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Feasibility Study of the Integrated Circuit Tag Monitoring System for Dementia Residents in Japan

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Videotaping, direct observation, and biomechanical devices have been used to measure the wandering behavior of institutionalized people with dementia and to identify patterns of movement. Owing to technical limitations, the variability in movement patterns or the distance traveled could not be examined. The present study examined the feasibility of an integrated circuit tag monitoring system to monitor the movement patterns of Japanese dementia residents. This system generated the following data: the frequency of detection by each receiver, the duration of stay in each location, the cumulative distance walked per day, and the graphic display of the movement pattern. This new system offers objective measurements of ambulation in time and space, which can be used to characterize demented patients and to evaluate the effects of treatment and care.

Keywords: integrated circuit tags; dementia; monitoring system; behavior

Wandering has been characterized as one of the most challenging behaviors to manage in people with dementia (PWD).[1] Although the existence of wandering has never been questioned, its definition differs across studies.[1,2] In reviewing wandering research, Algase characterized wandering according to 5 dimensions: volume, quality, environmental limits, navigational deficit, and temporal distribution.[2] Scales or behavioral checklists, videotaping, direct observation, and biomechanical devices have been used to document wandering.[1,2] However, all of these methods failed to measure objectively and for an extended period all 5 dimensions of wandering.

Scales or behavioral checklists have been used to measure the incidence of wandering and to examine the predictors of wandering. With the exception of the Present Behavioral Examination,[3] 1 or 2 questions were used to identify wandering. For example, Neuropsychiatric Inventories and Cohen-Mansfield Agitation Inventories have only 1 question pertaining to pacing.[4,5] These scales are inventories measuring agitated behaviors, and wandering is one of the components. The Algase Wandering Scale, the constructs of which were derived from published literature, is the only scale to specifically examine the pattern and rhythm of wandering.Although it has been used in a few countries,[6,7] its clinical applications have not been fully tested. The aforementioned scales are administered by caregivers and provide the patterns of wandering perceived by the caregivers. The reliability and validity of these scales are reported to be high.[3-5,7,8] However, wandering itself has not been validated by objective measures.

Videotaping has facilitated the examination of the patterns of movement in nursing home environments.

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Martino-Saltzman[9] used automatic detection-system-activated video recording to monitor 40 residents for 4 weeks and identified 4 types of spatial movements: direct, random, pacing, and lapping. Cognitive declines were associated with the prevalence of lapping. Although data were collected prospectively, the data analysis presented was a cross-sectional view of movement patterns.

Algase used direct observation to study the distribution and variability of wandering in 25 nursing home residents for a 3-day period.[10] The residents were observed for 24 hours only on the first day. Direct observation limited the number of individuals that could be observed at any given time as well as the duration of the observation. The number of individuals observed concurrently was not reported.[10]

Biomechanical devices have become available to quantify activity levels in various populations.[11-16] In PWD, step censors, accelerometers, and actigraphs were used to measure activity.[17-21] Step censors count the number of steps, and accelerometers measure movements in 3 dimensions.[19,20] The validity of these devices was tested by comparing measurement data with direct observation data.[22,23] The duration of the trial was short (< 24 hours) in these studies. In the first experiment, 4 types of devices were tested for only 10 minutes each,[22] whereas in the second experiment, these devices were tested for 16 hours.[23] However, the availability of the data was less than 60%, primarily because the subjects refused to wear the devices.

A monitoring technology is currently available that can compensate for the above mentioned problems. The purpose of the present study is to test the feasibility of the new monitoring system that uses integrated circuit (IC) tags to monitor the movement patterns of the residents in a psychiatric hospital dementia care unit in Japan.

Methods

Study Subjects

The study subjects were recruited from a dementia care unit at hospital A in the Chubu region, Japan. The unit selected for the study was a high-dependency unit, and 32 residents were being cared for in this unit during the study period. The majority of these residents required assistance in ambulation. The eligibility criteria for the study were as follows: (1) those diagnosed with dementia, based on cognitive assessment criteria (scoring 24 or below in the Mini-Mental State Examination [MMSE]);[24] and (2) those who were able to walk independently.

Ethical Considerations

This study was approved by the ethics committee of the Graduate School of Medicine, Osaka University, and the ethics committee of the study site. A medical social worker at the study hospital contacted the eligible subjects' authorized proxies and explained the purpose, research protocol, and ethical considerations when the proxies visited the hospital. The proxies then provided their written, informed consent. The ethical considerations were as follows: (1) participation in the study was voluntary, (2) any participant could withdraw from the study at any time, and (3) participation status would not affect the treatment or care of the subjects.

Study Procedure

Movement pattern monitoring system. An activity monitoring system (Matrix Co., Osaka, Japan) recorded the movement patterns of the subjects. This Power Tag system used IC tags measuring 2.8 cm × 4.2 cm × 0.68 cm that transmitted magnetic waves. The IC tag used in this study transmits magnetic waves with H-field strength of 0.707 A/m,[25] which complies with the North American safety standard (< 2.19 A/m).[26] Eight antennae were installed on the ceiling to receive the magnetic waves, which were then converted into the American Standard Code for Information Interchange (ASCII) format. The waves were then decoded into the identification data (ID) of the tag, the ID of the corresponding receiver, and the time and date. These data were sent to a personal computer—installed at the nurses' station—and compiled in chronological order. The IC tag was placed in a pouch, and this pouch was sewn onto the back collar of the subjects' shirts. Two tags were prepared for each subject so that he or she could wear the backup piece in case clothing became soiled or the subject otherwise changed clothes.

Data output and processing by the monitoring system. The system generated the following data: (1) the frequency of detection by each receiver, (2) the duration of stay in each location, the cumulative distance walked per day, and (3) a graphic display of the movement pattern.

The frequency of detection by each receiver and the duration of stay in each location. Each time a subject with an IC tag moved out of the receiving zone (the location where the receiving antennae were installed) and walked to another receiving zone, the subject was considered to have passed through a receiving zone once. The software counted the number of times a patient with the IC tag arrived at each receiving zone and how long he or she remained there.

Estimated distance walked by a subject per day. The monitoring software was programmed to compute the cumulative distance walked between the receivers daily for each study subject. In this case, the estimated distance walked refers to the sum of the shortest distances between the zones at which the subject was detected by the receiver.

Estimation of time spent in the subject's room during the day and night. The movement data were converted into Excel data, and we estimated the sleeping times of the subjects (times when they were not detected at any other point between 2 consecutive times at which they were detected in front of their rooms) and the time they spent in their rooms during the day (times during the day when they were not detected at any other point between 2 consecutive times, separated by more than 10 minutes, at which they were detected in front of their rooms).

Movement pattern mapping for 24 hours. The monitoring software produced chronological graphics that displayed the course of a subject's movement from one receiving zone to the next.

Data abstraction. The medical records of the study subjects were abstracted to gather the following information: age, sex, dementia classification, history of present illness, former occupation, time spent at the facility, body mass index (BMI), and medication. To test the subjects' cognitive functions, an MMSE was administered by a trained researcher. Information on various aspects of the subjects' daily routine was collected—meal hours, bath time, recreation hours, and activities.

Direct observation of one study subject. To evaluate the accuracy of IC tag monitoring, Resident A—a known wanderer—was observed between 9:00 AM and 5:00 PM for 7 days and for 2 evenings between 5:00 PM and 10:00 PM. Observations were carried out by student nurses and a research assistant who received training on how to record the subjects' activities.

Results

Thirteen residents were monitored using the IC tag monitoring system for 1 week in August 2005. One resident was transferred out during the study period. Of the remaining 12 residents, 5 were diagnosed with Alzheimer's disease (AD). Another 2 were diagnosed with vascular dementia, and the remaining residents were diagnosed with an unspecified type of dementia. The mean age of the residents was 69.6 ± 7.5 years, and the mean MMSE was 11.2 ± 5.5. With the exception of Resident A, all residents had low mobility, and the mean distance walked per day was 561 ± 105 meters. Resident A—a reported wanderer—was the only one who had been observed to compare the IC tag monitoring data with the observation data. Therefore, this paper presents the monitoring device data and the observation data pertaining to Resident A.

Resident A is a 61-year-old male with AD, an MMSE score of 17, and a BMI of 19.2. He had been institutionalized for 13.5 months and had a history of heavy drinking. Prior to being admitted, Resident A, who is a college graduate, was then the manager of a company. During the study period, no significant changes were detected in his blood pressure or body temperature. His clinical records and the nurses' records revealed that there had been no changes in his condition. During the week, Resident A walked a daily distance ranging from 6 km to 13 km (Figure 1). The estimated mean number of hours of sleep was 8, and the estimated number of hours of rest in his room during the day was 2 (Figure 1).

Cumulative Distance Walked by Resident A per Day

The examination of the cumulative distance walked by Resident A per day during the 7-day observation period failed to reveal any typical pattern of wandering (Figure 2). Intensive walking in the morning was observed on the second and seventh days, whereas intensive walking in the evening was observed on the third and fourth days. Further, the distance walked in the morning was either average or below average (Figure 2).

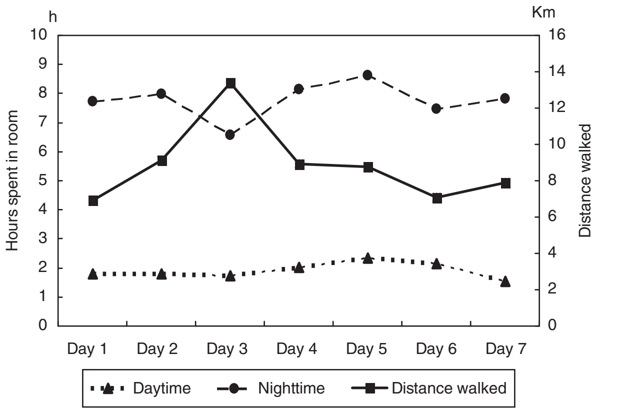

Figure 1. Changes in the distance walked by Resident A per day and the hours he spent in his room at night and in the day during the 7-day observation

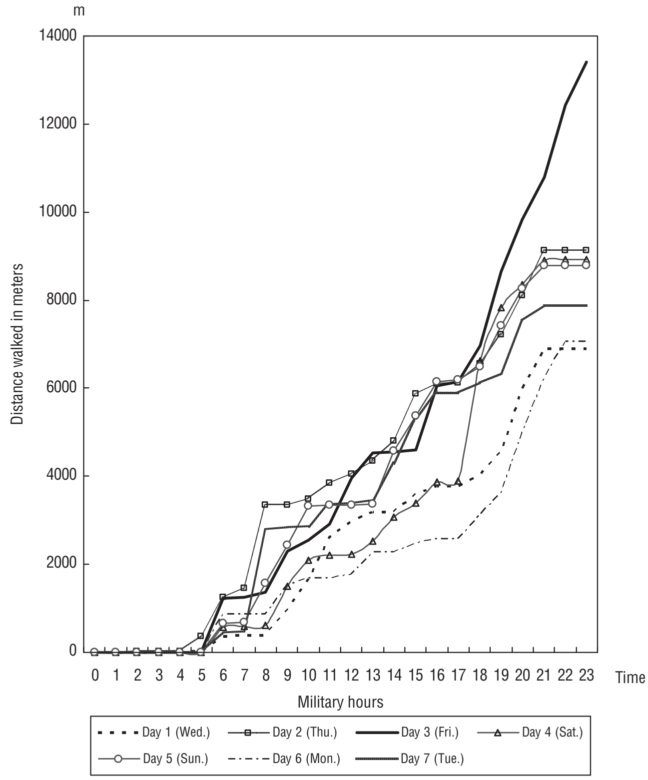

Figure 2. Cumulative distance walked by Resident A per day during the 7-day observation

Variations in the Distance Walked per Hour

The minimum and maximum distances walked per hour were 5 meters and 2738 meters, respectively. The median distance walked per hour was highest in the evening, followed by the morning, before and after breakfast (Figure 3). The variance was the greatest in the morning between 8:00 AM and 9:00 AM, followed by the afternoon, and then the late evening.

The changes in the distance walked per hour during the 24-hour period for 7 days were examined. Figure 4 displays the changes in activity levels during the day. The activity levels alternated between the active and inactive phases, which corresponded to mealtimes and group activities (Figure 4). An unusually active phase was characterized by a distance that exceeded 1.5 km in the morning (days 2 and 7) and 2 km in the evening (day 4).

Movement Pattern Mapping on Day 2

The software printout of the movement pattern mapping of Resident A on day 2 of observation represents the median distance walked (Figure 5). He was unusually active before and after breakfast—he paced in the hallway. When he wandered, he generally walked all across the floor, which was similar to the pattern observed in the evening.

Comparison with Direct Observation

The observational records provided information on the participant's meals, recreation time, etc. The participant's major movements—as recorded on observation sheets for Resident A—and the movements by the movement pattern mapping were in agreement. The only movements that were not detected by the monitoring system were those that took place inside the room. A couple of times a day, Resident A walked into the dining room, walked in circles several times, and then walked out. When he was not wandering, he tended to rest in his bed after breakfast for a few hours every day. Other than intensive wandering, Resident A did not exhibit any psychobehavioral problems such as violent behavior. The caregivers had different interpretations of his wandering behavior. One of these interpretations was that he still considered himself to be managing the company and was visiting the places in which the company had dealings.

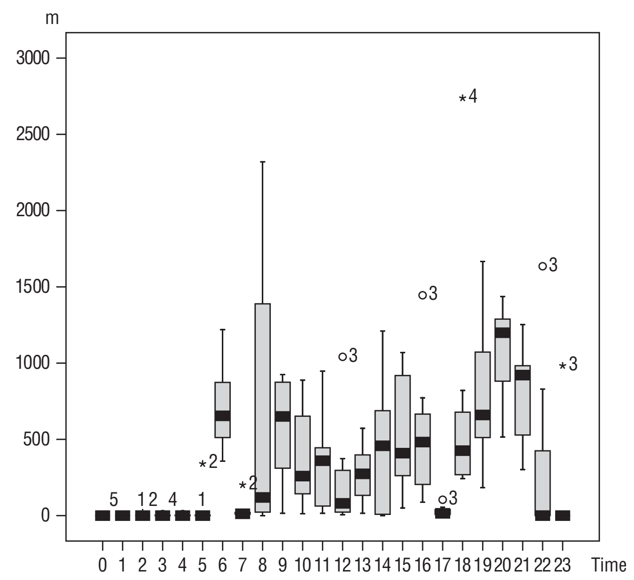

Figure 3. Box Plot of Distance Walked by Resident A per Hour during the 7-day Observation

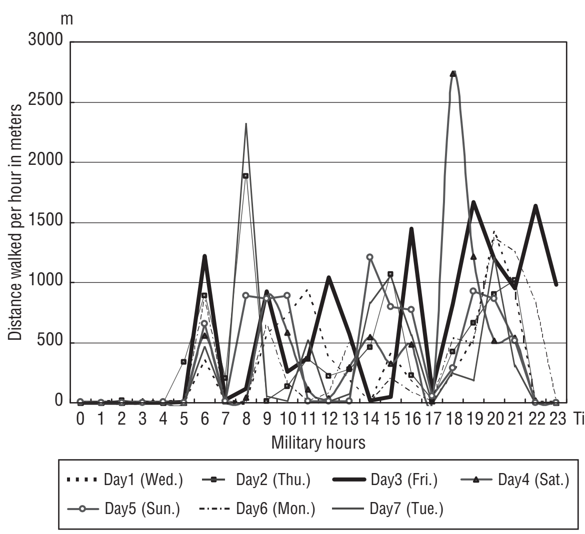

Figure 4. Changes in the Distance Walked per Hour during the 7-day Observation

Discussion

The new monitoring system was successful in capturing the continuous movement of the residents over a 7-day study period. Compared with the biomedical devices used to monitor demented patients,[22,23] the system was well tolerated by the residents for a period of 1 week. The movement pattern mapping system offers objective methods to evaluate the spatial movement, the intensity and frequency of ambulation, the temporal pattern of ambulation, and the distance traveled.

In the current study, the movement pattern mapping depicted pacing, demonstrating back and forth movements in the hallway. However, random movements described in previous studies[9,27] were recorded neither by movement mapping nor on an observation sheet for Resident A. He tended to walk straight down all the hallways in a particular order, as if he was in a hurry to arrive at his destination. The physical exercise level of Resident A prior to the disease onset is not known. Since no comparable data on the distance walked by AD patients were available in the published literature, it is difficult to label his intensive ambulation as aberrant. To examine the prevalence and risk factors involved in intensive wandering, further research is necessary to accumulate data on AD patients.

The direct observation and video recording used in previous studies have numerous limitations with regard to capturing the movements of dementia residents.[9,27] Direct observation would influence the behavior of the study subjects, and the number of observers would have to be limited at any given time. Furthermore, continuous monitoring by direct observation limits the duration of study.[10] In contrast, video recording can be used for a longer period of observation. However, reconstructing the subject's movements or coding these movements can be laborious. A study by Martino-Salzman and associates[9] identified nearly 5800 independent movement events for coding. The IC tag monitoring system eliminates the necessity for coding and the training of the coders for the collection of ambulation data.

If the new monitoring technology becomes readily available, a large number of subjects in a variety of settings could be monitored for longer periods. This system can objectively describe wandering and monitor the progression of the disease. It would also assist in examining the risk factors of wandering and in evaluating interventions.

Research and Clinical Implications

This system is capable of monitoring dozens of individuals for an extended period and can be used to evaluate treatment or interventions by examining all 5

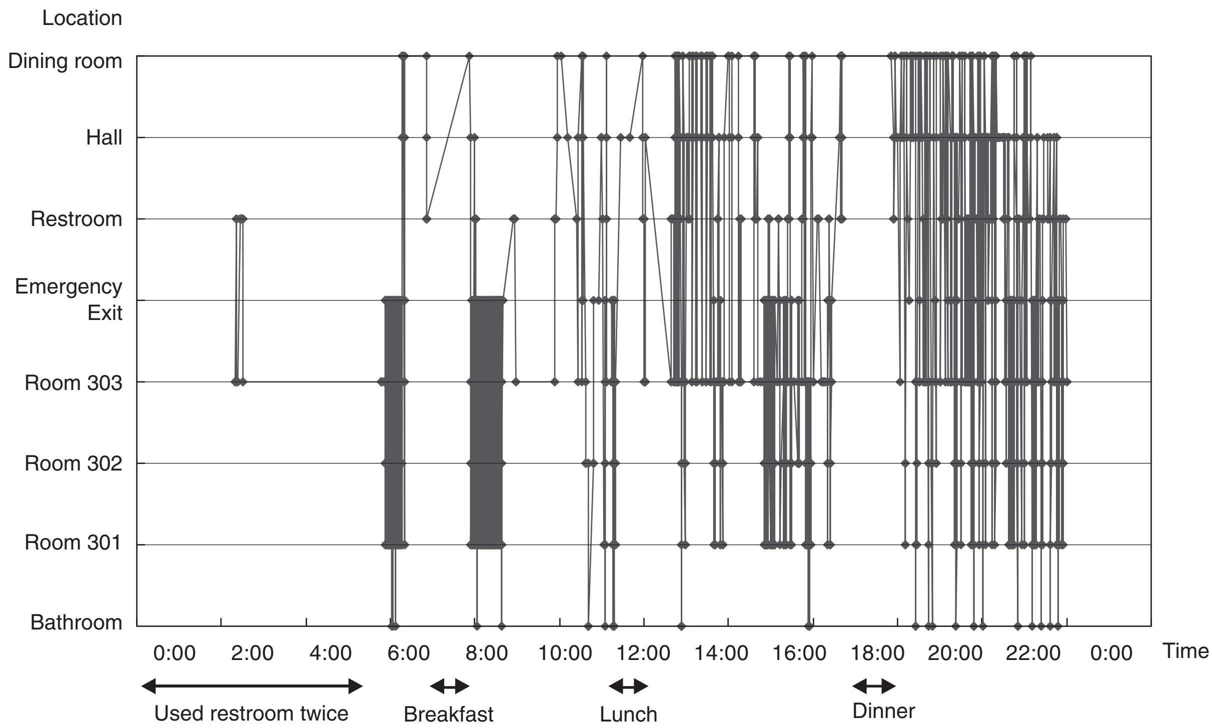

Figure 5. Movement Pattern Mapping on Day 2

dimensions of ambulation. The system can also estimate the energy expenditure of intensive wanderers so that appropriate nutritional requirement can be easily calculated.

The evaluation of interventions for PWDs depends primarily on the scales administered by caregivers.[28,29] The monitoring system would be useful for the evaluation of PWDs who have circadian rhythm disturbances and vascular dementia and who are intensive wanderers.

The real-time monitoring system for institutionalized PWDs has the potential to contribute toward improved safety. Such a system is particularly useful for the monitoring of residents who have a tendency to elope or who are at a high risk of falling. Eloping can be fatal in certain circumstances.[30] The system can identify attempts to elope and successful exits by setting up antennae both inside and outside the exit. In the event of successful exits, an alarm can be triggered to notify the staff at the nursing station, or the alarm can be relayed to cell phones carried by the staff.

Real-time monitoring and concurrent data analysis will facilitate the examination of trigger events for intensive wandering. For example, if the distance walked per hour accounts for more than 95% of the study subject's movements, the trigger events can be examined immediately.

Currently, 2 studies are in progress. The objective of one study is to collect data of PWDs in the Korean population for a cross-cultural comparison of wandering behaviors. The objective of the other study is to examine variations in the patterns of ambulation over a 3-month period. To explore the pattern of interactions between the staff and patients, the interactions between care workers and patients are also being monitored. In conclusion, this monitoring system has considerable potential for dementia care research.

Limitations of the Study

Owing to budget constraints, the major limitation of this feasibility study was the limited number of antennae used. Therefore, the detailed movements of Resident A could not be monitored. For example, one antenna was placed by the door of the dining hall, and the movement occurring inside the dining hall could not be detected by the system. The system used in the current study could only record movements. If facial expressions, attitudes, or ambiance are necessary for interpreting movement patterns, videotaping or personal observation has to be conducted concurrently.

The system's maximum capability was not tested in this study owing to the budget limitation. An antenna can be installed in the bedroom to determine whether or not a resident with an IC tag was staying in bed. The budget constraint also limited the duration of the study. Therefore, the pattern of behaviors associated with weekly activity programs could not be examined. Moreover, the IC tags were sewn into the subjects' clothes by the research assistant, and sewing was not practical for monitoring many residents. In the new study, a strong adhesive tape is being tested for attaching IC tags to the patients' clothes.

Conclusion

This study tested the feasibility of using the IC tag monitoring system to monitor wandering behavior in a resident with AD. The system enabled the continuous monitoring of the movement patterns of this resident for 24 hours during a 7-day period. This new system offers objective measurements of ambulation in time and space, which can be used to characterize demented patients and to evaluate the effects of treatment and care.

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