FULL LENGTH ORIGINAL RESEARCH

Post-ictal accelerometer silence as a marker of post-ictal immobility

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Objective: Movement-based wearable sensors are used for detection of convulsive seizures. The identification of the absence of motion following a seizure, known as post-ictal immobility (PI), may represent a potential additional application of wearables. PI has been associated with potentially life-threatening complications and with sudden unexpected death in epilepsy (SUDEP). We aimed to assess whether wearable accelerometers (ACCs) could be used as a digital marker of PI.

Method: Devices with embedded ACCs were worn by patients admitted to an epilepsy monitoring unit. Participants presenting with convulsive seizures were included in the study. PI presence and duration were assessed by experts reviewing video recordings. An algorithm for the automatic detection of post-ictal ACC silence and its duration was developed and the linear pairwise relationship between the automatically detected duration of post-ictal ACC silence and the duration of the expert-labeled PI was analyzed.

Results: Twenty-two convulsive seizures were recorded from 18 study participants. Twenty were followed by PI and two by agitation. The automated estimation of post-ictal ACC silence identified all the 20 expert-labeled PI. The regression showed that the duration of the post-ictal ACC silence was correlated with the duration of PI (Pearson $r = .92; P < .001$), with the age of study participants (Pearson $r = .78; P < .001$), and with the duration of post-ictal generalized electroencephalography suppression (PGES; Pearson $r = .4; P = .033$).

Significance: We highlight a novel application of wearables as a way to record post-ictal manifestations associated with an increased risk of SUDEP. The occurrence of a fatal seizure is unpredictable and the continuous, non-invasive, long-term identification of risk factors associated with each individual seizure may assume a great clinical importance.

KEYWORDS
convulsive seizures, m-health, risk factors, technology, wearables

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Movement is a common semiological component of seizures, and an increasing number of wearable seizure detectors incorporate three-dimensional accelerometers (ACCs) to measure acceleration along three movement axes, allowing motion-based activity to be captured. Movement analysis based on ACC signals has demonstrated an overall good performance for detection of convulsive seizures (generalized tonic-clonic seizures and focal to bilateral tonic-clonic seizures) in epilepsy monitoring units (EMUs) and, to a lesser extent, in real-life settings. A potential application of movement sensors may also be the identification of the diametrically opposite feature: the absence of motion. Immediately following a seizure, this phenomenon represents an interesting clinical manifestation, known as post-ictal immobility (PI). PI has been recognized by clinicians for more than a century, although the pathophysiological mechanism has remained largely unclear. Frequently observed after convulsive seizures, PI has been associated with potentially life-threatening complications and with sudden unexpected death in epilepsy (SUDEP). In addition, PI has often been observed in association with post-ictal general electroencephalography suppression (PGES), a pattern recorded in SUDEP cases. The identification of PI through wearables has not yet been adequately explored. Because most convulsive seizures do not lead to SUDEP and the occurrence of a fatal seizure is unpredictable, the automatic, continuous, long-term identification of risk factors for SUDEP associated with each individual seizure assumes great clinical importance. In a population at high risk of SUDEP, we aimed to assess whether the ACC could be used as a reliable digital marker of PI and of its duration after convulsive seizures. In addition, we investigated the association of post-ictal ACC silence with PGES and with other physiological and clinical variables associated with SUDEP.

2 | METHODS

2.1 | Study participants

The current study was developed in the context of RADAR-epilepsy, a multicenter study designed to assess the clinical utility of multiparametric remote measurement technologies (RMTs) in a clinical population with epilepsy, in the hospital and real-world environment. The study population consisted of consecutive patients with epilepsy (PWEs) who were admitted, for diagnostic reasons or presurgical evaluation, to the EMU at either the neurophysiology department at King’s College Hospital, London, or the Epilepsy Centre at the University Hospital Freiburg. Participants presenting with convulsive seizures (generalized tonic-clonic seizure or a focal to bilateral tonic-clonic seizure) were included.

Key Points
- The wearable accelerometer (ACC) is an accurate digital marker of post-ictal immobility and of its duration after convulsive seizures
- Post-ictal ACC silence is correlated with other known risk factors of sudden unexpected death in epilepsy (SUDEP), including post-ictal general electroencephalography (EEG) suppression
- New technologies may offer the possibility to automatically gather information on the presence of dangerous post-ictal states
recorded. Convulsive seizures were classified according to Alexandre et al.\textsuperscript{23} in three categories: with bilateral and symmetric tonic arm extension (type 1); without tonic posturing (type 2); and with asymmetric bilateral tonic arm extension, unilateral tonic arm extension combined with contralateral tonic arm flexion, bilateral tonic arm flexion, or unilateral tonic arm extension (type 3). Early intervention by a nurse (during the seizure or within the first 5 seconds after seizure termination), early administration of oxygen (with oxygen mask during the seizure or within the first 5 seconds after seizure termination), and prone position at seizure end were also annotated.

2.3.3 | Seizure, PGES, and PI annotation

Two neurologists with EEG expertise (EB, NE) reviewed the video-EEG recording independently and manually labeled the start (first EEG or clinical manifestation) and the end of the seizures (EEG end) and the presence/absence, onset/offset, and duration of PI and PGES. A random sample of video-EEG was reviewed by both the annotators to guarantee consistency of the labeling procedures. PGES was defined as the post-ictal generalized absence of electroencephalographic activity <10μV in amplitude, allowing for muscle, movement, breathing, and electrode artifacts.\textsuperscript{18} Seizures presenting with a PGES duration ≥20 seconds were considered at higher SUDEP risk.\textsuperscript{18} PI was defined as the post-ictal absence of movements (allowing for respiratory movements) on the video recording. The duration of PI was defined as the time from the onset of PI to the onset of the first post-ictal active nonrespiratory movement.\textsuperscript{12}

2.3.4 | Wearable devices data

Raw data from the wrist-worn wearable device were streamed via Bluetooth to an android app during the recordings and collected on a centralized data server.\textsuperscript{22} Raw data from the upper arm device were transferred directly from the device to a laptop via cable at the end of the recording. Both devices and the video-EEG were synchronized with a time server at the beginning of each recording. If there was still time drift left on the signal during a seizure, the offset was manually determined by visual comparison of the expert-labeled video and raw data.

2.4 | Data analysis

2.4.1 | Automatic detection of post-ictal ACC silence

The ACC data immediately around the seizure event were plotted and visually inspected by an expert (SB). The information obtained from the plots was used to create an algorithm for the automatic detection of the post-ictal ACC silence. Given the seizure end time, the post-ictal ACC silence detection algorithm marked the “start” of the post-ictal ACC silence if the moving standard deviation was <0.2 for 5 seconds. The algorithm then marks the “end” of the post-ictal ACC silence if the moving standard deviation was ≥0.2 for at least 5 seconds. Hence, the duration of the post-ictal ACC silence was calculated. The moving standard deviation was calculated over a 5-second window.

2.4.2 | Electrodermal activity

The EDA was plotted around the seizure for visual inspection. To account for the typically slow changes in tonic EDA, an additional hour of data before and after the seizure events was also included in the plots. The analysis of the EDA signal was based on Poh et al.\textsuperscript{24} The signal was filtered and smoothed to reduce motion artifacts and to obtain the tonic component of the raw EDA signal. The EDA baseline was computed over the 60-minute pre-ictal segment. The start of the EDA response was defined as the point after the labeled start of the seizure where the filtered EDA signal first reached a value of baseline + 2σ. The end of the response was defined as the point after the start of the response where the filtered EDA signal first dropped below 80% of the response peak. The EDA duration was estimated as the time between start and end of the EDA response. Furthermore, the response amplitude (EDA amplitude) was defined as the difference between the response peak and the pre-ictal baseline.

2.5 | Statistical analysis

Linear regression was used to analyze the linear pairwise relationship between the automatically detected duration of post-ictal ACC silence and other variables, such as duration of PI, seizure duration, and others. The strength and direction of the linear relationship between the different pairs of variables were quantified using the Pearson correlation coefficient.

Variables with $P < .2$ at univariate analysis were entered in a multivariate model. A two-sided Mann-Whitney-Wilcoxon (MWW) rank-sum test was used to assess the relationship between the duration of the post-ictal ACC silence and binary clinical variables, whereas the Kruskal-Wallis (KW) test was used for categorical variables. To account for multiple comparisons, the resulting $P$-values were adjusted using the Bonferroni method. Each test was performed at a significance level of .05. When seizures were captured with both the devices (Empatica E4 and IMEC armband), we included in the analysis the signals collected from the wrist-worn device.
Figure S3 illustrates the ACC signals captured during the labeled by experts, and an example of post-ictal agitation. detected by the algorithm and its correspondence with PI. Figure 1 illustrates an example of the post-ictal ACC silence in recorded SUDEP cases.14–21 In the same context, the duration of post-ictal ACC silence and seizure duration, duration of the clonic phase, and duration of the tonic phase. The ACC signal was available for 16 of 20 seizures, whereas in 4 seizures the signal was either not recorded or corrupted. A post-ictal ACC response was observed in 13 of 16 seizures (Figure S4). The duration and amplitude of the ACC response were not related to the duration of the post-ictal ACC silence (Table 1) or to the duration of the PGES (duration of EDA \( P = .43 \); amplitude of \( EDA \ P = .67 \)). These results were also confirmed when the analysis was restricted to data recorded with the wrist-worn device only. The relationship between the duration of post-ictal ACC silence and categorical seizure-specific variables is reported in Table 2. The post-ictal ACC silence was longer in seizures followed by PGES (adjusted \( P = .05 \)), in seizures presenting a higher risk of SUDEP (PGES \( \geq 20 \) seconds; adjusted \( P = .037 \)) and in seizures showing an ACC response (adjusted \( P = .038 \)), the latter also showed longer PGES durations (adjusted \( P = .004 \)). There was no association with convulsive seizure type and number of AEDs taken, whereas a borderline significance was found in seizure originating from the temporal lobe (adjusted \( P = .059 \)) and seizures arising from sleep (adjusted \( P = .24 \)).

3 RESULTS

3.1 Participants and seizure characteristics

Twenty-two convulsive seizures were recorded from 18 study participants between September 2017 and October 2019. The mean age of study participants was 37.1 years (SD 12.8). The mean disease duration was 19.8 years (SD 7.4) and the median number of anti-epileptic drugs (AEDs) taken was 2 (range 1-4). The majority of the participants (66.7%) reported \( \geq 3 \) convulsive seizures per year. All were admitted to the EMU for presurgical evaluation of their pharmaco-resistant epilepsy. Eleven patients wore the wrist-worn device, four the arm band, and three both devices. Thirteen seizures were recorded with the wrist-worn device, five with the arm band and four with both.

3.2 PI and ACC silence

PI occurred in 20 of 22 seizures (90.9%), whereas 2 seizures were followed by post-ictal agitation and confusion. PGES occurred following 15 seizures (75.0%) and it was \( \geq 20 \) seconds in 11 (55.0%), which were considered at higher SUDEP risk.

Early nurse intervention was performed in all the seizures recorded and consisted mainly of assisting the patient into the recovery position or repositioning the head. Oxygen was administered early in 10 seizures (45.4%). None of the patients was observed in prone position at seizure offset due to nurse intervention. In the post-ictal period, the automated estimation of post-ictal ACC silence identified all the 20 expert-labeled PI, discarding post-ictal agitation, and performing equally in both the wrist and upper arm-worn devices. Figure 1 illustrates an example of the post-ictal ACC silence detected by the algorithm and its correspondence with PI labeled by experts, and an example of post-ictal agitation. Figure S3 illustrates the ACC signals captured during the same seizure by the two different devices and the similar performance of the algorithm on the two different body sites. Occasionally, the post-ictal ACC silence lasted beyond the PI labeled by experts, as very subtle movements of the hands or neck were used by experts to establish the end of clinical PI and were not captured by the ACC.

The linear regression (Table 1) showed that the duration of the post-ictal ACC silence was correlated with the duration of expert-labeled PI (Pearson \( r = .92 \); \( P < .001 \); Figure 2), with the age of study participants (\( r = .78 \); \( P < .001 \)), and with the duration of PGES (\( r = .4 \); \( P = .033 \)). After inclusion of the duration of PI and age into a multivariate model, the association with the duration of PGES became nonsignificant. No relations were observed between the duration of post-ictal ACC silence and seizure duration, duration of the clonic phase, and duration of the tonic phase. The EDA signal was available for 16 of 20 seizures, whereas in 4 seizures the signal was either not recorded or corrupted. A post-ictal ACC response was observed in 13 of 16 seizures (Figure S4). The duration and amplitude of the EDA response were not related to the duration of the post-ictal ACC silence (Table 1) or to the duration of the PGES (duration of EDA \( P = .43 \); amplitude of \( EDA \ P = .67 \)). These results were also confirmed when the analysis was restricted to data recorded with the wrist-worn device only. The relationship between the duration of post-ictal ACC silence and categorical seizure-specific variables is reported in Table 2. The post-ictal ACC silence was longer in seizures followed by PGES (adjusted \( P = .05 \)), in seizures presenting a higher risk of SUDEP (PGES \( \geq 20 \) seconds; adjusted \( P = .037 \)) and in seizures showing an ACC response (adjusted \( P = .038 \)), the latter also showed longer PGES durations (adjusted \( P = .004 \)). There was no association with convulsive seizure type and number of AEDs taken, whereas a borderline significance was found in seizure originating from the temporal lobe (adjusted \( P = .059 \)) and seizures arising from sleep (adjusted \( P = .24 \)).

4 DISCUSSION

ACC sensors built onto consumer electronics such as smartwatches have been widely used for the identification of convulsive seizures at rest,25 additionally demonstrating good correlation with seizure motion duration.26 The present study demonstrated a novel application of wearable ACCs. In a population at high risk of SUDEP, represented by patients with refractory epilepsy, potentially candidates for epilepsy surgery and with a large majority reporting more than three or more convulsive seizures per year, wearable ACC was an accurate digital marker of PI and of its duration after convulsive seizures. Both these functions certainly assume a great clinical value, providing information to identify and characterize potentially life-threatening seizures. In fact, although immobility following a convulsive seizure is a frequent post-ictal event, the occurrence of PI has been regarded as a precipitating factor for post-ictal cardiorespiratory dysfunction in recorded SUDEP cases.14–21 In the same context, the duration of PI has been considered as a factor contributing to the lethality of some convulsive seizures.

There is an urgent need for appropriate markers to delineate individual risk of SUDEP and to track the evolution of
The possibility of automatically gathering information on the presence of dangerous post-ictal states, such as prolonged immobility, is a step forward in this direction.

Alongside its role as a marker of PI, the post-ictal ACC silence was also correlated with other known SUDEP risk factors. The duration of the post-ictal ACC silence was correlated linearly with the age of study participants. This finding is of interest as age is known to affect the occurrence of seizure-related autonomic responses and may play a role in autonomic dysregulation-supported phenomena, such as SUDEP. Notably, the average risk of SUDEP is age dependent, ranging from 0.2/1000 PY in children to 1.2/1000 PY in adults. However, to the best of our knowledge, the correlation of PI with age has not been explored and additional investigations and larger samples, including children with epilepsy, are required to confirm this observation.

A long post-ictal ACC silence indicated the presence of seizures followed by PGES $\geq 20$ seconds ($P = .037$), carrying a higher risk of SUDEP, and a linear correlation was highlighted between the duration of post-ictal ACC silence and the duration of PGES ($P = .033$). However, the moderate coefficient found ($r = .4$) suggests that a nonlinear relation may exist between these variables, and different models should be investigated in larger data sets. Moreover, the linear correlation disappeared in the multivariate model, probably due to the presence of a correlation between PGES and PI durations. These findings are consistent with, and replicate, previous studies analyzing the relationship between PI and PGES, where seizures associated with PGES had a longer
duration of immobility as compared to those not followed by PGES.9,10

We found no association with seizure duration and duration of the clonic or tonic phase. The lack of association between PI and seizure duration was first reported by Gowers in 188132 and confirmed in later studies.11,12 With some exceptions,13 additional observations demonstrated no correlation with either the duration of the convulsive phase or the tonic phase of the seizure.12

Of interest, prolonged post-ictal ACC silence and PGES were observed in seizures showing an EDA response. However, there was no clear relation between the amplitude of the EDA and the duration of the post-ictal ACC silence or the duration of PGES, nor was higher amplitude of EDA observed in seizures associated with PGES ≥20 seconds, as reported elsewhere.24 The surge of EDA in the peri-ictal period is an index of sympathetic overactivation33 that may be relevant in the pathogenesis of SUDEP.24,34,35 As hypothesized in previous literature,27 our findings reinforce the idea that the combination of multiple biosignals, such as post-ictal ACC silence and EDA, could increase the possibility of identifying seizures and thus PWE, potentially carrying a higher likelihood of seizure-related mortality. The association of PI and state of arousal is unclear and has not been adequately assessed. We found that the duration of post-ictal ACC silence was higher (although did not reach statistical significance) in seizures arising from sleep. Data show that seizures from sleep are associated with higher PGES incidence,9,23 more severe hypoxemia36 and, most importantly, higher incidence of SUDEP, especially when patients are unsupervised and not stimulated. Once more, our finding highlights the importance of an automatic assessment of PI, which may be particularly relevant for nocturnal seizures, which are often unnoticed. Seizures originating from the temporal lobe showed longer duration of post-ictal ACC silence, with a borderline significance. Once again, the limited number of events observed prevents us from clear explanation, and this finding deserves further investigation.

Finally, we would like to point out some limitations of this study. The small sample of patients and seizures may limit the generalizability of findings, which need to be interpreted with caution and replicated in larger cohorts and in real-life settings. Nevertheless, our small cohort is certainly of interest given that it is potentially at higher risk for SUDEP due to its characteristics. PI was defined as the post-ictal absence of movements, allowing for respiratory movements that are not detectable with wearable ACC and cessation of which is relevant for possible SUDEP events. However, the evidence

| Variable              | Univariate analysis | Multivariate analysis |
|-----------------------|---------------------|-----------------------|
|                       | r       | P-value | r       | P-value |
| PI duration           | .92     | <.001   | .000    |         |
| Age                   | .78     | <.001   | .041    |         |
| Seizure duration      | .88     |         |         |         |
| Duration of tonic phase| .42     |         |         |         |
| Duration of clonic phase| .38     |         |         |         |
| PGES duration         | .40     | .033    | .75     |         |
| EDA duration          | .46     |         |         |         |
| EDA amplitude         | .33     |         |         |         |

Note: Abbreviations: ACC, accelerometer; EDA, electrodermal activity; PGES, post-ictal generalized EEG suppression; r, Pearson coefficient.

FIGURE 2 Correlation (Pearson correlation coefficient r = 0.92; P < .001) between the duration of the post-ictal accelerometer (ACC) silence estimated using the algorithm and the duration of the expert-labeled post-ictal immobility (PI). The red line represents the linear regression
on how PI contributes to SUDEP is uncertain and not exhaustive. The cessation of body movements (here defined as PI) and the cessation of respiratory movements (potentially leading to respiratory arrest) may be correlated but are driven by different mechanisms and contribute to SUDEP in different ways. Case studies have demonstrated that seven of the eight SUDEP cases published over the last 20 years died when unsupervised, immobile, and in the prone position, suggesting a potential role of PI in the terminal cascade of events leading to death. The role of PI may be independent from the cessation of respiratory movements. In the post-ictal period, a persistent immobility and inability to change body position alone may exacerbate post-ictal hypoxemia and seizure-related homeostatic alterations, such as pulmonary edema, leading to asphyxia and asystole. Indeed, although the duration of PI has been correlated with the duration of ictal oxygen desaturation, the association of PI with respiratory and cardiac disturbances, including respiratory movements, arrest, apnea, and bradycardia, has not been investigated and may represent a future area of interest to improve our understanding on mechanisms leading to SUDEP. Moreover, it is likely that the absence of body movements represents an “early stage” of total cessation of movements (including respiratory movements), and that the automatic identification of such an “early sign” (alone or, preferably, in association with tools to detect hypoxemia) may be clinically significant.

Seizures were recorded with two different devices. Although this may have influenced the data recorded and in particular the EDA response, which is more easily detected at the wrist as compared to the arm, the ACC biosensors had similar characteristics and the signals obtained during periods of movement and immobility were comparable despite the different position of the device on the upper limb. False detection is a potential major weakness of wearable technology applied to both seizure and seizure-related phenomena detection. The trade-off between detection benefits and potential false detection should always be accounted for when dealing with digital technologies. Scenarios where a device has fallen from the patient during a seizure or where at the end of the seizure the patient is lying on the limb to which

| TABLE 2 Duration of post-ictal ACC silence and categorical seizure-specific variables (N = 20 seizures) |
|---------------------------------------------------------------|
| Seizure focus | N (%) | Post-ictal ACC silence duration in seconds (mean ± SD) | P-value | P-value after correction for multiple comparisons |
| Temporal lobe | 7 (35.0) | 481.0 ± 396.3 | .22 (KW) | .059 |
| Extratemporal lobe | 3 (15.0) | 90.0 ± 91.7 | | |
| Unknown | 10 (50.0) | 167.3 ± 184.8 | | |
| Number of AEDs | | | | |
| <3 | 12 (60.0) | 244.5 ± 270.7 | .93 (MWW) | .72 |
| ≥3 | 8 (40.0) | 297.0 ± 377.1 | | |
| Seizure type | | | | |
| Type 1 | 7 (35.0) | 262.6 ± 246.5 | .79 (KW) | .78 |
| Type 2 | 2 (10.0) | 119.5 ± 13.4 | | |
| Type 3 | 11 (55.0) | 293.9 ± 373.9 | | |
| State of wakefulness | | | | |
| Awake | 9 (45.0) | 174.8 ± 204.4 | .18 (MWW) | .24 |
| Asleep | 11 (55.0) | 399.7 ± 366.8 | | |
| PGES | | | | |
| Present | 15 (75.0) | 336.2 ± 328.2 | .016 (MWW) | .05 |
| Absent | 5 (25.0) | 53.4 ± 39.1 | | |
| PGES ≥20 s | | | | |
| Present | 11 (55.0) | 393.0 ± 153.9 | .088 (MWW) | .037 |
| Absent | 9 (45.0) | 109.7 ± 153.9 | | |
| EDA response | | | | |
| Present | 13 (65.0) | 457.0 ± 388.8 | .036 (MWW) | .038 |
| Absent | 7 (35.0) | 162.4 ± 206.7 | | |

Abbreviations: ACC, accelerometer; AEDs, antiepileptic drugs; EDA, electrodermal activity; KW, Kruskal-Wallis; MWW, Mann-Whitney-Wilcoxon; PGES, post-ictal generalized EEG suppression; SD, standard deviation.

P-values in bold are statistically significant.
the device is attached may occur, although they were not observed in our cohort. Despite being possible, these events are probably infrequent, making the beneficial effects of PI detection greater than the nuisance of potential but rare false detections. ACC false detections may be mitigated by the simultaneous use of video and automated analysis. Video has been used as a sensitive way to quantify movement and could enable remote detection of PI. However, although feasible especially in seizures happening from sleep (which are considered at higher risk of SUDEP), automated video detection may present disadvantages. In a mobile patient, video can be as uninformative as wearable ACC if the patient leaves the predefined space where the camera is placed and, at night and during sleep, when patients are covered by blankets.

The duration of post-ictal ACC silence sometimes lasts beyond the PI labeled by experts. According to our definition of PI, experts considered subtle movements as “PI end.” However, these movements were mainly hand, finger, or neck movements, which are certainly insufficient for an adequate body repositioning after a seizure. It is then likely that the duration of post-ictal ACC silence is a better indicator of the duration of dangerous post-ictal stages during which the patient is still unable to move. Nurse intervention was prompt in many of the events recorded and has likely interfered with the cascade of post-ictal events observed. PI in SUDEP cases has been often observed in combination with a prone position in the bed, a variable that could add an additional layer in the assessment of SUDEP risk. However, none of our patients was prone due to nurse intervention and this prevented us from the possibility of studying the usefulness of the gyroscope in combination with ACC to identify the body position postictally. Conversely, the passive movements produced during nurse intervention had no impact on the detection of PI via ACC, as they consisted mainly of assisting the patient into the recovery position (body rotation) or in repositioning the head, resulting in either nondetected movements or short, rapid accelerations (<5 seconds).

In conclusion, PI is one of the most common seizure-activated phenomena, often associated with negative outcomes, which was demonstrated to be easily monitored via new technologies at different body sites. In combination with other remote measures and paired with an automated identification of convulsive seizures, the detection of the post-ictal ACC silence could be regarded as a risk assessment tool in individual seizures, as a way to monitor disease progression and evolution and, possibly, as a potentially modifiable outcome when assessing the impact of preventive measures, interventions, and surveillance systems.

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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.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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