Measuring nocturnal activity in Alzheimer's disease patients in a 'smart' hospital room

Soutrik Banerjee MD
Laboratoire Interuniversitaire de Gérontologie,
Pavillon Elisée Chatin, CHU de Grenoble,38043 Cedex 09,France
e-mail: Soutrik.Banerjee@ujf-grenoble.fr

Pascal Couturier MD PhD
Unité de Médecine Gériatrique et Réadaptation, Département de Médecine Gériatrique
et Communautaire, CHU de Grenoble, 38043 Grenoble, France

François Steenkeste M Engg
INSERM U.558, 37 allées Jules Guesde, 31073 Toulouse cedex, France

Philippe Moulin BSc MA
Unité de Médecine Gériatrique et Réadaptation, Département de Médecine Gériatrique
et Communautaire, CHU de Grenoble, 38043 Grenoble, France

Alain Franco MD
Unité de Médecine Gériatrique et Réadaptation, Département de Médecine Gériatrique
et Communautaire, CHU de Grenoble, 38043 Grenoble, France

29

S.Banerjee, P.Couturier, F.Steenkeste, P.Moulin, A.Franco. Measuring nocturnal activity in Alzheimer's disease patients in a 'smart' hospital room. Gerontechnology 2004; 3 (1): 29-35. Demented elderly patients in the hospital need continuous follow-up. For this reason, we created a system of continuous telesurveillance with the help of eight passive infrared sensors and installed it in an experimental hospital bedroom to analyse patients' motor activity. Patients were continuously monitored by the system from 21:00 until 6:00 the next morning. We monitored patients' motor activity and correlated it with his or her illness as well as patient management. We present here three Alzheimer's patients, which included 147 nights of observation. The first, otherwise stable patient, presented an acutely confused state. In the second patient, chronic sleep disturbance was noted. In the third patient, a superimposed episode of nocturnal agitation on chronically prevailing sleep disturbance was found. Thus, the preliminary results show that this method of monitoring patients' motor activity could be a useful adjunct to patient diagnosis and management for the clinician.

Keywords: smart room, actimetry, actigraphy, Alzheimer's disease

Most studies on telemonitoring the elderly using 'smart' sensors were performed at the patient's home[1-3]. Demented elderly patients are frequently admitted in hospital for acute conditions and behavioral problems. Patient management is difficult

especially during the night because of sleep problems or wandering. The usual tools for evaluation do not take into account day-to-day fluctuations of motor activity and give only a subjective analysis of patient behavior over time. For these patients, passive teleassistance can be envisaged in the current practice of geriatric medicine. We developed and installed an automated system of passive infrared sensors in an experimental hospital room to monitor the nocturnal activities of the patient in that 'smart' room[4-6]. We present three different cases of Alzheimer's disease patients.

METHODS
A hospital bedroom (3m x 3m) for a single patient was selected for the study. Our system was named G.A.R.D.I.E.N.®, a French acronym, where 8 passive infrared sensors were installed in different locations in the room at a height of about 2 m on the walls (Figure 1). The sensors were numbered as 1 (entry-outside), 2 (entry-inside), 3 (wall), 4 (wall-window), 6 (window), 8 (bed), A (centre), and C (toilet). Only sensor 1 was situated just outside the room. Each sensor was activated (on-off) by human movement in its field of view, covering a floor area of approximately 2m x 1m. The sensors were connected through cables to an I/O parallel card of a PC, kept in a separate observation room. The PC automatically captured data from the different sensors every night from 21:00 until 06:00 the following morning. After the surveillance period, a computer program analysed the signal data from all 8 sensors by the sequence of activation-deactivation, registered in a log file and, using artificial intelligence, generated an automated report (*activity chart*) showing different activities (displacements) in the room with indication of the date and time of the start and the end of each displacement[6].
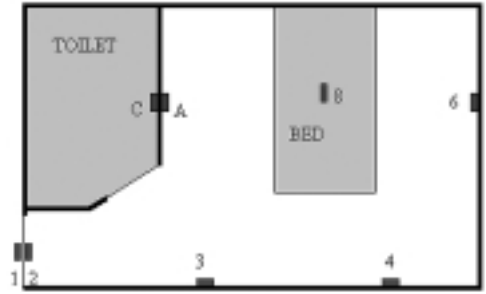

Figure 1. Locations of the eight infrared sensors inside the room. Sensor 8 surveys the zone over the bed[6] (published with permission from The Journal of Telemedicine and Telecare)

The program, in addition, calculated the total duration of nocturnal activity (cumulative) by summing up the duration (end time minus start time) of each displacement. Similarly, it calculated separately the cumulative activity in the bed and in the room, including activity in the toilet from the patient only, excluding activity from personnel and visitors by an algorithm using spatio-temporal filters[6]. The parameters on patient activity could be put in the form of a graph indicating the duration of bed and room activity (y-axis) for the continuous nights observed (x-axis) as illustrated in Figures 2-5.

The 'duration' of activity plotted against each night was used to follow-up the patients in the long-term. The 'frequency' of sensor activation was printed after each night as an *actigram,* which along with the activity chart was used to analyse that particular night's activity. An *actigram* plots the time in the x-axis (in 15-minute intervals), the number of times a sensor is activated during each 15-minute interval (called frequency of sensor activation) in the y-axis, and the different sensors in the z-axis. In the activity chart, the duration of bed, room and toilet activity were given as well as the duration of total nocturnal activity[6].
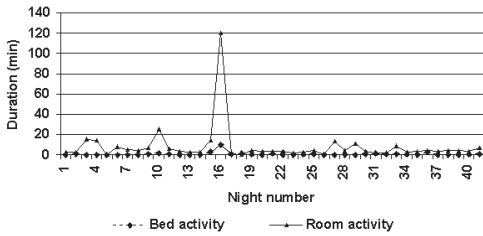
Figure 2. Nocturnal activity of Case 1, with acute nocturnal agitation on the 16th night
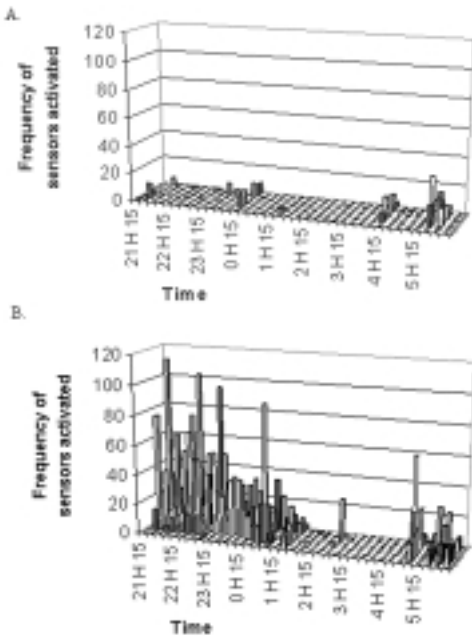

Figure 3. Comparison of activity histograms or actigrams on a 'normal' average night (A) and on the 16th night ('abnormal' night) (B) of the same patient (Case 1)

Prior to registering nocturnal motor activity of the patients, we took a written consent from each of the patient's next-of-kin, because the patients were incapable of giving written consent.

RESULTS
Case 1 (Figure 1)
This concerned a 77-year-old male patient, who was diagnosed as Alzheimer's

Table 1. Characteristics of the 3 ambulatory patients studied

Characteristic	Patient		
	Case 1	Case 2	CASE 3
Number of nights observed	41	63	38
Age (Years)	77	87	93
Sex	Male	Female	Male
Mini-Mental State Examination (Scale 1 to 30)	13	8	17
Activities of Daily Living (Scale 1 to 6)	4.5	4	5.5
Motor activity in room and toilet (Min)	8.2±18.4	18.7±13.4	51.1±34.2
Motor activity in bed (Min)	0.7±1.6	4.6±4.8	7.1±6.6

disease three years ago (Table 1). He was admitted to the rehabilitation unit in the geriatric department for agitation, aggressiveness and violence against his wife at home, in addition to the inversion of sleep-wake rhythm. At home, he was on Donepezil (anti-cholinesterase) for Alzheimer's disease, Gingko Biloba, hormone therapy for prostate carcinoma and Meprobamate (anxiolytic).

Analysis. He was observed right from the first night in the 'smart' room for 41 consecutive nights. In addition to the treatment that he was getting before, Paroxetine (anti-depressant) was added from the 5th day. He complained of pain in the upper abdomen on the 11th, 13th and 15th day of observation, which was treated with analgesic-antispasmodic combination. He also complained of shortness of breath on the 12th day in the afternoon. However, these complaints were not reflected as a change of nocturnal activity (bed or room) as seen in Figure 2. On the 16th night, he remained awake all the night till 01:30 am, during which he constantly moved about in the room. He then slept for some time and got up again at 5:00 in the morning (Figure 3). This excessive movement detected by the system that particular night, was

communicated to the treating physician. On the basis of this and his previous complaints, an abdominal Ultrasound Scan (USS), pulmonary Scintigraphy, and Echo-Doppler study of the lower limb were performed. Abdominal USS was found to be negative, but pulmonary Scintigraphy showed a strong possibility of Pulmonary Embolism (PE). In addition, d-dimers were positive. The Echo-Doppler study of the lower limb was however normal. On the basis of these results, a diagnosis of PE was made and anticoagulant therapy was started. The patient recovered fully after treatment before returning home. A comparison of activities, in the same patient, between a 'normal' average night and the 'abnormal' night with excessive movements, is shown in Figure 3 in the form of activity histograms or actigrams.
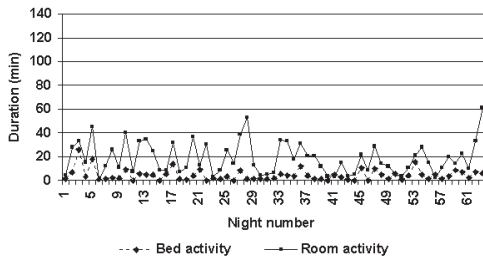

Figure 4. Chronic nocturnal hyperactivity having a fluctuating pattern within range (Case 2)

Case 2 (Figure 4)
This concerned an 87-year-old female patient, diagnosed as Alzheimer's disease since 18 months for which she was receiving Donepezil at home (Table 1). She suffered a fall and was presented with shortness of breath, which was diagnosed as pneumothorax caused by rib fracture, subsequently treated in a local hospital. Then she was transferred to the rehabilitation unit in the geriatric department. Finally, she was discharged on Done-pezil, Zopiclone (hypnotic), and oral anti-coagulant (for Deep Venous Thrombosis).

Analysis. The patient was transferred to the 'smart' room seven weeks after admission and followed-up for 63 consecutive nights. She didn't manifest any abnormally significant hyperactivity or nocturnal agitation during her stay. Figure 4 shows irregular fluctuations in the duration of activity, to which no cause could be attributed. On analysing each night's activity, we found that her sleep was often fractionated, that is she slept several times during small intervals, interrupted by frequent motor activity in the room or passages to the toilet.
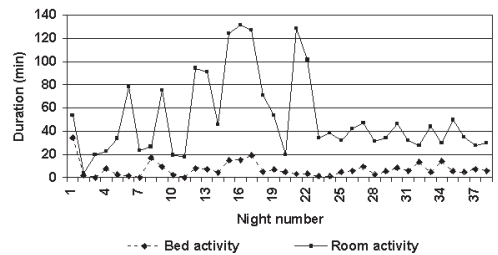

Figure 5. Superimposed nocturnal agitation (initial phase) on a 'baseline' chronic nocturnal hyperactivity (latter phase) (Case 3)

Case 3 (Figure 5)
This concerned a 93-year-old male patient diagnosed with Alzheimer's disease since two years (Table 1). He was admitted to the geriatric rehabilitation unit for the evaluation of chronic persistent pruritus and cognitive function. The cause of pruritus was determined to be due to hypersensitivity to Aspirin, which was subsequently stopped. At home, he was on Rivastigmine for Alzheimer's disease. He was admitted for agitation, delusion, aggressiveness, and violence against his wife. Three days following admission, he underwent psychiatric consultation, where delusion, confusion, a rigid personality, and spatio-temporal disorientation were noted. The fact of his being captured as a prisoner during the Second World War was the central thought behind his

delusion. He was continued with Rivastigmine from the first day of admission, except that the dose was doubled. Meprobamate and Tiapride (neuroleptic) were added to the treatment following psychiatric consultation. During the first six days, he was noted to be aggressive during the evening and night by the staff, but drowsy during daytime. On the 6th day Rivastigmine was stopped by the treating physician as the possible cause of his behavioral disturbance.

Analysis. He was transferred to the 'smart' room from the 7th night of admission and observed for 38 consecutive nights. His nocturnal motor activity increased significantly from the 6th night of observation, as appeared from the increasing trend (and peaks) in the legend 'room activity'. This was marked by several peaks in activity that continued until the 22nd night. Paradoxically, he was always very calm during the day. On the 14th day, the treating physician reduced the morning dose of Meprobamate and also Tiapride to only once in the evening, adding Zolpidem (hypnotic) in the night in order to reduce the patient's daytime somnolence and restore sleep during the night. But we can see that this change of therapy didn't have any beneficial effect on the patient and it corresponded to peaks in motor activity. Zolpidem was stopped on the 29th day, because the treating physician thought that it could be the cause for the patient's nocturnal aggressiveness (due to parasomnia). We can however see that from the 23rd night of observation, the patient's motor activity declined, maintaining a steady-state level around a 'baseline' of chronic hyperactivity until the end of his stay. From the activity histograms, we found that he practically didn't sleep until 22nd night, whereas his sleep became fractionated (small intervals of interrupted sleep) from the 23rd night onwards (chronic sleep disturbance).

DISCUSSION

In our study, we have attempted to monitor patients' motor activity using non-invasive passive infrared sensors and correlate it with the patients' illness and management. In Table 1, we can see that the mean duration of activity (in the room and in the bed), the level of cognitive function (MMS), and the level of autonomy (ADL) are different in each patient. Although all three patients were Alzheimer's patients, their nocturnal motor activity patterns were not the same, which illustrates the necessity for monitoring and analysing their motor activity *individually* by new telemedicine technologies such as used here.

We found in the first case, a model of *acute nocturnal agitation*, where the patient was normally stable, except that he manifested significant nocturnal hyperactivity on one night due to PE. In the second case, we found that the patient didn't manifest any major deviation from fluctuating nocturnal motor activity trend and was relatively stable within range, which was a model of *chronic nocturnal hyperactivity*. In the third case, there was an initial phase of significant nocturnal hyperactivity followed by chronic 'baseline' nocturnal hyperactivity pattern similar to the second case. This was a model of an episode of *mental confusion superimposed on chronic nocturnal hyperactivity*. We observed (Figure 5) that the patient suffered from an episode of nocturnal agitation lasting for about two weeks during which he slept very little. Though we couldn't ascertain its exact cause, we found that the patient fell down in his room immediately following the peak period of agitation (*i.e.*, on the 20th night reported by the staff). We observe here a 'dip' in the motor activity seen on the 20th night in which he fell down. Also, we found that the therapeutic changes made by the treating physician didn't have any immediate effect in decreasing nocturnal motor activity. We inferred that this two-week episode of nocturnal agitation was a phenomenon of 'superimposed nocturnal hyperactivity' observed from the peaks during this period

(mean 72.2 minutes, s.d. 40.7 minutes) on an already prevailing chronically disturbed sleep pattern in this patient: his motor activity graph stabilised around a 'baseline' of chronic nocturnal hyperactivity (mean 36.3 minutes, s.d. 7.1 minutes) from the 23rd night onwards (*p < 0.01*). From our experiment with three Alzheimer patients, we found behavioural problems as the most important factor in determining patient's nocturnal motor activity.

We chose infrared sensors for the advantage of not having to be worn by the demented patients. Our intention in the future is to use such a system on a larger scale in the old-age homes for demented elderly patients. There it would be problematic for the health personnel to ensure the proper wearing of devices every time as pendant alarms, bracelets, arm-bands, etc. Our study envisages in the long-term to install passive infrared sensors in the patient's room, observing the patient without disturbing him or her, and alerting the personnel in case of emergency, among which nocturnal agitation or hyperactivity. In addition, it can provide to the physician information on patient activity, quality of sleep, response to treatment, follow-up in an objective and consistent manner, not influenced by subjective and discontinuous observer assessment of the patient using standard geriatric assessment tools.

We thought that it was most important to monitor patient activity during the night, when interventions are minimal, and keeping a round-the-clock check on each patient activity not possible. However, currently it is programmed to register patient activity for the day as well as the night to reveal more information on a patient. The drawback in using our system of infrared sensors during the daytime in the hospital set-up is that it is not able to register patient activity outside the room.

This underestimates actual patient activity during the day, but still provides an objective information of the patient activity while he/she is inside the room.

In the future, with the advent of new telemedicine technologies, increased safety, proper assistance, and improved care of the demented elderly patients at a substantially lower cost can be envisaged.

References
1. Tamura T, Togawa T, Ogawa M, Yamakoshi K. Fully automated health monitoring at home. Studies in Health Technology and Informatics 1998;48:280-284
2. Sixsmith A J. An evaluation of an intelligent home monitoring system. Journal of Telemedicine and Telecare 2000;6:63-72
3. Ohta S, Nakamoto H, Shinagawa Y, Tanikawa T. A health monitoring system for elderly people living alone. Journal of Telemedicine and Telecare 2002;8:151-156
4. Couturier P, Tyrrell J, Banerjee S, Debray M, Moulin P, Franco A. Téléassistance en milieu gériatrique: besoins et réponses technologiques. [Teleassistance in a geriatric environment: needs and technological solutions]. In: Enjalbert M, editor. Rencontres en Rééducation: Aides techniques et matériel d'assistance en gériatrie [Rehabilitation meetings: Technical aid and assisitive devices in geriatrics]. Paris: Masson; 2002; pp 63-73
5. Steenkeste F, Bocquet H, Chan M,

Campo E. La mise en place d'une technologie pour observer le comportement nocturne des personnes âgées en institution. [The installation of a technology to observe the nocturnal behavior of elderly persons in an institution]. Innovation et Technologie en Biologie et Médecine - RBM 2001;22:25-30

6.   Banerjee S, Steenkeste F, Couturier P, Debray M, Franco A. Telesurveillance of elderly patients by use of passive infrared sensors in a 'smart' room. Journal of Telemedicine and Telecare 2003;9:23-29