). Wake and sleep periods are marked in gray and purple. All seizures occurred during wakefulness. There were no patient reported events.

Subsequently, the patient mistakenly reported seizure freedom after initiation of a new antiseizure medication, although five seizure patterns were objectively documented on sqEEG during the 3-month period. The high-quality EEG provided by the UNEEG device allowed us to identify those seizures with clear-cut rhythmic right temporal EEG seizure patterns. This further supported the indication for epilepsy surgery and enabled objective evaluation of seizure frequency pre- and postoperatively. The lack of accurately self-identified events during the monitoring period also underscores the already well-known misreporting of seizures by patients. Following epilepsy surgery, sqEEG monitoring was continued, and no further EEG seizure patterns have been recorded to date in our patient.

There is great demand for reliable seizure documentation following therapeutic interventions, including epilepsy surgery. Prior research indicates the value of sqEEG to inform pharmacological and surgical treatment decisions.^{2,18} For example, Weisdorf et al.¹⁸ discussed the usefulness of sqEEG in evaluating the response to anti-seizure medication adjustments and identifying breakthrough seizures. In their case, objective seizure counts suggested a positive effect of add-on treatment that was not evident from the patient's seizure diary. Consequently, sqEEG has also been used to support the decision to consider non-pharmacological treatment approaches for a patient with drug-resistant epilepsy.² These studies highlight

how sqEEG recordings can complement patient-reported seizure documentation, optimizing treatment pathways, potentially reduce unnecessary interventions, and enable timely referral to non-pharmacological treatment options.

Our case highlights the even broader potential of sqEEG devices to support both presurgical evaluation and postoperative follow-up. However, there are several limitations that have to be mentioned. Given the novelty of the technology, clinical experience and systematic data remain limited, particularly regarding the application of sqEEG in perioperative settings. Although comprehensive scalp EEG data were available in our case, the absence of simultaneous recordings with sqEEG still restricts our ability to directly correlate electrographic patterns between the two modalities. Even though preoperative seizure patterns recorded on both modalities were consistent with a single seizure-onset zone and were very similar in morphology, we cannot entirely exclude seizures that may have escaped detection on sqEEG due to signal quality or spatial limitations. Specifically, we cannot exclude that seizure patterns changed after temporal lobe resection and we missed potential postoperative seizures due to altered seizure pattern morphology. In the presented case, we were able to rule out subclinical seizures with high confidence because there was no indication of such events in the inpatient monitoring or the patient's history. However, sqEEG monitoring is limited by the lack of clinical correlation in an outpatient setting.

Moreover, the limited number of channels on sqEEG requires substantial electrophysiological expertise to identify and visually confirm seizure patterns in this modality.

Finally, several questions remain regarding the optimal integration of sqEEG into routine clinical practice, including the appropriate monitoring duration before and after surgery. Further research in this area is needed to establish evidence-based approaches for the use of sqEEG in the context of epilepsy surgery.

AUTHOR CONTRIBUTIONS

T.L.: Conceptualization, data curation, visualization, validation, writing—original draft, writing—review and editing. J.P.K.: Data curation, validation, writing—review and editing. C.D.: Data curation, validation, writing—review and editing. C.L.: Writing—review and editing. S.P.: Writing—review and editing. M.T.: Data curation, writing—review and editing. K.R.: Data curation, writing—review and editing. C.B.: Conceptualization, data curation, writing—original draft, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest relevant to this manuscript. We confirm that we have read the journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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