

An AI enabled Predictive Harm Response Management algorithmic tool to reduce adverse events in healthcare settings (PreHaRM) research protocol

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Abstract

Background: Current data analysis methods do not effectively support nurses in risk reduction as retrospective reporting lacks real-time insights and precludes proactive care. However, analysis of administrative data within Australia's healthcare sector may have the potential to address this short coming. Predictive analytics can transform this data into meaningful insights, identifying harm risk profiles that benefit the performance of Australian and international clinical programs. Importantly these tools may offer support to nurses in precluding adverse events and predicting high-risk situations.

Researchers, with assistance from local health network staff, are developing a proof-of-concept predictive risk algorithm. The 'Predictive Harm Response Management algorithmic tool to reduce adverse events in healthcare settings' program (Project #DHCRC-0156) will provide real-time insights via an interactive dashboard, enabling nurses to assess risks and optimize resources in healthcare settings. This protocol details the algorithm development activities for sub-project 1a: 'Predictive risk model development'; which aims to develop and pilot-test a predictive harm algorithm for two South Australian local health networks.

Objective: 1) Identify the clinical harm outcome of interest and relevant data sources per site and build a suitable data solution to model predictors of harm risk.

2) Identify actionable clinical, workforce, and environmental factors that are affecting the harm outcome of interest.

Methods: This study design includes three phases (i) model generation, (ii) model evaluation, and (iii) prototype development. Data linkage by the SA-NT DataLink can only proceed following receipt of approval from each of the following: SA DHW ethics, UniSA ethics, and Hospital governance committees. The clinical dataset will be divided into a training set, validation set, and test set. Exploratory Data Analysis will be undertaken to ascertain features and classify outcomes from the raw dataset. Initially, modelling packages will be used for feature selection with imputed data. Imputation models will be built using features that have at least a minimal correlation with the variable being imputed. Once feature selection is complete, imputation will be repeated, incorporating additional predictors. Iterative model development will occur over three stages while a dashboard to display these results will be developed.

Results: The study commenced on 19 July 2021 and will cease on 31 June 2025. Finalised results are expected November 2025.

Conclusions: This research will conclude with a presentation of the PreHaRM tool, consisting of the algorithm and dashboard, within two South Australian Local Health networks. Research activities will be reported in publicly-available reports and manuscripts prepared for peer-reviewed journals and be drafted in accordance with existing and appropriate checklists. Clinical Trial: N/A

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An AI enabled Predictive Harm Response Management algorithmic tool to reduce adverse events in healthcare settings (PreHaRM) research protocol

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Abstract

Background:

Current data analysis methods do not effectively support nurses in risk reduction as retrospective reporting lacks real-time insights and precludes proactive care. However, analysis of administrative data within Australia's healthcare sector may have the potential to address this short coming. Predictive analytics can transform this data into meaningful insights, identifying harm risk profiles that benefit the performance of Australian and international clinical programs. Importantly these tools may offer support to nurses in precluding adverse events and predicting high-risk situations.

Researchers, with assistance from local health network staff will develop a proof-of-concept predictive risk algorithm. The 'Predictive Harm Response Management algorithmic tool to reduce adverse events in healthcare settings' program (Project #DHCRC-0156) will provide real-time insights via an interactive dashboard, enabling nurses to assess risks and optimize resources in healthcare settings. This protocol details the algorithm development activities for sub-project 1a: 'Predictive risk model development'; which aims to develop and pilot-test a predictive harm algorithm for two South Australian local health networks.

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Keywords

Nursing,
Artificial intelligence,
Risk prediction,
Patient Falls,
Medication Error,
Occupational Violence.



Introduction

Adverse events occur despite of the efforts and diligence of health professionals. Their occurrence is experienced amongst patients, their families as well as the staff and the healthcare system generally. Across the Australian healthcare system, patient falls, medication errors and occupational violence and aggression have a frequency and consequence that is as pronounced as it is avoidable.

Hospital falls represent a significant challenge in healthcare settings. A multisite prospective cohort study conducted from 2011 to 2013 across 12 acute medical and surgical wards in six Australian hospitals found that out of 27,026 hospital admissions, 3.6% involved at least one fall, and 1.2% resulted in a fall-related injury. [1] Estimates suggest that the cost per fall in a healthcare setting can range from approximately AUD 10,000 to AUD 40,000 per fall. [1, 2]

Following falls, medication errors are the second most frequently reported incidents in healthcare settings,[3] and are defined as mistakes occurring at any stage of the medication process, whether ordering, dispensing, administering, or monitoring, that result in harm or pose a risk to patients. [4] It is estimated that medication-error-related hospitalization in Australia costs approximately AUD \$1.2 billion annually. [5]

Although all healthcare professionals are at risk, nurses often face the highest risk of assault with research estimating that approximately 67% of nurses are likely to have experienced some kind of occupational violence in the past year. [6, 7][8] A systematic review identified that overall exposure to violence toward nurses can be estimated at 36.4% for physical violence, 66.9% for nonphysical violence, 39.7% for bullying, and 25% for sexual harassment. [9] Beyond the direct distress and physical harm caused by such violence, there is a range of negative outcomes including increased risk of psychological disorders such as post-traumatic stress disorder and depression, [10] [11] higher rates of occupation burnout and absenteeism. [12] [13]

Ward workforce availability and composition can affect patient outcomes, with lower skill mix levels linked to longer stays, and reduced nurse numbers leading to increase in adverse patient outcomes, including ‘mortality, infections, falls, and longer lengths of stay’. [14] Skilled nursing care has substantial potential to prevent HACs, as nurses spend the most time at the bedside and directly influence patient outcomes. Determining the optimal balance of trained professionals is essential to maintaining high-quality care while managing staffing costs.

Current data analysis and reporting methods do not effectively support nurses in risk reduction, with existing retrospective reporting failing to provide real-time risk insights, thereby limiting proactive care. The vast amount of routine administrative data is collected and stored within the Australian healthcare sector contains a wealth of insightful and actionable information. Access and analysis of which could enable clinical process improvement, enhanced patient safety and clinical outcomes, as well as future workforce planning. However, it is currently not being utilised to its full potential. Predictive analytics can use this data to provide meaningful insights in to the harm risk profiles for Australian as well as international clinical programs, to support nursing staff to proactively minimize the likelihood of adverse events, and to predict the manifestation of high-risk clinical situations.

PreHaRM project overview

An initial examination hospital ward and workforce data by the Rosemary Bryant AO Research Centre (RBRC) at the University of South Australia (UniSA), in collaboration with Central Adelaide Local Health Network (CALHN) identified the presence of factors that may contribute to the occurrence of adverse events. Based on this finding, a proposal to develop a prognostic predictive risk algorithm was submitted to the Digital Health Cooperative Research Centre (DHCRC).The resultant ‘PreHaRM: A Predictive Harm Response Management algorithmic tool to reduce adverse events in healthcare settings’ program (PreHaRM program) will seek to develop a predictive risk algorithm and results dashboard (henceforth known as the PreHaRM tool). Development of the PreHaRM tool in collaboration with the Industrial AI Research Centre at UniSA will utilize existing

software platforms to build a visual, interactive application for Ward Nurses and Nurse Unit Managers to view real-time insights, input variables and data of their own, and produce assessments and resource predictions based on real clinical and administrative data.

The PreHaRM program is comprised of the following two main projects 1) Algorithm development and implementation; and, 2) Development of dashboard design and function recommendations. The objectives per project, and sub-projects are detailed in the following table:

Project	Sub-project	Objectives
1	1a	1) Identify the clinical harm outcome of interest and relevant data sources per site and build a suitable data solution to model predictors of harm risk.
		2) Identify actionable clinical, workforce, and environmental factors that are affecting the harm outcome of interest.
	1b	3) Use an appropriate implementation research framework to ensure the tool is useable in the clinical environment as intended, so that it has the greatest chance to maximise the project's long-term objectives
		4) Use the information derived from objectives 1-3 to develop a suitable interactive, software solution designed to meet end-user needs
		5) Evaluate the effectiveness of the tool to (i) support proactive clinical staff decision-making with the goal of reducing clinical harm outcomes (e.g.: adverse events such as in-patient suicides, falls and code blacks), and (ii) reform the way health services manage their services and their ability to undertake long term planning for organisational and clinical strategic redesign
2		1) Identify health professionals design preferences for GUI aesthetics and function.
		2) Identify health professional usability levels for professional practice and PreHaRM GUIs.
		3) Identify health professional acceptability levels for professional practice and PreHaRM GUIs.
		4) Identify health professionals' perceptions of AI in health care in relation to its implementation and adoption.

This protocol details the algorithm development activities for sub-project 1a: 'Predictive risk model development'; noting that the protocol for subproject 1b: 'Implementation of the tool in a clinical environment' are being finalised for ethics review. In addition, the method developed for sub-project 2 has been published in an earlier protocol (<https://doi.org/10.2196/47717>).

The PreHaRM program, is supported by Digital Health Cooperative Research Centre (DHCRC) Limited. DHCRC Limited is funded under the Australian Commonwealth Government's Cooperative Research Centers Program (Project #DHCRC-0156).

Methods

Aim:

Develop and pilot-test a predictive harm algorithm for two South Australian local health networks.

Objectives:

1. Identify the clinical harm outcome of interest and relevant data sources per site and build a

suitable data solution to model predictors of harm risk.

2. Identify actionable clinical, workforce, and environmental factors that are affecting the harm outcome of interest.

Design:

This study design includes three phases: model generation, model evaluation, and, prototype development. The planned approach to these stages is outline below.

Model Generation:

- Individual predictive classification models will be created to predict each clinical harm factor of interest. Suitable model architectures will be selected to account for the imbalance of the target variable and patient cohort distribution, temporal variation of features, and high-dimensionality of the dataset. Classification model architectures such as weighted logistic regression, random forest, gradient boosting, and recurrent neural networks will be considered.
- A risk score will be derived from the predictive models, and the contribution of specific features to predicted risk outcomes will be quantified using statistical and feature importance analysis techniques.
- Model selection and model optimisation will occur using a separate validation data set to avoid bias. Cross-validation will be considered if a separate validation set is at risk of bias.
- The models will be developed using Python, scikit-learn, and pytorch.

Model Evaluation:

- The models will be evaluated using metrics including Specificity, Sensitivity, F1 score, Receiver operating characteristic curve (ROC curve), and accuracy.
- The experiment will be repeated several times to eliminate stochastic variation.
- The final chosen models will be evaluated on the independent test set to obtain an unbiased estimation of predictive outcomes.
- Transparent reporting of a multivariable prediction model for individual diagnosis or prognosis (TRIPOD-AI) reporting guideline will be followed during model development and evaluation. [15]

Prototype development:

- Visualization elements to be drawn as a dashboard based on the Key Performance Indicators (KPIs) according to the gathered information from the workshops by leveraging facts and dimensions for insightful analysis and decision-making.
- A prototype will be developed that incorporates the model developed in the previous phases with the dashboard.
- Loading of the prototype onto laptop for demonstration purposes.

Table 1: Alignment of project objectives to outcomes.

Objectives	Phase	Outcomes
1) Identify the clinical harm	Model development	• Confirmation by local health networks on pertinent adverse events of interest.

outcome of interest and relevant data sources per site and build a suitable data solution to model predictors of harm risk.	Model evaluation	• Confirmation by local health networks of datasets and date ranges can be accessed. • De-identification and data-linkage of datasets. • Scoping review identification of data-variables related to adverse events of interest. • Construction of a predictive model. • Comparison of chosen model results against actual outcome. • Phase reporting in accordance with TRIPOD-AI.
2) Identify actionable clinical, workforce, and environmental factors that are affecting the harm outcome of interest.	Prototype development	• A dashboard for Nurse Unit Managers that visualises the risk of patient falls created using Sub-project 2 results. • Completion of the PreHaRM prototype tool (Algorithm model linked to dashboard). • Presentation of prototype to local health network staff to identify factors related to this adverse event.

Setting

The settings required to achieve this research differ depending on the phase of research being conducted, and have been detailed below:

- Model development and evaluation activities will occur at the Central Adelaide Local Health Network (CALHN) and the Southern Adelaide Local Health Network (SALHN), the SA-NT DataLink, and the UniSA High Performance Computing facility.
- Prototype development activities will occur that the Rosemary Bryant Research Centre, the UniSA High Performance Computing facility, and the CALHN and SALHN.

Research materials:

Patient clinical event data routinely captured by hospitals will be sought where it meets the following criteria:

- Attended the following health services between the 1 July 2019 until 30 June 2022.
- CALHN – Royal Adelaide Hospital (RAH) and Queen Elizabeth Hospital (QEH): Inpatient, general medical wards.
- SALHN – Flinders' Medical Centre (FMC) Emergency Department, all general medical wards & Margaret Tobin Centre.

Data linkage

Data linkage by the SA-NT DataLink can only proceed following receipt of approval from each of the following: SA DHW ethics, UniSA ethics, and Hospital governance committees. On receipt of these approvals, data will be released from hospitals within the CALHN and SALHN jurisdictions to SA-NT Datalink who will work to de-identify and link patient data prior to hospital data release to the UniSA research data management facility.

Data Analysis Plan

Exploratory Data Analysis will be undertaken to ascertain candidate features from the raw datasets. Integration of patient, hospital, and staff-related data will be performed to form a comprehensive dataset. Drawing on medical and organisational knowledge, potentially relevant features will be identified, and additional features may be synthesised from the data. Feature selection and feature engineering using domain knowledge to identify potentially useful intrinsic and time-variant features to be considered in the model. The data will be partitioned into training, validation, and test data sets while accounting for the imbalance of the target variable distribution and temporal variation of features.

Data management

The information for this project is expected to be stored for a maximum of five years post publication of the findings, consistent with the National Health and Medical Research Council (NHMRC) guidelines for research data. [16] Written approval will be obtained from the Dean of Research (UniSA Clinical and Health Sciences) to delete all data files after the retention period has elapsed, with a digital data destruction certificate issued confirming that the University has destroyed the data.

Project reporting

It is intended that, where appropriate, research activities will be reported in publicly-available reports and manuscripts prepared for peer-reviewed journals. Where appropriate reporting will follow the TRIPOD+AI checklist. [15] It is intended that the project, and any available results, will also be presented at scientific and public conferences; noting no individual-level, or identifiable data will be reported.

Sample size estimation & justification:

A total of between 500,000 and 1,500,000 samples will be sought in total across the two settings of interest.

Ethics:

To commence research activities, this project has sought and received each of the following requisite approvals:

- SA Health DHW ethics approval: 2022/HRE00131
- UniSA ethics approval: #204143
- SA Health DHW governance approval: 2022/SSA00288
- Royal Adelaide Hospital governance approval: 2022/SSA00273
- Queen Elizabeth Hospital governance approval: 2022/SSA00274
- Flinders' Medical Centre governance approval: 2022/SSA00275
- Population Health Research Network approval: P0081_2021

Project governance:

The project is governed by a project control group (PCG) that includes executive representation from each of the stakeholders: UniSA, CALHN, SALHN, SA Health DHW, SA-NT DataLink and the DHCRC. In addition, three working groups have been established:

- A Technical Architecture Group (TAG) that discusses details related to development of the algorithm and development of the software solution.
- Two Clinical Implementation Groups (CIG), one CIG per LHN, that discusses dataset related details, LHN implementation, and current issues within the health system that may affect project delivery.

Results

The study commenced on 19 July 2021 and will cease on 31 June 2025. Finalised results are expected November 2025.

Discussion

Identifying and quantifying risk allows nursing staff greater insight when initiating preventative and/or therapeutic measures in a timely fashion to mitigate undesirable effects of adverse patient events. The patient safety implications from this research are significant; the algorithm will provide early recognition of potential patient falls, medication errors and occupational violence and enable timely intervention.

As a result of successfully developing and implementing the PreHaRM solution, clinical leaders will have a predictive analytical tool embedded within an interactive software interface located on an appropriate health system IT infrastructure. This will enable nursing staff to identify harm and reduce risks that lead to adverse events, this resource planning enabled by PReHaRM insights will place participating Local Health networks in an advantageous position when faced with resources constraints.

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