



## Actigraphic monitoring in critically ill patients: Preliminary results toward an “observation-guided sedation”

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Sedation;  
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### Abstract

**Purpose:** The aim of this study is to evaluate continuous wrist actigraphy (measurement of limb movements) in intensive care unit patients as a neurologic status monitoring.

**Materials and methods:** This is a prospective, observational study on motor activity of adult patients using wrist actigraphs. Nurses recorded the number of sleep and agitation hours as well as assessed pain and anxiety level (verbal numeric rating) and the agitation/sedation level (Richmond Agitation-Sedation Scale).

**Results:** Thirteen mechanically ventilated patients were studied during their whole intensive care unit stay (total, 165 patients/d). The number of surveyed movements was gathered for each hour, obtaining an estimation of patient motor status. This measure was different between days and nights (33.3 [20.3-49.0] vs 8.5 [4.4-13.8];  $P < .001$ ), with a correlation with sleeping hours estimated by nurses ( $P = .017$  during the days [D],  $P < .001$  during the nights [N]), agitation hours ( $P = .002$  D,  $P = .017$  N), Richmond Agitation-Sedation Scale value ( $P < .001$  D and N), pain ( $P = .012$  D), and anxiety ( $P < .001$  D) verbal numeric rating. No differences were found using epochs of 15 or 120 seconds. Compliance with patients and nurses was acceptable.

**Conclusions:** Patients' limb movements were significantly related to all studied neurologic status indexes. Continuous actigraphy measuring may become important as a clinical tool both to guide utilization of sedative drugs and to enhance early recognition and management of agitation.

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## 1. Introduction

Critically ill patients require adequate analgesia and sedation to overcome distress as a result of the harsh intensive care unit (ICU) environment [1,2]. In spite of this, acute neurologic dysfunctions can easily occur in ICU [3].

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The causes of agitation are often multifactorial (pain, confusion, delirium, withdrawal, adverse drug effects) and difficult to ascertain, and the effects could be dangerous [4].

Although many different sedation-agitation measurement tools have been proposed for ICU patients [5], they showed to be unreliable in clinical practice: they are mainly intermittent, and only few scales include multiple levels to describe excessive activity and agitated behavior. These subjective scales have been tested for validity and reliability in adult ICU patients [6], but no neurologic status measure has been uniformly accepted as a standard. Agitation is frequently associated with excessive restlessness; the ability to continuously detect increased activity may then be an important step in assessing agitation level [7].

Actigraphy provides a continuous measure of body movements, and it was initially developed to measure sleep-wake cycles [8]. This small electronic device containing an accelerometer can be strapped to the wrist or ankle, continuously sensing and recording minimal movements or activity, summarizing such data in numerical form. Actigraphy is easy to use and has been proved reliable in noncritical populations of patients to track circadian rest-activity cycles and to identify states of wakefulness and sleep [7]. Polysomnographic examinations have shown significant agreement with data from wrist actigraphy for assessing sleep-wake cycles in healthy volunteers [9] but not in ICU patients [10]. Otherwise, wrist actigraphy provided objective indications of changes in depth of anesthesia or sedation during surgery and recovery [11,12]. In ICU, patient limb movements indicate nursing interventions and purposeful or nonpurposeful activity [13].

Actigraphy has rarely been tested as a measure of agitation/sedation in ICU patients in relation with analgesic and sedative therapy [7] or in evaluating sleep time [13]. It could become particularly important as a continuous measurement of activity to enhance early recognition and management of the excessive activity that characterizes agitation; besides, if the depth of sedation was greater, less limb movements might be expected.

The purpose of the present study is to determine, in critically ill mechanically ventilated patients, the feasibility of continuous measurement of limb movements via wrist actigraphy. This measurement was compared with other neurologic indexes used in a specialized environment like the ICU: sleep and agitation hours observed by nurses, pain and anxiety verbal numeric rating (VNR), and agitation/sedation status (Richmond Agitation-Sedation Scale, or RASS).

## 2. Materials and methods

This prospective, observational, feasibility study was conducted in a 6-bed mixed medical-surgical ICU of a university hospital. Exclusion criteria were age lower than 18 years and any neurologic disease with motor dysfunction. On the day of ICU admission, once the written consent from

patient or relatives was obtained, demographic and clinical data were recorded.

Movements were collected with a small-size ( $8 \times 2 \times 1$  cm), light-weight actigraph (BioTrainer-Pro Activity monitor; IM Systems, Baltimore, Md). This instrument measures the number of body movements over a certain intensity, recording every "epoch" data and storing them for few days. Epochs of 15 or 120 seconds were used. Because of the small intensity of critically ill patients' movements, the highest sensitivity of the instrument was used.

As soon as possible after admission in ICU, the actigraph was placed at the dominant wrist of patients, and the right positioning was checked regularly at each nurse shift. Each morning, the staff physician, once the desired level of sedation was established, prescribed the therapy according to the local ICU guidelines on use of sedatives ("awake-sedation" [14] and early use of enteral approach [15]), whereas the nursing staff evaluated subjectively the number of sleeping hours and agitation hours during the day (from 06:00 AM to 08:00 PM) and the night (from 08:00 PM to 06:00 AM). Agitation and anxiety assessment was based on observation of the following: patient/ventilator asynchrony, restless body movements, tachypnea, rigid limbs, self-extubation risk, and facial expression. Moreover, the nurse in charge evaluated 3 times a day (at 08:00 AM, at 04:00 PM, and at midnight) the RASS score and the pain and anxiety with a VNR, ranging from 0 (absence) to 10 (the worst imaginable). From these data, the nurses evaluated daily the satisfactoriness of sedative therapy, if it was adequate, or excessive, or insufficient. Soft restraints were used if necessary, but patients always had the possibility of moving their arms sufficiently to activate the actigraph sensing. Patients and nurses were asked daily about difficulties or discomfort related to the presence of actigraph.

### 2.1. Statistical analysis

The gross number of actigraphically revealed movements adjusted for time (hours) were used for the nonparametric Spearman correlation with other neurologic status indexes (sleeping hours, agitation hours, RASS, pain and anxiety VNR). All variables are indicated as mean  $\pm$  SD if normally distributed or median (interquartile range) if not. Data were analyzed with Wilcoxon rank sum test, Pearson  $\chi^2$  test, and Spearman rank correlation when appropriate, always considering  $P < .05$  as statistically significant. Statistical analysis was performed using Stata 9.2 (Stata Corporation, College Station, Tex).

## 3. Results

Thirteen consecutive high-risk patients [16] were enrolled, with a total of 165 days observed. Epidemiological data are shown in Table 1.

**Table 1** Demographic characteristics of patients and total number of observations

Patients	
Sex (male)	6 (46.2%)
Age, mean $\pm$ SD, y	60.2 $\pm$ 15.9
SAPS III (points), mean $\pm$ SD	67.6 $\pm$ 16.7
ICU length of stay, d (range)	6 (3-11)
Critical length of stay, d (range) [17]	5 (2-9)
Actigraphy, d (range)	3 (2-6)
Diagnosis	
Postoperative	5 (38.5)
Acute lung injury	4 (30.8)
Acute pulmonary edema	1 (7.7)
Pulmonary embolism	1 (7.7)
Pneumonia	1 (7.7)
Gastric hemorrhage	1 (7.7)
Admission from	
Ward	3 (23.1)
Operating theater	6 (46.2)
Emergency room	4 (30.8)
Admission type	
Medical	7 (53.8)
Surgical unscheduled	4 (30.8)
Surgical scheduled	2 (15.4)
Hospital outcome (alive)	12 (92.3)

Data analyzed (on 165 patients/d of the whole length of stay)		
	Days	Nights
Actigraphy	128 (77.6)	123 (74.5)
Nurse-observed sleep hours	83 (50.3)	88 (53.3)
Nurse-observed agitation hours	88 (53.3)	82 (49.7)
RASS	128 (77.6)	104 (63.0)
Pain VNR	139 (84.2)	104 (63.0)
Anxiety VNR	135 (81.8)	93 (56.4)

Values are in n (%), unless otherwise specified.

SAPS indicates Simplified Acute Physiology Score.

All patients received sedatives according to their clinical conditions during ICU stay. The desired daily level of sedation decided by physicians was RASS scores of  $-4$  in 12 cases (7.2%),  $-2$  in 18 cases (10.9%), and 0 in 135 cases

(81.8%). The desired level of sedation corresponded to the observed one in 58.3% of days with a RASS score of  $-4$ , in 38.9% with a RASS score of  $-2$ , in 78.5% with a RASS score of 0. The sedative therapy was judged adequate in 90.9%, excessive in 2.4%, and not sufficient in 6.7% of cases.

Total amount of registered movements adjusted for the number of hours and other neurologic observation is shown in Table 2. No statistical differences were found during the day using epochs of 15 seconds (36.6 [20.6-57.2]) or 120 seconds (27.6 [18.5-42.4]), neither during the night (9.5 [4.2-19.2] vs 8.1 [5.2-9.5]).

Nonparametric correlations showed that the total number of actigraphically recorded movements adjusted for hours was significantly related with the other indicators of neurologic status such as sleep hours, agitation hours, RASS, and pain and anxiety VNR (Fig. 1). No operative difficulties were found with actigraph use, neither from ICU staff nor from patients.

#### 4. Discussion

The number of wrist movements of 13 ICU patients was actigraphically recorded during their whole critical length of stay [17] and was related to the neurologic indexes recorded at the bedside. More than 80% of patients per days had an “alert and calm” condition (RASS, 0) as an end-point of sedative therapy. The desired sedation level was obtained more frequently in awake patients (RASS, 0) than in sedated ones (RASS,  $-2$  or  $-4$ ). Differences between days and nights (Table 2) are explained by the effort of ICU staff in guaranteeing the best environmental condition for sleep during the night, whereas during the day, patients were kept awake.

The sedation level “desired” by the ICU medical staff had been relatively lighter than values reported in the literature, highlighting that conscious sedation [14] is frequently possible during the critical ICU stay. Hence, the measurement of actual agitation/sedation level could be useful for an accurate and perspective control of sedative therapy.

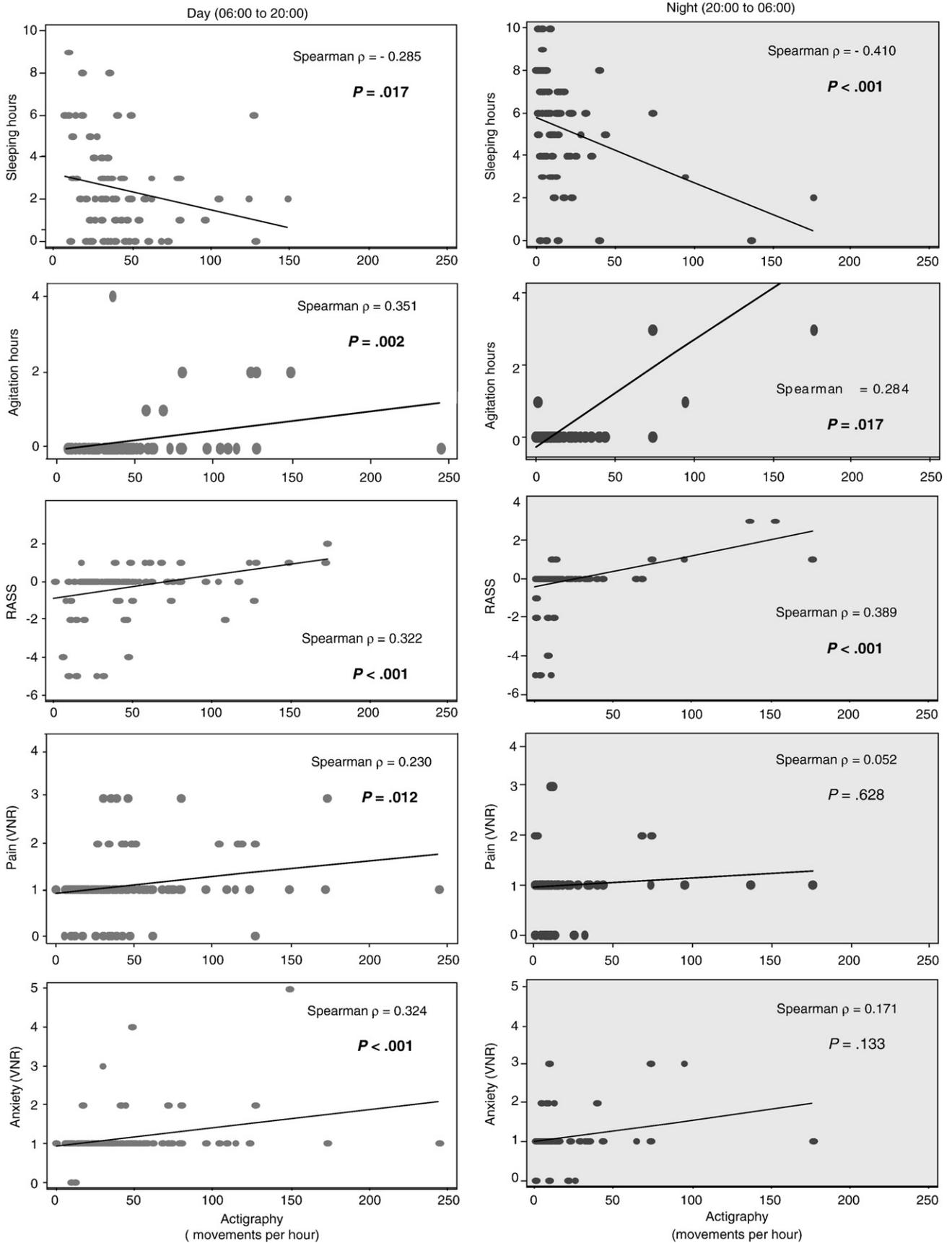
**Table 2** Neurologic observations used for Spearman correlation

Neurologic status indexes	Days (14 h)	Nights (10 h)	P
Actigraphy: movements/h (median [IQR])	33.3 [20.3-49.0]	8.5 [4.4-13.8]	<.001 <sup>a</sup>
Nurse-observed % sleeping time (median, [min-max])	16.4 [0-64]	52.7 [0-100]	<.001 <sup>b</sup>
Nurse-observed % agitation time (median, [min-max])	1.8 [0-57]	2.4 [0-90]	NS
RASS (median [min-max])	0 [-5 to +2]	0 [-5 to +3]	NS
Pain VNR (median, [min-max])	1 [0-6]	1 [0-3]	.028 <sup>a</sup>
Anxiety VNR (median [min-max])	1 [0-5]	1 [0-3]	NS

IQR indicates interquartile range; NS, not significant.

<sup>a</sup> Wilcoxon rank sum test.

<sup>b</sup> Pearson  $\chi^2$  test.



**Fig. 1** Spearman nonparametric correlations between actigraphy and neurologic status indexes.

Clinical and experimental methods described in literature (electroencephalography like bispectral index, blood concentration of drugs, auditory evoked potential, frontal muscles electromyography, and lower esophageal sphincter contractility) [18] are especially suitable for the “deep” levels of sedation (RASS -5 to -2), whereas they have less effectiveness in awake patients, having great intraindividual variation (RASS -1 to +1) and poor correlation with agitation (RASS, +2 to +4) [19]. Otherwise, these correlations suggest that online actigraphically guided neurologic status index could be useful in titrating sedative therapy.

The search of total-sleep-time estimation in ICU patients by actigraphy has been shown inaccurate and unreliable [10], probably because of continuous bed rest and the small number of movements made by this patient group. The software-based total-sleep-time analysis was not used in this study because the number of revealed movements was found to be too low to adequately evaluate the sleep cycles (data not shown). The implementation of new algorithms for ICU patients could be helpful in actigraphical identification of sleep-wake cycles.

Even if it is impossible to identify voluntary movements (finalistic or afinalistic) from passive movements due to nursing, the simple normalization of the number of recorded movements during a period has been shown capable to get round these intrinsic difficulties, offering an effective tool to titrate sedative therapy. Actigraphy could then become part of the sensing side of a closed-loop sedation system: independently from the sedation regimen in use, the online assessment of body movements, analyzed with the adequate algorithm, could provide an evaluation of the actual level of sedation, which is useful in terms of earlier achievement of the desired one.

A limitation of the present study is the observed sleep hours overestimation: the patients’ observations recorded by nurses have shown ineffective in understanding the real amount of sleep time, if compared with polysomnography [13]. Despite this, clinical observation is still the most common evaluation of sleep amount and adequacy because polysomnography is not achievable in the daily clinical practice, contrary with actigraphy, that was judged simple, and during the 165 observed days, no problems were noticed from the patients or nurses.

## 5. Conclusions

Wrist actigraphy provides nonspecific useful observations for ICU physicians; even if it does not discriminate the lack (or the excess) of analgesics and sedatives from other neurologic acute dysfunctions, these preliminary results suggest that the measurement of body movements

could provide a timely indication of acute changes in neurologic status generating motor agitation or hypoactive behavior, and it could prevent the insufficient or excessive use of sedatives.

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