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Reducing Falls in Dementia Inpatients Using Vision-Based Technology

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Objectives: Falls have a significant negative impact on the health and well-being of people with dementia and increase service costs related to staff time, paramedic visits, and accident and emergency (A&E) admissions. We examined whether a remote digital vision-based monitoring and management system had an impact on the prevention of falls.

Methods: Our study was conducted within the Manor dementia inpatient wards at the Coventry and Warwickshire Partnership Trust. Data were retrieved from incident reports before and 22 months after installation of the system. We examined number of night time falls, severity of fall, number of paramedic visits and A&E admissions, and the number of enhanced observations during both time periods.

Results: There was a significant 48% reduction in the number of nighttime falls ($P < 0.01$), a 49% reduction in visits from paramedics ($P < 0.2$), and a 68% reduction in A&E admissions ($P < 0.02$). In addition, the data indicated an 82% reduction in the number of moderate severity falls and that enhanced one-to-one observation hours were reduced by 71%.

Conclusions: The study demonstrated that a contact-free, remote digital vision-based monitoring and management system reduced falls, fall-related injuries, emergency services time, clinician time, and disruptive night time observations. This benefits the clinicians by allowing them to undertake other clinical duties and promotes the health and safety of patients who might normally experience injury-related stress and disruption to sleep.

Key Words: falls prevention, dementia, subacute care, digital monitoring technology

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Reducing falls in the older people is a major health challenge. The long-term consequences of falls can be life-changing with permanent injuries and a loss of independence. Kennedy et al[1] observed a fall rate of 2.51 falls per person per year with 62% of residents experiencing a fall over a 1-year period across 40 Canadian residential care facilities. Most people living in care homes are frail with multiple needs and may have higher risks for falls. However, falls are not restricted to care homes alone. An observational study in an inpatient acute and subacute setting of the Aneurin Bevan University Health Board General Hospital, United Kingdom (267 beds across two sites) reported a fall incidence of 5.44 ± 4.76 falls/1000 patient-bed days on a multibedded ward and 15.82 ± 19.56 on a single-room ward ($P < 0.01$).[2] In elderly care wards in a UK district general hospital in 2004, the reported rate was as high as 18.0 falls per 1000 bed days.[3] Medical-surgical units in the United States reported between 3.67 and 6.26 falls per 1000 patient days.[4] A fall incidence of 6.45 falls per 1000 bed days was found in 24 Australian medical and surgical wards with most falls in inpatient settings (75% of 70,000) occurring in the bedroom and bathroom.[5] Higher fall incidences of 10.9 and 17.1 falls per 1000 bed days were found in 8 Australian rehabilitation/geriatric units[6] and psychogeriatric wards,[7] respectively.

In relation to time spent after a fall, a Delphi study in the Netherlands reported that nonsevere falls in care homes required 5 extra hours of time per patient by clinicians. A severe fall resulting in a fracture requires 132 additional hours of staff time.[8]

A total of 240,000 falls are reported from hospitals and mental health units in England and Wales annually, more than 700 per day.[9] Falls have a substantial social and economic cost: The National Institute for Health and Care Excellence clinical guidelines on “Falls in Older People” estimated that falls across all settings cost the National Health Service more than £2.3 billion per year.[10] The direct cost of falls in hospitals (acute and mental health settings) is approximately £611 million per year, which is equivalent to approximately £3.9 million for an 800-bed acute hospital trust.[11]

Reducing the occurrence of falls, therefore, has considerable financial benefits in addition to reducing the harm to patients caused by falls.

Technology for Fall Prevention

A range of technologies have been developed to reduce the number of falls. One example is a mobile software-based application worn by the patient.[12] Technologies, such as this, require patients to wear or carry battery-powered monitoring devices that can be uncomfortable and inconvenient, with batteries requiring frequent recharging and the possibility of devices being lost on the ward. Considering the high incidences of falls in patients with dementia, the high costs, the distress to patients and their carers, and the drawbacks identified with other technologies, the Coventry and Warwickshire Partnership Trust sought an alternative support system. We identified a digital vision-based patient monitoring and management system that was developed by Oxehealth and was entirely noncontact.[13] This system was selected because it was the only noncontact monitoring and management system of its type available. Barrera at al[14] installed this system on an acute mental health inpatient ward to carry out regular observations and monitor patients. Their preliminary data on 755 nights of observation reported no adverse events and suggested a positive and safe impact on patient and staff experiences at night.

This novel technology had not previously been used in an inpatient dementia setting.

Vision-Based Patient Monitoring and Management System

The system uses computer vision algorithms to provide physiological and physical monitoring of pulse rate, breathing rate, movement, and position within the bedroom.

It has infrared illumination and a digital video camera, called the sensor, held within a discreet wall-mounted casing in a corner

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FIGURE 1. The system hardware installed above the bed in a patient room.

of the room. Figure 1 shows the sensor in the top left-hand corner of a patient bedroom.

Patient privacy is maintained as, unlike a CCTV camera, there is no video feed continuously displayed. When an alert is set off from a room, for example, if the patient is getting out of bed unattended, the user follows a workflow allowing them the option of viewing the room for a limited time duration. Members of staff can then either help the patient back into bed or help them to the bathroom, etc, avoiding a potential fall. The user may turn the system off during activities of daily living, such as bathing and cleaning, avoiding unintended use.

The system software divides the bedroom into regions (i.e., bed, room area, and doorways to the bathroom and corridor) and measures movement within each region so that episodes of increased fall risk can be notified to staff (e.g., if a patient is getting out of bed unattended at night). If a patient does fall, the system can be used retrospectively to assess the incident. For example, if the patient did not hit their head, they would not require an unnecessary intrusive assessment for head injury. As assessments for head injuries after a fall would normally occur, the retrospective visual recording saves staff time allowing staff to undertake other tasks. It is also less disturbing for the patient. The system offers other functionality, such as a report of the night time activities of patients, which could inform clinical care, such as a change in sleep medication. The system was installed in 12 bedrooms (6 per ward) of the 24 bedrooms across 2 wards.

METHODS

Study Design and Setting

This cohort study was approved by the Wales REC 5 Research Ethics Committee (reference 17/WA/0193). The study was conducted within the Manor dementia inpatient wards at Coventry and Warwickshire Partnership Trust. Participants included patients with dementia, some with comorbid conditions, from 1 male ward and 1 female ward. For patients who were not able to provide informed consent, the decision on their participation was made by an appropriate advocate. The age range of the patients was 57 to 92 years. As part of the standard ward processes, all patients were assessed on admission for risk of falls. Both before and after the introduction of the system, a large majority of patients on these wards were assessed as being at high risk of falling.

Data Collection

Trust incident forms containing falls data were pseudonymized by the Trust research team and sent to the study team. The aim was to (1) calculate the number of falls, (2) assess the nature of the fall, (3) assess the severity of the fall, (4) obtain the number of visits by emergency services, and (5) obtain the number of patient visits to accident and emergency (A&E), equivalent to U.S. emergency departments. Data were extracted to provide baseline measures (T1, March 2017 to February 2018) before installation of the system and follow-up measures from the 22 months after installation of the system (T2, March 2018 to December 2019). Falls were

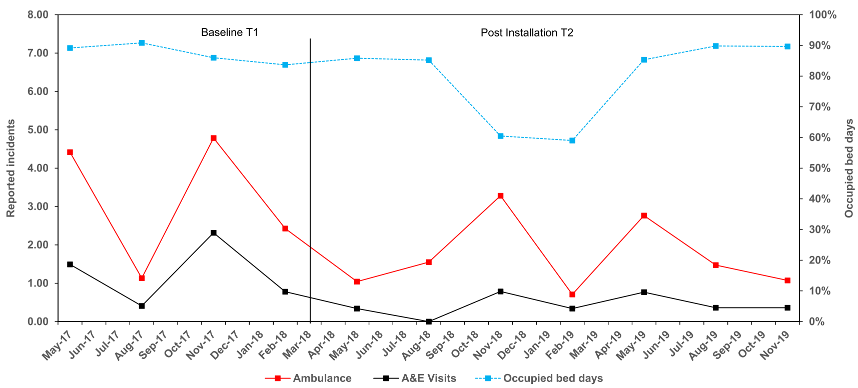

FIGURE 2. Occupancy, number of A&E visits, and onsite emergency services visits.

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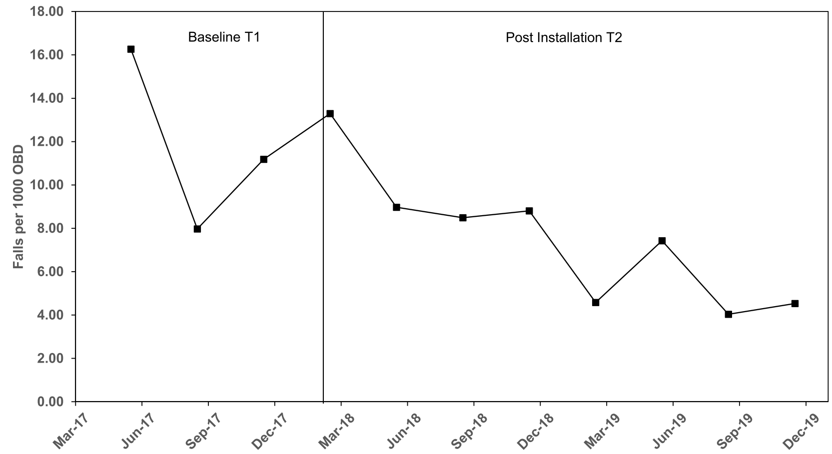


FIGURE 3. Number of falls per 1000 bed days for the baseline period (T1) before the system was in use and for the subsequent 22 months with the system in use (T2).

analyzed if they were documented on the wards during the nighttime period from 19:30 P.M. to 07:30 A.M. when patients are more likely to be in their bedroom. Bedroom falls during the daytime period of 07:30 A.M. to 19:30 P.M. were not evaluated as part of this study as hospital practice is to encourage patients to spend their time outside their bedrooms during these hours.

Data are presented as the number of falls per 1000 bed days, a measure to track falls as recommended by the Agency for Healthcare Research and Quality.[15] The number of bed days in each month is the sum of the number of days each patient spent on the wards. Dividing the number of falls each month by the occupancy of the wards in bed days causes the results to be normalized for occupancy. In this study, occupancy remained stable at approximately 90% throughout the study period as shown in Figure 2. There were approximately 11 patients and 5 members of staff (2 nurses and 3 healthcare assistants), on each ward each night.

In addition, falls were categorized into no harm, low harm, and moderate harm. Low-harm falls require additional observations and may require minor treatment. Moderate-harm falls require additional observations and treatment interventions, such as admission to hospital with a fracture, but do not result in irreversible injury. There were no incidences of serious harm, which could include a serious head injury, heart attack, or even death, during the study period. The severity of falls was measured for the 12 months before the system went live (T1) and for the 22 months after the system went live (T2).

Staff surveys (n = 12) were carried out across both the wards to assess the effectiveness and ease of use of the system in providing nursing support.

The costs of enhanced (i.e., one-to-one) observations were analyzed before and after the system was installed. We wished to analyze as much data as possible to increase the power of the study but excluded a Trust policy change, which could confound the results. By this logic, we, therefore, selected 8 months before the system was installed and 8 months afterward.

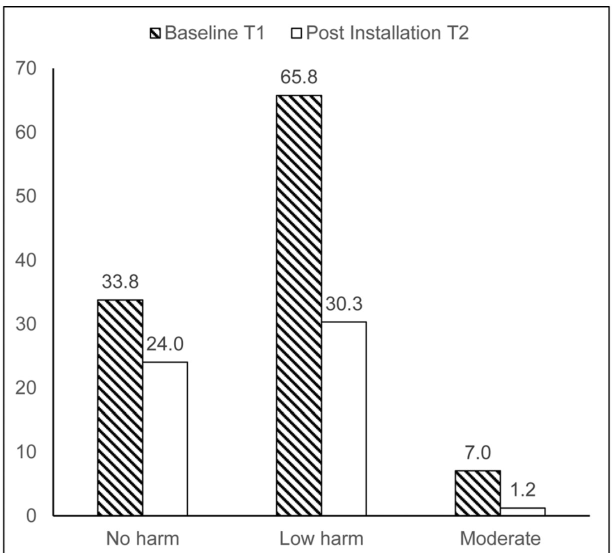
Statistical Methods

One-sided *P* values were calculated using a basic bootstrap approach (bootstrapping on individual patients) to test the hypotheses that the technology had reduced (1) number of nighttime falls, (2) visits from paramedics, and (3) A&E admissions. The analysis was performed using the R software application with methods in accordance with the book "*Bootstrap Methods and Their Application*,"[16] for both the treatment of hierarchical data and the generation of nonparametric basic bootstrap confidence limits.

RESULTS

There was a significant 48% reduction in the rate of nighttime falls during T2 compared with T1 ($P < 0.01$) as shown in Figure 3. No falls were reported during December 2019. There was a 68% reduction in A&E visits ($P < 0.02$) and a 49% reduction in visits from paramedics ($P < 0.2$) as shown in Figure 2. No A&E visits or onsite emergency services visits were reported during December 2019.

The severity (no harm, low harm, or moderate harm) of the falls that occurred during the 12 months before the system went live (T1) and during the 22 months after the system went live (T2) are shown in Figure 4. The values in Figure 4 have been annualized to facilitate direct comparison.



	Baseline T1	Post Installation T2
No harm	33.8	24.0
Low harm	65.8	30.3
Moderate	7.0	1.2

FIGURE 4. Severity of falls during T1 and T2.

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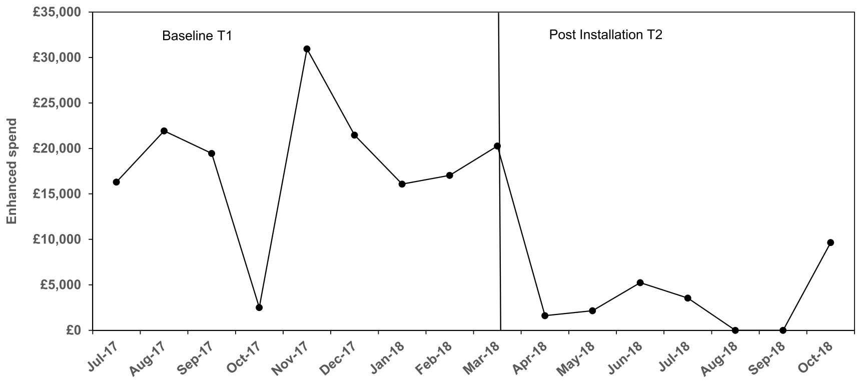

FIGURE 5. Change in monthly cost of enhanced observations during the 8 months before and after the introduction of the system.

Data on the costs of enhanced (i.e., one-to-one) observations indicate that these observational hours reduced by 71% after the system became operational, as shown in Figure 5 (a *P* value could not be calculated for this reduction because patient identifiers were not available for the enhanced observations data).

DISCUSSION

This study assessed the impact of using a digital vision-based patient monitoring and management system to support staff caring for patients in a dementia inpatient facility and improve patient safety. It demonstrated that the system's functionality has a positive effect by alerting staff to patients who are getting out of bed, thus enabling them to respond immediately. Bedroom falls were reduced by 48% when the digital vision-based monitoring and management system was installed.

The total number of moderate-severity falls in bedrooms at night decreased significantly by 82% across the whole facility during the study period. These data match the perceptions of staff using the system on the wards. One ward manager stated, *"The severity of falls and associated injuries have reduced massively at night. I think it's because we can intervene earlier. For example, we can attend to patients within seconds if they are disoriented or confused so they do not slip and fall."*

An analysis of recent literature suggests that 41% of all emergency admissions to A&E from care homes and residential homes are avoidable and could be managed locally, thereby reducing strain on the overall healthcare system.[17] In our study in a related setting, there was a 68% reduction in visits to A&E and a 49% reduction in visits by paramedics to the dementia inpatient facility. An estimated 420 clinical hours per year for the 24-bedroom inpatient facility have been saved as a result of the reduction in falls, reduction in visits to A&E, and visits by paramedics. Importantly, these reductions also imply that patients have experienced a better quality of life as a result.

At the Manor Hospital, clinical protocol requires staff to ascertain whether a patient has struck their head in a fall. If this is unknown, staff must assume that the patients have struck their head and appropriate assessments and neurological observations must take place. The system enabled staff to "replay" a fall by viewing video footage of the incident enabling an assessment of the incident including whether the patients struck their head and how the fall occurred.

The reduction in enhanced observations shown in Figure 5 may suggest that the hospital staff are better supported in managing patient fall risk at night, reducing the requirement for enhanced observations to be carried out and improving patient care. This reduction in enhanced observations provides a valuable operational benefit; it is the equivalent to saving 7810 clinical hours per year for the 24 bedroom inpatient facility.

Hospital staff embraced the technology and felt that it improved patient care. One nurse said, "*I like the alerts when a patient is on the edge or at risk of falling. Staff are able to attend and prevent a fall from happening*." Another said, *"For staff it's an experience, which will help to manage our time on the ward and help to prioritize our work."*

A total of 8230 clinical hours were saved based on the 2 main drivers of clinical time saving: observation hours, equivalent to 7810 clinical hours saved per year, and reduced bedroom falls at night, equivalent to 420 clinical hours saved per year.

Limitations

The study only took place in 2 wards at a single hospital and analyzed only falls in bedrooms at night time. Data on enhanced observation hours were only recorded from July 2017 to October 2018 because of operational changes implemented at the hospital in the first quarter of 2017, which resulted in modification of usage of enhanced observations in one ward, and unavailability of data after October 2018. The calculation of the number of clinical hours saved per year after the system was installed is limited to the reduction of enhanced observation hours and the reduction in fall incident–related activities, excluding the clinical time saving that may have been realized from being able to view unwitnessed falls.

CONCLUSIONS

These results indicate that the digital vision-based patient monitoring and management system enables inpatient care and safety to be optimized through early warning alerts, in this case fall risk alerts, and postincident assessments. Specifically, the system can reduce falls and associated injuries and save significant clinical time in dementia wards, improving patient well-being. These enhancements in inpatient care have led to positive clinical and operational outcomes in a dementia inpatient facility setting. They can be applicable to other inpatient healthcare settings, including working age psychiatric inpatient care, elderly care, postoperative care, and assisted living care. Further research is underway to analyze the effects of noncontact patient monitoring and management in other clinical settings and how it can best support and enhance clinical workflows.

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