Hospital Delirium is Associated with Lower Mean Activity Counts: Secondary Analysis of a Large Cohort Study of ICU Patients

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Abstract

Hospital delirium is a dangerous condition characterized by confusion and altered consciousness. Delirium is frequently missed or not recognized by hospital teams. Hypoactive delirium, the most common type of delirium in hospitals, is associated with decreased spontaneous movements. We evaluated the use of wrist accelerometers to detect an association with delirium in hospitalized patients. We found that daily mean activity count was lower in patients with delirium, even controlling for age and mechanical ventilation status. This suggests that accelerometers could be a good biosensor to assist hospital staff with delirium detection and management.

Keywords: delirium, wearable biosensors, intensive care unit, accelerometer

1. Introduction

Delirium is a dangerous type of acute brain dysregulation that occurs in a third of all hospitalized older adults and half of hospitalized older adults with Alzheimer's and related dementias (Carpenter 2021, Rohatgi 2021, and Han 2022). When delirium occurs, it is associated with increased hospital length of stay, higher mortality, and permanently worsened cognition (Fick 2013 and Welch 2019). Despite being a common and deadly condition in hospitals, we are still not good at detecting delirium. Diagnosis of delirium is based on a clinician's assessment of the patient's thinking and activity levels and subtle presentations are easily missed in our busy hospitals. Current clinical scoring tools for delirium detection are very specific but at most 64% sensitive, meaning that they are correct when they identify delirium, but poor at ruling out delirium (Carpenter 2021). This leads to delirium being missed. And the longer delirium goes on unrecognized, the more likely there are to be permanent and potentially deadly effects. Current testing/screening methods for delirium are nursing intensive and so many hospital wards do not do them (Ragheb 2023). Delirium testing in hospitalized patients is mandated in other countries but not in the U.S., so the majority of U.S. hospital wards do not have delirium screening and management protocols. A recent study of geriatric Emergency Departments found that only 22% of these specialized centers have delirium screening protocols (Kennedy, 2022). One reason given for this lack of adoption in hospitals and Emergency Departments is the lack of a simple, easy screening tool that doesn't take nursing time away from other needed activities (Eagles, 2022).

Biosensors have great potential to improve our ability to accurately diagnosis delirium in the hospital setting and take some of the screening burden off nurses. A hallmark characteristic of delirium is psychomotor agitation (called hyperactive delirium) or, conversely, psychomotor slowing (called hypoactive delirium). Davoudi et al (2019) performed a systematic review of biosensors for delirium detection and found 6 studies with a total of 194 participants. These studies varied in their settings and were mostly post-operative patients, whose activity counts may be limited by their recent operations. Biosensors have also been studied in Intensive Care Units (ICU) to assess level of sedation, sleep, and

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functional status (Schwab 2020) but again are limited by smaller sample sizes and different definitions of delirium.

Better understanding the relationship between delirium and activity could help us design biosensors to predict the development or measure the duration of delirium in hospitalized patients. This would be clinically significant because 1) it could remove or reduce the burden of delirium screening from hospital nurses, 2) improve the detection of delirium by providing continuous screening rather than the current episodic nurse screening (Figure 1), and 3) improve research on delirium management interventions.

We wished to understand the association between delirium and daily activity in all-cause hospitalized patients. Since hypoactive delirium (low activity type) is the most common delirium subtype in hospitalized patients, we hypothesized that in aggregate, delirium will be associated with lower activity counts. We also wanted to see if there was a difference in activity counts on days when patients were delirious vs days they were not.

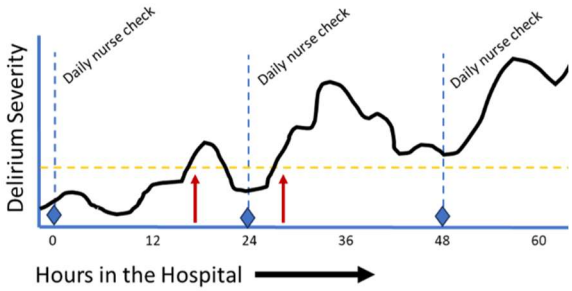

Figure 1: In this example patient, delirium waxes and wanes in severity (black line). Episodic checks can delay the diagnosis or misrepresent delirium severity. Red arrows indicate when additional nurse checks could have identified delirium earlier as symptoms increased above the detection threshold (yellow dotted line).

2. Methods

This is secondary data analysis of a prospective observational cohort of adults (age ≥18 years) admitted to a medical or surgical ICU in two large academic hospitals. We performed a secondary analysis of data from the Measuring Outcomes of Activity in Intensive Care (MOSAIC) study (https://clinicaltrials.gov/ct2/show/NCT03115840). The full trial results are pending. The study's primary goal was evaluating the association between ICU mobility and 3 and 12 month functional and cognitive status in adults in the Intensive Care Unit (ICU). The exposure variable, activity, was measured using multiple accelerometers. The study's primary outcome is to determine the relationship between physical activity in ICU patients and long term functional and cognitive status. We measured delirium using the well-validated Confusion Assessment Method for the ICU (CAM-ICU). Trained research personnel performed the CAM-ICU twice daily in the ICU and daily thereafter until hospital discharge (for up to 28 days) (Ely 2001 and Krewulak 2020). To measure activity, participants wore ActiGraph GT3x-BT accelerometers (ActiGraph, Pensacola FL) on their wrist and ankle. The accelerometer measures accelerations in the x-,y-, and z-directions and reports them as counts over time (Neishabouri 2022). For these analyses we combined activity counts from both accelerometers and calculated the mean daily activity counts.

This was a secondary analysis to address two questions:

1. Do mean daily activity counts differ between participants who did experience delirium and those who never experienced delirium during their hospital stay?

2. Day to day, does daily activity count differ significantly based on delirium status that day?

For question 1, we compared participants with at least one positive delirium assessment to those who never had a positive delirium assessment. We used log transformations of mean daily activity counts to provide an approximately normal distribution. An unadjusted analysis of the relationship between delirium and mean daily activity counts was done with a two-sample t test. To adjust for potential confounders of the association between delirium and activity counts, we used logistic regression, adjusted for the following a priori selected covariates: age at enrollment, sex, and mechanical ventilation at any time during the hospital stay.

For question 2, we used a linear mixed model to analyze the relationship between daily delirium status and daily activity counts. For this analysis, we used values on a given day of the trial (day 1, 2, 3 …. 28) with the exposed group being all participants who tested positive for delirium on that given day, and the control group being all participants who were not positive for delirium on that day (not all participants had data for each day, as some were discharged before 28 days). Variables for model included age at enrollment, sex, and the use of mechanical ventilation for that patient on that trial day.

3. Results

The study cohort consisted of 312 participants. Average age was 59 (±15.8) years and 58.7% (n=183) were male. Median length of stay in the hospital was 8.96 days (IQR 5.0-16.1). Over half (59.3%, n=185) experienced delirium.

For this preliminary analysis, we used the presence or absence of delirium as a dichotomous variable, without adjusting for hyperactive vs hypoactive type. A positive delirium screen at any time during the study hospitalization was considered positive for delirium. Linear regression was performed with an unadjusted association of 29.6% lower mean activity count if delirium was ever present during the hospitalization (Table 1).

Table 1. Associations between delirium with activity counts, reference is patients without delirium during their hospital stay.

	Point Estimate, beta coefficient	95% Confidence Interval		P value
Delirium at any time during hospitalization, unadjusted	-0.35	-0.5	-0.1	0.002
Delirium at any time during hospitalization, adjusted	-0.29	-0.5	-0.1	0.012
Delirium on a given day, adjusted	-0.502	-0.6	-0.4	<0.01

After adjusting for age, sex, and mechanical ventilation, delirium at any time during the hospital stay was associated with a 25% lower mean activity count (beta coefficient -0.29 (log scale), 95% CI: -0.51, -0.07, p = 0.012) (Table 1).

For our second investigation the presence of delirium was dichotomized into present or absent for each day. Mechanical ventilation on each day was also used as a dichotomous variable. Linear regression of mean activity counts found that on any given day, the presence of delirium during that day was associated with a 39.5% lower daily mean activity count ($p<0.01$, Table 1) compared to patients without delirium that day. This analysis was adjusted for age, sex, and mechanical ventilation that day.

4. Discussion

In this large cohort of hospitalized patients, we found delirium was associated with lower activity counts, consistent with our hypothesis. Delirium at any point during hospitalization was associated with a 25% lower mean activity counts, and delirium within a given day was associated with a 39.5% lower activity count that day. These data suggest that activity counts could be a strong marker of the presence of delirium. This data is compelling because this is the largest cohort to date examining the association between activity and delirium.

Our results are more generalizable than prior studies as MOSAIC included data on patients while they were in the ICU as well as other care areas of the hospital, such as step-down units and regular care units. It also includes medical patients. Surgical patients, who made up the majority of prior studies, are likely to have different activity parameters as they are in the hospital for surgical repair of an illness or injury. We did not differentiate between surgical and medical patients in this preliminary analysis, but that may be helpful as a factor when developing a biosensor algorithm for delirium detection.

One difference between our study and others is that we found higher levels of delirium, with an overall prevalence of 59%. Pooled prevalence in prior studies of ICU patients was 29-35% (Krewulak 2018). This higher rate could be due to our long patient follow up (up to 28 hospital days) or heterogeneity in assessment tools used. Longer hospital stays are associated with a higher risk of hospital acquired delirium.

Accelerometry is promising for delirium detection but will likely need to be combined with other clinical factors and potentially other biosensor data. It is likely that biosensors can contribute more information about the arousal and delirium status of a patient if more sensors are added. In at study of post-surgical patients (Osse 2009) noted recovery of sleep/wake activity cycles after delirium with biosensors. We evaluated mean total daily count, but other parameters such as sleep/wake cycle dysregulation are often seen with delirium. As biosensor technology improves, combining accelerometry with other measures of pain (such as heart rate variability) and arousal (sleep/wake level) could be sensitive enough to allow for real time clinical detection of delirium.

Clinically, biosensors offer several advantages as a continuous delirium assessment device in hospitals. If they can be integrated into the other automatic data inputs, such as blood pressure cuffs and oxygen monitors, wearable biosensors would not rely on staff time to perform and document delirium assessments.

They also can provide continuous monitoring rather than twice every 24 hours, which is the typical "once a nurse shift" delirium assessment timing in hospitals. Finally, they could improve accuracy in detection in patients with baseline cognitive deficits, such as Alzheimer's Disease and other Related Dementias or persons with traumatic brain injuries. These patients have an abnormal cognition at baseline which can lead to false-positive responses in the delirium detection questions asked. In fact, patients with a history of severe dementia or neurologic disease were excluded from the initial development and validation trials for the CAM-ICU. The CAM-ICU also functions better in the ICU setting than in general medical wards, suggesting that different tools may be needed to improve our detection of delirium in different hospital settings or within different populations (Chen 2020).

Real time clinical delirium detection would assist not only in the care of patients, but also in the development of delirium prevention and management interventions. Understanding when delirium comes on and when the patient improves (or is improving) would help us develop better delirium management interventions. Current interventions for the prevention and management of delirium include both pharmacological (medications to manage confusion and agitation) and non-pharmacological interventions. Pharmacologic interventions so far have had minimal impact (Kim 2020) and may be harmful especially to older adults. Non-pharmacological interventions such as music therapy, engaging family and caregivers to provide support, and nurse-led multifactorial interventions have had some limited success (Lee 2021). But these interventions are time- and nursing-intensive. They need to be maintained daily and require attention to mobility, sleep hygiene, pain control, and feeding which can be difficult in a busy hospital. The global shortage of nurses means that hospital nurses are already stretched thin, and hiring more staff to provide these interventions is a costly decision for hospitals (Haddad, 2023). Biosensors could help. By tracking mobility and sleep, we could t and target resources towards patients who most need them. In this way, wearable biosensors could help with both delirium detection and targeted management.

One aspect of wearable biosensors that this study did not address is patient comfort and acceptability. Patients in the hospital are already forced to wear multiple sensors, such as cardiac monitors and oxygen monitors. The wrist sensors used in this project are small, compact, wireless, and use a soft silicon band to stay on the wrist. Their similarity to a wristwatch should make them less irritating or frightening to patients. Our team plans to include assessments of patient and caregiver acceptability and preferences in future studies.

In summary, we found that delirium is associated with lower activity counts in hospitalized patients. We predict that wearable biosensors will become an important aspect of delirium detection and management in hospitals in the future.

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