Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

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ORIGINAL RESEARCH

Using a Co-Designed Implementation Enhancement Plan to Increase the Adoption of a Digital Fall Prevention Platform: A Non-Randomized Pre-Post Interventional Study

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Background: Falls are a major cause of hospital acquired complications and inpatient harm. Interventions to prevent falls exist, but it is unclear which are most effective and what implementation strategies best support their use. This study sought to ascertain the impact of a co-designed implementation enhancement plan on the adoption and effect of a digital fall prevention platform in a new hospital.
Methods: A non-randomized pre-post interventional study using multi-methods. A bespoke survey as well as descriptive and inferential statistical analysis of hospital administrative data and were used to identify the impact on: (1) adoption of the system and (2) the rate of falls.
Results: The co-design implementation enhancement plan successfully improved the adoption of some key platform functions, most importantly, a 39% increase ($p = 0.04$) in setting a patient as having a high risk of falling on the staff station console. There were also improvements in staff response times, satisfaction and perceptions of the fall prevention platform. A risk reduction in falls per 1000 bed days was observed among cognitively intact patients post implementation enhancement plan, however, this difference was not statistically significant (OR = 0.97 95% CI [0.78,1.22] $p = 0.77$).
Conclusion: The co-designed implementation enhancement plan improved uptake of the platform and is likely to be effective for other similar interventions. The platform shows the potential to reduce falls among cognitively intact patients, but longer periods of observation and a larger sample are needed to confirm the effect. Aside from falls, a reduction in nurse response time is likely to improve patient care and experience.

Plain language summary: This paper outlines methods to improve the implementation of falls prevention interventions using a co-designed implementation enhancement plan. The findings have broader implications for the implementation of other fall prevention interventions.

Evidence is generated in support of digital falls prevention systems in the context of providing more efficient and responsive care, as well as improved patient-staff communication and satisfaction.

Keywords: implementation science, health information technology, nursing, co-design

Background

A significant number of falls occur in Australian hospitals each year, some causing serious harm to the patient. In 2022–23, more than 55,000 falls were reported with 3,813 (2,991 in public vs 822 in private) resulting in fracture or other intracranial injury.[1] Patients with these types of falls can remain in hospital for much longer on average (18.8 days longer) leading to higher hospital acquired morbidity and mortality compared to those that do not experience Hospital

Received: 11 April 2025
Accepted: 8 June 2025
Published: 17 June 2025

Acquired Complications (HACS).[2] In addition to patient harm, the cost of falls is very significant with an average acute overnight hospital stay costing approximately $2,074; falls can be associated with more than $38,991 in additional costs per patient, per stay, or in the range of $117m AUD additional costs for hospitals annually.[1,2]

Numerous fall prevention interventions have been developed, including education, medication review, exercise, assistive technologies (such as bed or chair alarms), and hospital environmental safety measures (eg, keeping the call bell in reach).[3] Current World Falls Guidelines suggest the use of individualised, multidomain interventions.[4] A 2018 Cochrane systematic review concluded that while evidence supporting the effect of fall prevention interventions exists, the quality and generalisability of the evidence to wider healthcare environments (such as hospitals) remains low.[5] The review identified that the majority of the current fall prevention intervention studies were localised to a single site and delivered the interventions in varying combinations, making it difficult to parse which approach actually helps prevent hospital inpatient falls.[5] Another review found a similar issue with high heterogeneity of included studies, and lack of high quality evidence in general, but during meta-analysis, they identified that fall prevention interventions focusing on improving patient and staff education were associated with a reduction in fall rates (RaR = 0.70 [0.51–0.96], $p = 0.03$) in high quality studies.[6] The review concluded that further research is still required on a variety of fall prevention interventions in order to discern which are the most effective.[6]

In this study, we measure the effect of a digital fall prevention platform developed by Rauland Australia (Concentric Care fall prevention platform) on inpatient falls. The platform has multiple functions including i) specific nurse call buttons on the bedside handsets, ii) audio/microphone in bathrooms, iii) integrated workflow terminals on room entry points for regular rounding, iv) mobile/nurse station phone and smart bed/chair integration, v) direct nurse-patient communication functionality in the patient handset.[7]

In addition to the lack of clarity on effective fall prevention interventions, the identification of implementation strategies that influence the adoption of fall prevention interventions remains undetermined.[8,9] A systematic review of fall prevention implementation strategies concluded that some strategies had promise, however, concrete generalisations about their actual effect were impossible to make due to the poor quality of reporting in the reviewed studies.[10] For example, many studies provided unclear, suboptimal reporting of their approaches for the intervention, context or study cohort differences.[10] As such, further research is needed to properly discern the most effective implementation strategies for fall prevention interventions in hospital environments. In this study, we test the impact of a previously developed, co-designed Implementation Enhancement Plan (IEP) on the adoption of the Concentric Care fall prevention platform. Details of how it was developed are available elsewhere.[11] We hypothesized that using a context specific, tailored bundle of strategies and modifications to the intervention would improve the adoption of the Concentric Care fall prevention platform, and may reduce the number of patients who fall.

Methods

Aims

To understand if the use of a co-designed IEP increases the adoption of a digital falls prevention platform, and, if that increased utilisation results in a reduction in the rate of patient falls.

Design

A non-randomized pre-post interventional study using a multi-methods design.[12] Descriptive and inferential statistical analysis of hospital administrative data and a bespoke survey were used to identify the effectiveness of a co-designed IEP on the uptake of the Concentric Care fall prevention platform and its effect on the rate of falls among cognitively intact patients. The primary implementation outcome measure was the adoption of key system functionality (eg, setting a patient as having a high risk of falling). Secondary implementation outcomes included staff satisfaction and perceptions of the system post IEP. The primary patient outcome (effect) measure was the rate of falls per 1000 bed days in cognitively intact patients. Secondary patient outcome measures included the time taken for staff to respond to patients, absolute number of falls, harm sustained from falls and length of stay. The Standards for Reporting Implementation Studies (StaRI) checklist guided reporting of the study (Supplementary File 1).[13]

Setting

A newly built (opened January 2022) 300-bed rural referral hospital in New South Wales, Australia that provides medical, surgical and maternity services to approximately 92,000 public patients annually. The intervention (Concentric Care fall prevention platform) was operational in four inpatient wards (two surgical and two medical) of the new hospital throughout the research period.

Ethics

Ethics approval (reference: 2021/ETH11953) for this project was granted from Hunter New England Human Research Ethics Committee on 16 Feb 2022. Reciprocal ethics approval (reference: 2022_012_RR) was obtained from CSIRO Health and Medical Human Research Ethics Committee on 25 Feb 2022. For the survey, participants were provided with an information sheet and were asked to confirm their consent to participate in the survey before proceeding. For hospital data, a waiver of consent was sought as it was not practical to obtain it individually given the number of records included in the study. It was also reasonable to assume that consent would be granted. As part of admission paperwork, patients consented to the reuse of their data for research purposes. All data was de-identified before submission to ensure confidentiality. The study complied with the requirements of the Declaration of Helsinki.

Intervention (Concentric Care Fall Prevention Platform)

Rauland Australia developed technology to support falls prevention management in the healthcare sector.[7] Specific workflows (protocols) were designed within their Concentric Care fall prevention platform to provide functionality to manage patients at high risk of falls such as: i) specific nurse call buttons on the bedside handsets, ii) audio/microphone in bathrooms, iii) integrated workflow terminals on room entry points for regular rounding, iv) mobile/nurse station phone and smart bed/chair integration, and v) direct nurse-patient communication functionality in the patient handset. The system provides the platform for new workflows to be implemented to assist with providing care to high risk falls patients and was supported with clinician education delivered as part of the Concentric Care fall prevention platform nurse training. All components were available for use during the study period. Some modifications were made to improve the system usability, and these are outlined in Table 1.

Table 1 Influencing Factors and Implementation Strategies to Enhance Implementation[11]

Influencing Factors[14]	**Implementation Strategies**[15]	**IEP Action Items**
• **Access to knowledge and information** • **Self-efficacy** • **Knowledge and beliefs about the intervention**	Conduct educational meetings Provide ongoing consultation Conduct ongoing training Make training dynamic	Training on how to use the system integrated into annual mandatory training and provided to new starters. Online training moved to hospital education platform. Training methods changed to incorporate a mix of online and face to face simulation. Managers upskilled and provided with information on staff who have not completed training.
• **Compatibility** • **Design quality and packaging** • **Adaptability**	Promote adaptability	Alarm conditions modified to suit ward environment. Policy and procedure highlighted to staff and integrated discussion of the system into daily huddles. Use of system integrated into leader rounding to facilitate contemporaneous feedback to staff.

(*Continued*)

Table 1 (Continued).

Influencing Factors[14]	Implementation Strategies[15]	IEP Action Items
• **Patient needs and resources**	Obtain and use patients/ consumers and family feedback Involve patients/consumers and family members	Information about the system provided in existing hospital admission packs was expanded and updated. Nurse educators visited wards ad-hoc to remind staff to educate patients. Reminders to staff at huddles about care board conversations and include family members in discussions.
• **Leadership engagement** • **Cosmopolitanism** • **Relative advantage** • **Formally appointed internal implementation leaders**	Identify and prepare champions Build a coalition Involve executive boards	Integration of the falls prevention system metrics and strategies into the developing nurse clinical leadership program (support development of ward champions).
• **Executing**	Purposefully re-examine the implementation	Co-design workshop to identify actions to address recommended implementation enhancement strategies. Audit tool developed to be used in conjunction with existing audits to measure compliance. Share audit data at huddles and encourage discussion about how to improve. A question about the platform was integrated into leader rounding.
• **Available resources**	Access new funding	Not for actioning in the first round of enhancements.

Implementation Intervention (Co-Designed Actionable IEP)

Following a qualitative study reported elsewhere in which an IEP was developed based on stakeholder-identified influencing factors,[11] a co-design workshop was held with key hospital stakeholders in November 2023. The research team presented several implementation strategies to enhance uptake (Table 1) and worked with the stakeholders (eg, hospital program manager, nurse manager, IT manager, Rauland technical and clinical support) to assign specific actions, timeframes and responsible staff to each item. Once finalised, the site lead (MG) was responsible for ensuring the actions agreed to be progressing. Three months after the workshop, an exercise to confirm the actions that had been completed was undertaken through discussion with the site lead and executive sponsor. All actions were completed except "access additional funding", as reflected in Table 1. Six months after the plan was devised, follow-up surveys, interviews and focus groups were undertaken with hospital stakeholders.

Study Participants

Survey: All nursing staff working on the relevant wards were invited to participate in the survey (n = 180) across each time point (n = 360 total).

Administrative data: Patient data was extracted from March 2022 (two months after staff moved to a new hospital where the system was already installed) to allow a "run in period" so admission levels could normalise and staff could become familiar with the new facility and system, until June 2023 (six months after the IEP workshop, and approximately three months after all actions were complete) to allow time for changes to be embedded. No apriori sample size calculation was undertaken as 1) there was no baseline for comparison, 2) funding and timeline constraints meant the study needed to be completed over a period of 18 months.

Data Collection and Analysis

Patient data was collected from the Hospital Information Environment (HIE), Incident Management System (IMS) and the Concentric Care fall prevention platform. Staff responses were collected from a survey.

Hospital Information Environment (HIE)

The inclusion criteria were all patient admissions (18+ years) in a bed on the wards of interest between 1st March 2022–30th June 2023. Data fields included admission and discharge date, bed and ward numbers for the admitted episode, age at admission, sex, and International Classification of Disease (ICD)10-AM discharge diagnoses. A typical patient may be in several wards during their hospital stay. For example, a patient may enter via an emergency bed, have surgery, move to the ICU then move to a surgical ward. The dataset contained 15 ward/bed columns; however, no timestamps were attached to any individual bed stays, only the overall hospital length of stay. Therefore, no ward level analysis could be performed. Given that the system is designed to work for patients who can appropriately engage with it (including the predisposition of being cognitively intact), an analysis was undertaken that excluded all patients who had a noted cognitive impairment on their case mix data inclusive of dementia, delirium and other cognitive impairments. Patient cognitive status was determined by identifying patients with a noted ICD-10-AM (International Statistical Classification of Diseases and Related Health Problems – Australian Modification) code F00, F01, F02, F03, F05, G30. Data cleaning and refactoring were undertaken where required. Missing data from all sources were treated as intentional. Individual variable summaries included the number of missing values but results requiring cross-tabulations only included complete cases. Primary outcomes (falls overall and falls in cognitively intact patients per 1000 bed days) were analysed in Microsoft Excel™ using *t*-tests to determine if there was a significant difference in the before versus after periods. Primary and Secondary outcomes (length of stay) were analysed using the online Odds Ratio calculator by MedCalc.[16]

Incident Management System (IMS)

This is the main database that collects information relating to reportable falls incidents in the hospital. It collects general hospital information such as when and where an incident occurred, the age of the patient, an incident description and ascribes a harm score to the incident. Harm Scores range from the most serious[1] to the least serious.[4] Incident management system data was extracted to match patients and admission periods from the HIE extract. The data included all falls that occurred across the participating wards, during the inclusion period, and the level of harm sustained. The secondary outcome (harm sustained from a fall) was analysed using a *t*-test for significance.

Concentric Care Fall Prevention Platform

This system collects data on the type of call and the response times to answer the call, either verbally or physically, for each bed in the wards. Data consisted of bed number, ward, call type, response type (Voice or In-person) and duration of call. Call type categories were: Bed Exit, Cord Out, Emergency, Ensuite Assist, Ensuite Emergency, Falls Alert, In Pain, Need Toilet, Need Water, Nurse, Plug Out, Rails Alarm, Return to Bed, Shower, Staff Assist in Toilet. As the Concentric Care falls prevention platform had no unique patient identifier, records were linked to the IMS and/or HIE by using date, Bed number and Ward as linkage fields. The secondary outcome (staff efficiency of response to patient call) was analysed using a *t*-test for significance.

Surveys

A link to an online survey was distributed to staff at two timepoints on relevant wards by the site Principal Investigator in June–August 2022 (pre-IEP) and July 2023 (post-IEP). The survey contained quantitative rating questions as well as room for free text responses. The online survey was developed using REDCap (an online survey instrument distribution service) and hosted by CSIRO. The survey was pilot tested for content and face validity by research team members. There were three main components to the survey questions: demographics, engagement with functionality, satisfaction and beliefs about the implementation. For engagement with functionality, questions called upon the respondent to provide a "frequency rating" next to each function, which varied from Never to Very Often. For satisfaction questions, staff were asked to rate their overall satisfaction with the Concentric Care fall prevention platform between 1 and 10 with 1 being totally unsatisfied and 10 being totally satisfied. Staff were asked questions in the survey that related to their beliefs about the implementation of the Concentric Care fall prevention platform at two time points before and after the IEP. Staff were asked to answer using a scale that rated from Do Not Know, Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree. All questions were designed to ascertain the level of positivity regarding the system. Raw data was extracted from REDCap, cleaned and aggregated

in Microsoft Excel. Records that were partially completed were retained for analysis where relevant (eg, some staff only completed part one and two, and thus the numbers included for analysis are different). Following data cleaning, simple descriptive statistical analysis was completed to identify trends in system performance and staff perceptions of the system. All categorical variables are described using counts and percentages. Continuous variables are described used means and standard deviations.

Results

Hospital Information System – Patient Demographics

Demographics: There were 8,008 episodes amongst 6,892 patients for the wards and time periods defined. The number of diagnoses was equal to the total number of unique International Classification of Diseases (ICD) codes assigned to each patient. Cognitive impairment was determined by identifying patients with a noted ICD-AM code F00, F01, F02, F03, F05, G30 (see Table 2).

Patient Outcomes

Primary Outcomes

Falls per 1000 Bed days

Across the eight-month period before the IEP, there was a monthly average of 4.97 falls per 1000 bed days, and 4.88 post-IEP, representing a small absolute decrease of 0.09, however a *t*-test revealed that this difference was not statistically significant ($p = 0.21$). Since the incidence of falls as a proportion per 1000 bed days is small, a much longer period of observation would be required to analyse the true effect of the system over time on all admitted patients.

Table 2 Demographics of Admitted Patients During Study Period

Variable	Pre-IEP Mar-Oct 22	Post-IEP Nov 22-Jun 23	P value
Admissions	4,259	3,749	0.8
Patients	3,635	3,257	
Sex = n (%)			
• Female	2,147 (50)	1,804 (48)	
• Male	2,112 (50)	1,945 (52)	
Length of stay = mean (SD)	8 (10.8)	8 (9.4)	
Number of diagnoses = mean (SD)	8.9 (5.9)	8.8 (5.7)	
Cognitive impairment = n (%)	416 (9.8)	403 (11)	
Falls (n)	169	144	0.8
• Cognitively intact = n (%)	104 (62%)	76 (53%)	0.7
• Cognitively impaired = n (%)	65 (38%)	68 (47%)	0.8
Harm score = n	167	143	0.8
• 1 (Death) = n (%)	0 (0)	0 (0)	
• 2 (Permanent Harm) = n (%)	4 (1)	2 (1)	
• 3 (Temporary harm requiring intervention) = n (%)	53 (33)	51 (39)	
• 4 (Minor harm requiring no intervention) = n (%)	110 (66)	90 (60)	
Staff response time (seconds)	41	31	<0.001

Falls Among Cognitively Intact Patients

A small absolute decrease over time in the average rate of falls among the included wards was observed (3.85/1000 bed days pre- and 3.38/1000 bed days post-IEP), however, the *t*-test analysis demonstrated that the change was not statistically significant ($p = 0.42$).

Secondary Outcomes

Falls

Within the included IMS data set there were 320 falls documented to have occurred between March 2022-June 2023. Of those, seven records could not be matched. After matching, 313 falls were found with 169 occurring before the IEP, and 144 after, which is an absolute reduction of 25 falls. However, this should be considered in the context of patient admissions, which were also reduced (4,259 pre and 3,749 post). Thus, the difference was not statistically significant (OR = 0.97 95% CI [0.78, 1.22] $p = 0.77$).

Harm Score

The impact of the Concentric Care fall prevention platform on harm sustained from falls before and after the IEP was explored. Overall, 310/313 included records had a harm score allocated. Overtime, the proportion of each harm category remained largely unchanged, with each category 1 = Death (0% before; 0% after); 2 = Permanent harm (2% before; 3% after); 3 = Temporary harm requiring intervention (32% before; 37% after); 4 = Minor harm requiring no intervention (66% before; 63% after) remaining similar.

Length of Stay

Overall, there was a slight increase in the length of stay over time from pre-IEP (mean 8.13 days) to post-IEP (mean 8.23 days), but this was not statistically significant ($p = 0.65$).

Health Service Outcomes

Secondary Outcome

Response times: Staff response time to turn off the buzzer inside the patient room increased significantly over time (pre-IEP - 71 secs, post-IEP - 84 secs, $p < 0.001$). However, the mean staff voice response reduced significantly over time (pre-IEP - 41 secs, post-IEP - 31 secs, $p < 0.001$), demonstrating, with improved used of the system, there is improved efficiency in communication between patients and staff.

Staff Engagement and Perceptions – Participant Demographics

Demographics: An uneven spread of nursing staff from across the wards participated in the surveys (anonymised for publication purposes). In the pre-IEP period, n = 27 nurses responded (15% response rate) and in the post-IEP period, 17 nurses responded (9.4% response rate). Notably, there were no responses from ward 3B in the post-IEP period. This may impact the generalisability of our findings (see Table 3).

Implementation Outcomes

Primary Outcome

Engagement with Key Functionalities

100% (n = 27) of participants time point one and 100% (n = 17) of participants at time point two completed these questions. Engagement with fall system functionality was substantially improved at time point two, following implementation of the enhancement plan, with frequent utilisation (often/very often) improvement reaching statistical significance for two key functions setting a patient as having a high risk of falling on the staff station console (37% pre and 77% post-IEP [p =0.03]) and receiving a fall alert from a smart bed on a mobile device (52% pre and 83% post-IEP [p =0.04]). See Table 4.

Table 3 Spread of Participants Across Wards

	Pre-IEP	Post-IEP
Ward	**n (%)**	**n (%)**
1	5 (19)	5 (29)
2	5 (19)	9 (53)
3	11 (40)	0 (0)
4	3 (11)	2 (12)
All	3 (11)	1(6)
Total	**27**	**17**

Table 4 Key Functionality results

Function	N	R	S	O	VO	NA	Difference % (p value)
Programmed a smart bed to alert for a falls risk patient?							
Pre-IEP = %	15	7	15	15	48	0	+19% (0.30)
Post-IEP = %	0	12	6	29	53	0	
Received a fall alert from a smart bed on your mobile device?							
Pre-IEP = %	19	11	19	19	33	0	**+31% (0.04)**
Post-IEP = %	0	6	6	12	71	6	
Received a nurse call from a patient to your mobile device as the primary nurse?							
Pre-IEP = %	7	4	11	7	67	4	+8% (0.96)
Post-IEP = %	6	6	6	12	71	0	
Received a nurse call to your mobile device as the backup nurse?							
Pre-IEP = %	7	7	15	19	48	4	−2% (1.00)
Post-IEP = %	6	6	24	6	59	0	
Spoken with a patient on your mobile device when they called?							
Pre-IEP = %	7	7	0	30	56	0	−9% (0.74)
Post-IEP = %	6	12	6	6	71	0	
Set a patient as a high fall risk on the staff station console?							
Pre-IEP = %	30	11	22	11	26	0	**+40% (0.03)**
Post-IEP = %	6	12	6	18	59	0	
Allocated yourself or another nurse's patients in the Concentric Care fall prevention platform web application?							
Pre-IEP = %	48	0	7	11	26	4	+16% (0.42)
Post-IEP = %	18	12	12	6	47	6	

(*Continued*)

Table 4 (Continued).

Function	N	R	S	O	VO	NA	Difference % (p value)
Used the Staff Console to answer a nurse call?							
Pre-IEP = %	30	22	19	19	11	0	+17% (0.39)
Post-IEP = %	6	35	12	12	35	0	
Used the Staff Console to speak to a patient in their room?							
Pre-IEP = %	41	22	7	15	15	0	**+6% (0.95)**
Post-IEP = %	18	35	12	0	35	0	
Upgraded a nurse call to a staff assist call using the staff console?							
Pre-IEP = %	70	7	7	4	7	4	+18% (0.28)
Post-IEP = %	53	6	12	0	29	0	

Note: Bolded p values indicate statistical significance at $p < 0.05$.
Abbreviations: Legend: N, Never; R, Rarely; S, Sometimes; O, Often; VO, Very Often; NA, Not Applicable.

Staff Satisfaction

Overall, n = 21/27 respondents gave a rating in the first survey, and n = 14/17 gave a rating in the second time point. Overall, the mean satisfaction levels were very similar before versus after the IEP (6.4 before and 7.2 after).

Staff Beliefs About the System

Overall, n = 21/27 staff responded to these questions in the first time point and n = 14/17 staff at the second time point. Table 5 contains a summary of responses to each question, inclusive of those who responded Agree/Strongly Agree before versus after the IEP. Overall, a higher proportion of survey respondents was in agreement across all statements, with improvements ranging from 7% to 19% among ratings of "agree/strongly agree".

Table 5 Staff Perceptions of the System

Staff Survey Results – Answer of Agree/Strongly Agree			
The Concentric Care fall prevention platform has improved management of patients at high risk of falls		**The benefits from outcomes of the Concentric Care fall prevention platform implementation will outweigh the time and effort required to adopt it**	
Pre-IEP: 52%	Post-IEP: 71%	Pre-IEP:52%	Post-IEP: 59%
+19%		+7%	
I intend to use the Concentric Care fall prevention platform when appropriate to manage patients at high risk of falls		**Alerts to my mobile phone remind me to check on high falls risk patients**	
Pre-IEP: 63%	Post-IEP: 77%	Pre-IEP: 52%	Post-IEP: 71%
+14%		+19%	
The Concentric Care fall prevention platform can be adapted to local processes		**There has been sufficient local clinician time allocated to implement the Concentric Care fall prevention platform and workflows**	
Pre-IEP: 48%	Post-IEP: 59%	Pre-IEP: 33%	Post-IEP: 41%
+11%		+7%	

Discussion

This study is among the first to demonstrate the positive impact that a co-designed, theory informed IEP, can have on the uptake of an intervention.[11,17] The study observed improvements in engagement with key functionalities (eg, setting a patient as having a high risk of falling), staff beliefs, staff response to patients and staff satisfaction in using the digital fall prevention workflow. However, the study was not able to detect a significant impact on fall prevention as it was not sufficiently powered. The incidence of falls over time is small in the context of admissions, and a much longer observational time period would be needed to establish whether the platform can influence this outcome.

The importance of engaging with implementation science during intervention development has been well established.[18,19] However, it is not always feasible or desirable for robust formative implementation optimisation to occur. In these instances, a compromise exists where health services can implement an intervention and use the creation and execution of co-designed IEPs as a defined point from which to compare the effectiveness and uptake of interventions over time.[11] In the present study, a new hospital was being constructed, and it was necessary to install the requisite components of the digital fall prevention platform at the time of construction. Naturally, this left little time or scope to adequately engage and educate staff prior to use. Thus, the approach of using an IEP was taken. The use of IEPs is new, but they are becoming increasingly common. Numerous studies outline using this methodological approach and the development of implementation plans but are yet to test them.[20–22] An example of one study that has successfully tested the use of implementation mapping sought to implement a preoperative anaemia and iron deficiency screening, evaluation and management pathway. A plan was developed using the CFIR and ERIC tool.[17,23] The study aimed to support intervention implementation and strategy selection and found that patients were 10 times more likely to receive care that was according to guidelines than previously after the introduction of an IEP using the CFIR-ERIC approach (OR = 10.6 95% CI [4.4–25.5] $p < 0.000$).[17]

Engaging in the implementation enhancement process resulted in significant improvements with key functionalities, demonstrating the impact on the behaviour change of staff when undertaking this process. As a result of the enhancement engagement and utilisation, we also noted improved staff voice response times and perceptions that patient care is enhanced with the system in place. People wishing to implement any new intervention, digital or not, could consider using the same approach. It is important that health facilities take ownership and demonstrate commitment to completing the recommended actions, otherwise the approach does not work. There is a paucity of evidence that demonstrates the application of the IEP approach on improving intervention uptake, and this is only one of two studies (to the authors knowledge) which have demonstrated the true impact.[17] Other work exists, but only at the point of identifying strategies, which may be suitable to address particular issues.[21,24,25] Further longitudinal research would be needed to fully establish the impact on falls and to fully understand the potential run-on effects that improved staff efficiency and patient care may have in the longer term.[9]

Fall prevention interventions, and in particular, those that are digital are increasingly being used despite limited or no evidence of their effectiveness.[26–29] There are several contributing factors to this including the speed at which digital interventions are being developed; the need to embed them during new health facility construction; a lack of control and governance over what tools are used, by whom, and when; the need for small-medium technological development companies to adopt an agile approach to creating and installing products and a lack of resources that can be dedicated to running robust effectiveness trials.[30] These challenges make it difficult to apply implementation science processes at the start of conception and testing, particularly in the context of limited resources for research and development and the length of time required to perform quality implementation studies. For all these reasons, the digital platform used in this study was not able to be prospectively tested for its impact on falls, and there are many examples where this will not be feasible. Replication of the approach outlined here may facilitate the generation of evidence over time as to effectiveness.

There are several important limitations to this study. First, it was not possible to sufficiently power the study to detect a change in clinical outcomes. The rate of falls is such that hundreds of thousands of admissions would be needed to establish if the system can make a difference, and the study funding and timelines did not allow for this. In addition, an apriori sample size calculation was not feasible due to the heterogeneity created by moving to a different hospital site, as well as funding and timeline constraints. Second, there were both inconsistent participation levels in terms of response

numbers and ward location for the survey results. We were also reliant on self-reported data in the context of system use. Administrative data that was not available at the time of the study may have shown true compliance with the system would make the study findings more robust. Finally, it was not possible to ascertain a length of stay on a ward basis. Given that there was variable ward participation in the survey, there was likely variable uptake across wards, which may have been more obvious if a ward level analysis was able to be performed. Future studies should try to ensure that data is inclusive of exact ward locations in the context of capturing length of stay and rate of falls.

Conclusion

While the digital fall prevention platform did not demonstrate the desired impact on clinical outcomes, there were other positive aspects noted about the system including significantly increased staff efficiency in communication, satisfaction and the perception that patients were better cared for. The use of a co-designed IEP positively influenced engagement and uptake and should be used in the future to maximise innovation uptake. In the future, well-powered longitudinal studies that focus on understanding the efficiencies identified are needed to better understand the system's impact on patient outcomes.

Acknowledgments

We would like to acknowledge the executive support of Ms Paula Richards (Director of Nursing & Midwifery, Lower Hunter Sector, Australia) to this project. We would also like to acknowledge the support of staff from Rauland Australia in facilitating system improvements and actioning enhancements. This paper has been uploaded to Research Square as apreprint: https://doi.org/10.21203/rs.3.rs-6372140/v1.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study was funded by Rauland Australia.

Disclosure

The authors report no conflicts of interest in this work.

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