A Systemised Approach to Smart Pump Integration with an Electronic Medical Record System – An Australian Experience

ORIGINAL RESEARCH

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ABSTRACT

Background: Smart pump integration with Electronic Medical Record (EMR) systems offers an opportunity to introduce a closed-loop medication management system in hospital settings. Closed-loop medication management systems minimise human errors, improve nursing workflow and efficiency, and optimise patient safety. In this descriptive observational study, we will outline some of the key steps required to successfully integrate a smart pump dataset with EMR computerised provider/physician order entry (CPOE) systems.

Methodology: The triple C model of consultation, collaboration and consolidation was used for the development and implementation of a smart infusion pump and EMR integration at a 160-bed specialist Australian hospital. This systemised approach allowed a methodical implementation process and ensured sustainability of the intervention. Key stakeholders were identified and engaged to establish a working group to align medication orders in the EMR and the smart pump library to ensure readiness of pump-EMR integration phase. Validation testing was conducted for each EMR infusion order to check successful auto-programming to a corresponding medication on the smart pump. The steps discussed are applicable to all hospital settings with EMR systems and smart pumps.

Results: The smart pump dataset contained a total of 217 unique medications and fluids that were tested for interoperability. A total of 87% (188/217) passed full record testing. The remaining 13 % (29/217) were excluded from interoperability. The 13% of medication and fluids that were excluded was due to the medication being prescribed on paper (i.e. medicines with desensitisation regimen), the medication unable to be prescribed as a medicine in the EMR (i.e. blood products), the smart pump limitations to build safety limits around only one medicine (i.e. multi-additive infusions) or excluded due to specialist hospital formulary.

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Conclusion: This study using a systemised approach, that described and identified key stages and phases required for integration of smart pump infusions with an EMR system, to create a closed-loop medication management system in an Australian hospital setting.

Highlights

- Smart pump integration with Electronic Medical Record (EMR) systems offers an opportunity for closed-loop medication management systems and has the potential to reduce human errors.
- Establishing a working group consisting of subject matter experts, clinicians, smart pump and EMR vendors, and information technology experts is required for successful delivery of interoperability.
- Described and identified key stages for integration of smart pumps with EMR in an Australian hospital setting.

INTRODUCTION

With the increasing use of infusion pumps for medication administration in health care services, smart pumps have been accepted as a standard of care for reducing infusion-related medication errors [1]. Features of smart pumps include medication libraries, profiles of care areas, built-in soft and hard limits for administration rates, doses and concentrations, and the option to integrate with Electronic Medical Record (EMR) systems [2].

The use of advanced medication technologies is an increasingly important part of health-system pharmacy practice [1]. Interoperability of systems refers to the automatic pairing of an EMR infusion order with a smart pump entry and subsequent upload of infusion-related information from the smart pump to the EMR [3]. Bi-directional communication between smart pumps and EMR can lead to improved patient safety [1]. These features play an important role in facilitating appropriate medication selection and reducing user errors in the medication administration process [2]. Administration is the final step of the medication management pathway and is therefore the last opportunity to check for any discrepancies between what is prescribed and what is intended for administration before the patient receives the medication [4]. Automation of the 'administration of medicine' step in the medication management pathway creates a closed-loop medication management pathway which reduces human errors and optimises patient safety [4, 5].

Well-documented medication safety initiatives to improve quality of care of patients in health settings that are cited in the literature involve the introduction of system-based interventions and elimination of human-based processes [5]. These include integration of various interfaces together, introduction of forcing functions in electronic medication management systems, as well as maximising opportunities for automation and computerisation of any relevant processes in the medication pathway [6]. These interventions have demonstrated reduction of medication errors across the medication management pathway which have the potential to drive excellence in healthcare [7, 8].

Auto-programming smart pumps via EMR integration is a medication safety initiative that offers an opportunity to introduce a closed-loop medication management system in hospital settings and improve patient safety [5]. This is achieved via a bi-directional wireless connection through which information from a Computerised Provider/Physician Order Entry (CPOE) order is transmitted from the EMR and pre-populates on the infusion pump device [9]. Auto-programming reduces keystrokes and opportunities for manual data input error [6]. Additionally, smart pump integration provides the ability for infusion-related actions performed on the pump to be automatically documented on the EMR. Auto-programming and auto-documentation enhances patient safety as a result of streamlined clinician workflows [6, 9].

The uptake of digital technology to integrate processes and functionalities to support automated documentation, and delivery of near real-time data between medical devices is becoming the new standard of care for infusion therapy that provides quality of care [1, 2]. To date, there is limited published data on interoperability of smart pumps with EMR in Australia [10]. This article outlines an Australian experience in mapping the steps required to integrate the BD™ (United States (US)) Alaris with Guardrails dose error reduction software (DERS) smart pump medication/fluid library with Cerner© (US) EMR CPOE systems across a 160-bed specialist health service.

To ensure successful alignment and interoperability of the systems, a hospital-wide, multidisciplinary, systematic approach is required to standardise pump medication/fluid library, EMR infusion orders and clinical workflows

[6, 11]. This methodology and implementation study used the Triple C method of consultation, collaboration and consolidation to develop and implement this project. The principles of this model allow for sustainability of the project implementation at all stages, through process mapping, defining key stakeholders' roles and responsibilities and standardising workflows within an organisation [12].

DESIGN AND DEVELOPMENT OF THE METHODOLOGY

STAGE 1: CONSULTATION PHASE

The project started with a kick-off meeting to define the scope of the project, timeline, key milestones and key stakeholders. The main goal was to ensure the smart pump and the EMR systems were capable of interoperability from a technical and clinical workflow standpoint. In line with recommendations from the Institute for Safe Medication Practices (ISMP) Guidelines for Optimising Safe Implementation and Use of Smart Infusion Pumps, an expression of interest was sent out to form our team [3]. This phase included 2 steps as follows:

1. Identifying and engaging key stakeholders

Our team included key stakeholders from external Becton, Dickinson and Company (BD™) smart pump vendors, Cerner© EMR vendors, pharmacists, subject matter experts in digital health integration, clinical nursing and nursing education, medical personnel, information technology (IT) experts, biomedical engineering and risk and project management [6, 13, 14]. All members of the group had extensive experience in their professional fields and were leaders in their practice area.

2. Defining roles and responsibilities of the key stakeholders

Integrated workgroups were formed following the identification of key stakeholders. A working group of staff were identified and started the initiative. Their roles and responsibilities are defined in ***Table 1***. The following steps were undertaken by the working group:

1. Defining project milestones and timelines.
2. Establishing the required infrastructure to support interoperability.
3. Setting up clinical priorities and workflow for integration.
4. Reviewing and aligning all EMR infusion orders and the smart pump medication/fluid library.
5. Ensuring there are processes for governance for maintenance of the smart pump library and EMR infusion orders.

STAGE 2: COLLABORATION PHASE

The collaboration process of this study required the team members to complete each of their allocated tasks to

TEAM	ROLES	PRIMARY RESPONSIBILITIES
Executive sponsors	Hospital • Chief Nursing Officer • Chief Operating Officer	• Project oversight
Project management team	Hospital • Project manager Pump supplier • Project manager *EMR provider • Integrated technologies owner	• Steer the project • Facilitates project meetings • Ensure timeline met • Co-ordinates resources • Coordinates technology conversion • Leads validation testing
Clinical management team	Hospital • Health system clinical nurse lead • SME*/CNE** Pump supplier • CNE EMR provider • Clinical consultant	• Facilitate project meetings • Policy and procedure revision • Lead new and ongoing workflows • Develop and lead education • Consults on dataset alignment
Pharmacy management team	Hospital • Pharmacy project manager • EMR pharmacist • Lead pump pharmacist • Medication safety pharmacist Pump supplier • Medication safety consultant EMR provider • Pharmacy clinical consultant	• Facilitate project meetings • Lead dataset alignment • Policy and procedure revision • Leads new and ongoing workflow • Develop infusion management workflows • Develop and deliver education • Drives validation testing • Oversees connectivity testing and troubleshoots any messaging errors
Medical	Hospital • Medical SME*	• Consult on dataset alignment • Consult on clinical workflow changes

(contd.)

TEAM	ROLES	PRIMARY RESPONSIBILITIES
Information systems	Hospital • IT support staff	• Software installation and upgrades • Support network wireless infrastructure and servers • Assist during validation testing
Biomedical engineers	Hospital • Clinical Biomedical Engineer	• Device software upgrade • Barcoding pump modules • Equipment setup, quality control and configuration

Table 1 Smart Pump and EMR Integration Implementation Project Team Roles and Primary responsibilities.

SME*: Subject matter expert (clinical nurse specialists or medical specialist).

CNE:** Clinical nurse educator.

***EMR:** Electronic medical records.

IT: Information technology.

ensure successful alignment of medication orders in the EMR and the smart pump. This is to ensure readiness of pump-EMR integration as outlined in similar studies [13].

1. Aligning of smart pump dataset and EMR formulary

To facilitate alignment, the EMR pharmacist and the medication safety and lead smart pump pharmacist, worked simultaneously to achieve this goal. Reviewing and alignment of all medication data sets were required for initial testing. An exact match was required of the medication names, standardised concentrations and units, dosing units and rates, diluent volume and dosing limits [3, 13].

2. Planning and reviewing medication and fluids dataset

Medicines and fluids included for EMR-smart pump interoperability were classified into three infusion categories: intermittent infusions, continuous infusions and fluids for interoperability validation testing. A total of 194 unique medicines and 23 fluids, corresponding to 484 medicines and fluid concentration entries, were required to be built in the hospital dataset and integrated with the EMR system. In this dataset, the same medicine has multiple concentrations built, accounting for the various doses and indications that it can be used for.

Dataset alignment started with simpler infusions, such as medications built in the smart pump dataset as intermittent infusions. This was followed by fluids, then continuous infusions. This approach was used to assist in understanding the integration process for simpler infusions, and to apply principles of integration on the more complicated, titratable medicines and fluids.

3. Building the smart pump dataset

A test server profile for the smart pump dataset was created by IT services from the systems vendors and hospital. This was built to assess interoperability. Each medication and fluid in the dataset was built and assigned a corresponding catalog CD or Alias (for multi-additive infusions) by the EMR medication management team and entered by the smart pump pharmacist. A catalog CD or Alias number is an EMR identifier used to associate an EMR CPOE order with a smart pump entry. An Alias is an organisation defined number that only exists to create a match with a smart pump entry. Conversely, a catalog CD is provided by the EMR system.

Any changes were made prior to validation testing in a systems test server to minimise disruption to daily clinical practice for the rest of the organisation.

4. Management of discrepancies of alignments

During the process of alignment between EMR formulary and smart pump dataset some of the challenges identified were:

- Multi-additive infusions: The smart pump library cannot always accommodate all possible combinations without compromising workflow and functionality. An example of this scenario includes subcutaneous palliative care infusions. These infusions can have infinite possible combinations of medications and doses, and restricting limits to only one high risk medicine can impact clinical workflow and patient safety.
- Weight-based versus non-weight-based infusions: EMR infusion orders allows for both weight-based and non-weight based dosing, whereas Dose Error Reduction Software (DERS) only offers the one option if not built out both ways. An example of this is antimicrobials which are commonly prescribed as a set dose (e.g. grams), as well as weight based (e.g. mg/kg).
- Medications where the dose prescribed is greater than one commercial pack size of the product. An example of this is fluconazole, where the proprietary product is 200 mg/100 mL, whereas doses can be prescribed up to 400 mg.

To overcome some of the above-mentioned challenges and after consultation with relevant stakeholders,

changes to medication build in the EMR and/or smart pumps medication/fluid library, as well as clinician's workflows were made. The following changes made included:

1. Excluding multi-additive infusions from interoperability as challenges could not be overcome at this stage. However, clinicians will still be able to manually program this infusion, which ensures patient safety as appropriate limits are built in the smart pumps.
2. Streamlining the build of all antimicrobial medications in the pumps as a non-weight based entry. This was decided upon as it suited the cohort of this specialist hospital and did not include paediatric patients.
3. Interoperability of high dose intravenous medications that used multiple infusion bags required a manual change of the total volume to be infused on the smart pump.

Once alignment had been established and instances where failed interoperability identified, an updated workflow was mapped out and documented for end users by the working group. This was completed according to the ISMP Guidelines for Optimising Safe Implementation and Use of Smart Infusion Pumps [3, 13, 14].

STAGE 3: CONSOLIDATION PHASE

The consolidation phase required extensive validation testing to verify that each catalog CD or Alias had been correctly assigned to the appropriate medication in the smart pump dataset. Additionally, it required designing clinicians' workflows and setting up governance of the new process.

1. Validation testing of interoperability

Validation testing of integration of the dataset was conducted as a live event. The lead smart pump pharmacist conducted testing and troubleshooting prior to the live event that included project managers, pharmacy, nursing, IT consultants and external pump and EMR vendors. This involved validating that each EMR infusion order had successfully auto-programmed to a corresponding medication on the smart pump [15]. Furthermore, this stage included mapping clinician workflows to ensure sustainability and successful integration into every day practice.

2. Outcome of validation testing of interoperability

A total of 217 unique medications and fluids that were built in the smart pump dataset were tested. Of these, a total of 87% (188/217) passed full record testing. The remaining 13% (29/217) were excluded from interoperability. Refer to ***Tables 2, 3*** and ***4*** for a breakdown of medications and fluids entries. The 13% of medication and fluids that were excluded were due to the medication being prescribed on paper (i.e. medicines with desensitisation regimen), the medication unable to be prescribed as a medicine in the EMR (i.e. blood products), the smart pump limitations to build safety limits around only one medicine (i.e. multi-additive infusions) or excluded due to specialist hospital formulary.

INTERMITTENT*			CONTINUOUS**			FLUIDS***		
MEDICATION CLASS	NO.#	%	MEDICATION CLASS	NO.#	%	FLUIDS	NO.#	%
Antiarrhythmic	4	3.4	Anaesthetic	5	8.3	Contrast	1	10.0
Antibiotic	39	33.1	Antiarrhythmic	4	6.7	Glucose	3	30.0
Antidiuretic hormone analogue	2	1.7	Anticoagulant	2	3.3	Glucose/sodium chloride combination	2	20.0
Antidote	3	2.5	Antidote	2	3.3	Hartmanns	1	10.0
Antiemetic	1	0.9	Antihypertensive	3	5.0	Sodium chloride	2	20.0
Antiepileptic	4	3.4	Antiplatelet	1	1.7	Parenteral nutrition	1	10.0
Antifungal	10	8.5	Beta2 agonist	1	1.7			
Antihypertensive	1	0.9	Diuretic	1	1.7			
Antineoplastic	1	0.9	Electrolyte	6	10.0			
Antipsychotic	1	0.9	Inotrope/vasopressor	10	16.7			
Antiviral	4	3.4	Insulin	1	1.7			
Bisphosphonate	3	2.5	Iron	1	1.7			
Corticosteroid	2	1.7	Monoclonal antibody	3	5.0			
Diuretic	1	0.9	Neuromuscular blocker	4	6.7			

(contd.)

INTERMITTENT*			CONTINUOUS**			FLUIDS***		
MEDICATION CLASS	NO.#	%	MEDICATION CLASS	NO.#	%	FLUIDS	NO.#	%
Electrolyte	7	5.9	Nitrate	1	1.7			
H2 antagonist	1	0.9	Opioid	4	6.7			
Immunosuppressant	5	4.2	Other	7	11.7			
Insulin	1	0.9	Other endocrine	2	3.3			
Iron	2	1.7	Proton pump inhibitor	2	3.3			
Monoclonal antibody	4	3.4						
Non-opioid analgesic	3	2.5						
Other	11	9.3						
Other endocrine	1	0.9						
Proton pump inhibitor	2	1.7						
Thrombolytic	1	0.9						
Vitamin	4	3.4						
Total	118			60			10	

Table 2 The classification of medications and fluids included for interoperability.

***Intermittent medicine**: A medication or fluid infusion that is delivered over a specified time at prescribed intervals.

****Continuous medicine**: A medication or fluid that is prescribed with a dose-rate (e.g., 10 mg/kg/min). The infusion continues until therapy is no longer required or when the solution container is depleted. Dose-rate programming changes may occur during the infusion.

*****Fluids**: A fluid that is prescribed with an infusion rate (e.g., mL/hour). The infusion continues until the therapy is no longer required or when the solution container is depleted. Rate programming changes may occur during the infusion.

#**No.**: The number of unique medicines and fluid in each class.

INTERMITTENT*			CONTINUOUS**			FLUIDS***		
MEDICATION CLASS	NO.#	%	MEDICATION CLASS	NO.#	%	MEDICATION CLASS	NO.#	%
Antivenom/Antidotes	5	83.3	Medication Challenge	9	90.0	Blood product	11	84.6
Other	1	16.7	Electrolyte	1	10.0	Palliative Care 24hr subcutaneous infusions	1	7.7
						Clinical trial	1	7.7
Total	6			10			13	

Table 3 The classification of medications and fluids excluded for interoperability.

***Intermittent medicine**: A medication or fluid infusion that is delivered over a specified time at prescribed intervals.

****Continuous medicine**: A medication or fluid that is prescribed with a dose-rate (e.g., 10 mg/kg/min). The infusion continues until therapy is no longer required or when the solution container is depleted. Dose-rate programming changes may occur during the infusion.

*****Fluids**: A fluid that is prescribed with an infusion rate (e.g., mL/hour). The infusion continues until the therapy is no longer required or when the solution container is depleted. Rate programming changes may occur during the infusion.

#**No.**: The number of unique medicines and fluid in each class.

	MEDICATIONS	FLUIDS	TOTAL NUMBER OF MEDICATIONS AND FLUIDS	PERCENTAGE
Passed	178	10	188	87% (188/217)
Excluded	16	13	29	13% (29/217)
Total	**194**	**23**	**217**	

Table 4 Number and percentage of medication and fluids tested for smart pump and EMR interoperability.

Passed: The number and percentage of medication and fluids that passed interoperability testing of smart pumps and EMR.

Excluded: The number and percentage of medication and fluids that were excluded from interoperability testing of smart pumps and EMR.

3. Workflow policies, procedures and governance

All stakeholders were involved in identifying emerging risks, discrepancies and refining workflows. In line with best practice and published literature, procedures and processes were documented to outline and guide workflows of medications [14]. These included:

- Transfer of patients between areas where there is no smart pump interoperability.
- Smart infusion pump dissociation between use on separate patients to avoid incorrect data association.
- Downtime procedures to guide workflow in situations when the system is not operational.
- Monitoring and sharing data available from smart pumps and EMR for ongoing Continuous Quality Improvement (CQI) metrics and maintenance.

All procedures and workflows were reviewed and endorsed by the hospital Medication Safety Committee to ensure they are embedded into the hospital governance process.

At the conclusion of this process, all 178 medications were successfully integrated with the EMR system and have undergone bi-directional integration with smart pumps. Clinician workflows were mapped out to ensure sustainability and integration into daily clinical practice.

DISCUSSION

This study used a consultation, collaboration and consolidation model to successfully develop and implement a complex intervention across a healthcare organisation to improve patient safety (refer to ***Figure 1***).

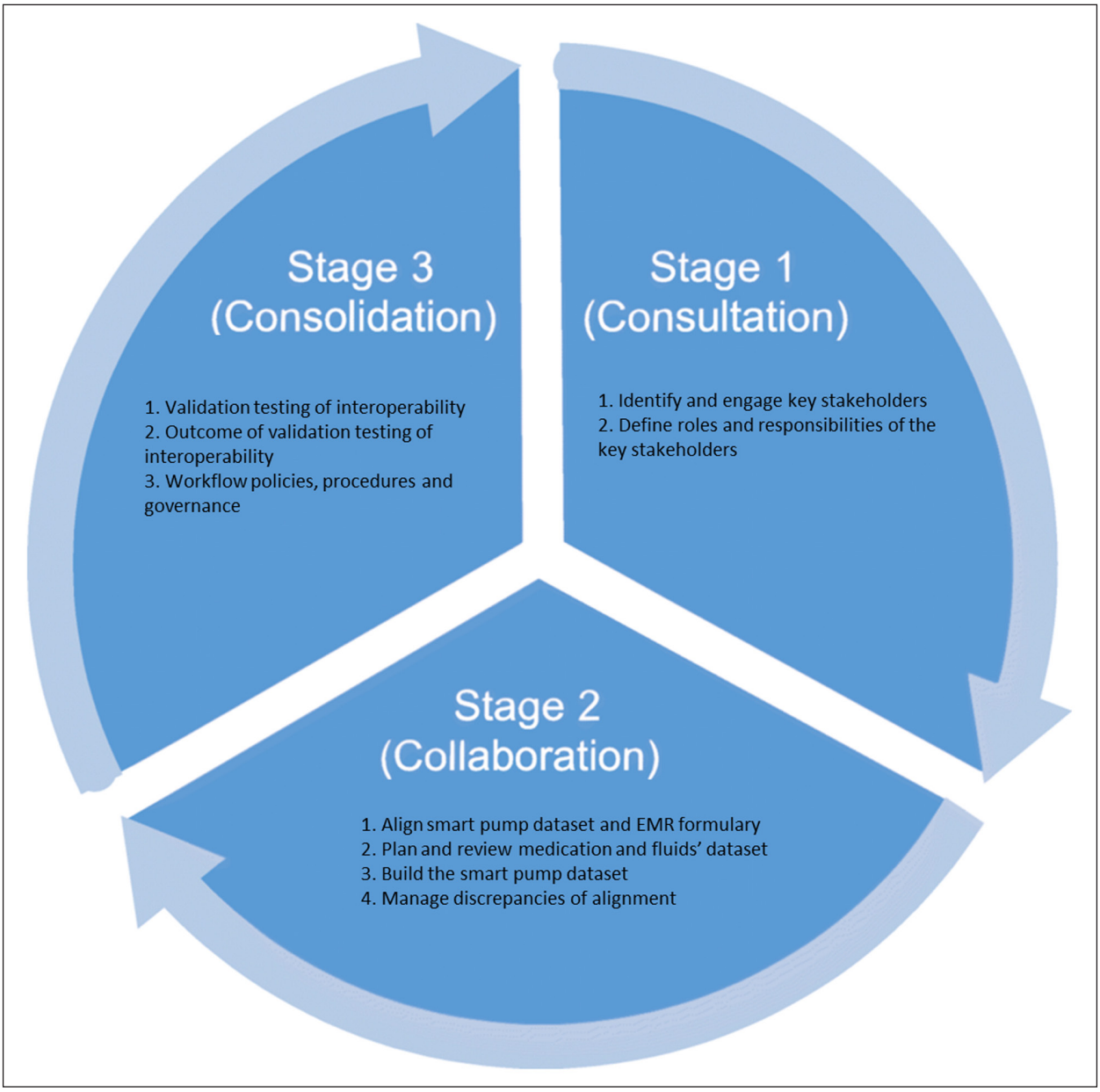

Figure 1 The Triple C Methodology for Implementation of Smart Pump and EMR Interoperability.

This process ensures adaptability and sustainability of the intervention discussed to enable continuous improvement processes in health organisations [12].

Auto-programming and integration between various systems interfaces removes human involvement with manual selection and transcription error. Studies have demonstrated that automation reduced keystrokes needed to program an infusion pump from 15 to 2 strokes (an 86% decrease), eliminating human errors [1, 6, 11]. Pump alerts, alert overrides, and reprogrammed or cancelled infusions also decreased [11], and studies demonstrated the use of DERS in smart pumps is guaranteed almost 100% of the time [3, 4, 6, 11]. EMR alerting systems also contribute to further improvements in patient safety [11]. More recently, automation in healthcare overall has been an area of considerable interest to reduce human errors, improve efficiency and deliver better care to patients [16].

This study demonstrated that applying an evidence-based methodology such as the Triple C method has resulted in the successful execution of the integration of smart pumps with EMR, and utilised a well-documented contemporary medication safety intervention to develop a closed-loop medication management system [6, 7, 17]. This intervention has the potential to significantly reduce human errors in the medication administration process, potentially improving patient care. Additionally, several studies have demonstrated similar contemporary initiatives when implemented successfully, reduce the overall incidence of medication errors in hospitals and improve patient safety [17].

Using a strategy of process mapping by clearly outlining the roles and responsibilities of each member of the stakeholder group in the project contributed to successful completion of the initiative. Similar to other studies, using a systemised approach enabled the successful development of a framework to guide integration of smart pumps and EMR interoperability [18]. In addition, as per other studies detailing interoperability of smart pumps with EMR, collaborative partnerships with key stakeholders of clinicians, informaticists, researchers, and engineers has led to successful implementation and development of a framework for interoperability to optimise patient safety [19, 20].

Although, the main strength of this methodology study is the detailed outline of implementation of an integrated medication and fluid dataset in smart pumps with EMR in an Australian setting, it has some limitations. This includes, the lack of quantitative data on the impact of the intervention on the frequency and patterns of intravenous medication administration errors involving the smart pumps. Additionally, qualitative data and economic cost for implementation was not evaluated.

Future work will focus on assessing user acceptability with interoperability, and the impact on workflow and organisational cost. This will be achieved by evaluating the DERS compliance, number of keystrokes and pump alerts, and the impact on medication errors to optimise patient safety. Additionally, this will include development of relevant policies and procedures to govern staff education and training, as well as, formalising quality improvement activities related to maintenance and updates of the datasets and their integration process.

Finally, this model of framework can also be used to map interoperability and automation of similar digital health projects such as integration of automated dispensing cabinets with EMR and dispensing software.

CONCLUSION

The study process described and identified key stages and phases for integrating smart pump infusions with EMR in an Australia hospital setting. They included collaboration and engagement of key stakeholders, consultation and support for technology infrastructure (such as the presence of pump wireless capability), and consolidation. Further work will include assessment of end user satisfaction as well as reviewing impact of both systems' interoperability on frequency and patterns of administration errors and patient safety.

SUBMISSION DECLARATION

This present work has not been published previously, is not under consideration for publication elsewhere, and will not be published elsewhere in the same form. All authors approved publication of this article.

DATA ACCESSIBILITY STATEMENT

The datasets for all medications that were tested during the current study are available from the corresponding author on reasonable request.

ETHICS AND CONSENT

This initiative was a methodology project of an improvement for a current practice and as it did not involve any participants, it received an exemption from the hospital ethics office. Study Human Research Ethics Committee (HREC) reference number: QA/82162/MonH-2021-294730(v1).

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