Nurses' Awareness Regarding Implementing Smart Pump to Enhance Safety and Error Reduction

Wafaa M Abd El kader[1], Maysa Saber M. Ismail[2]

[1]Pediatric Nursing Department, Faculty of Nursing, Alexandria University, Egypt
[2]Pediatric Nursing Department, Faculty of Nursing, Damanhur University, Egypt
wafaa.ahmed10@gmail.com

Abstract: Intravenous medication is essential for all pediatric hospital inpatients. However, providing intravenous therapy is complex and errors are common. 'Smart pumps' incorporating dose error reduction software has been widely advocated to reduce error. However, little is known about nurses' awareness regarding implementing smart pump to enhance safety and error reduction. Therefore, this study explored the nurses' knowledge regarding administration of intravenous infusion using smart pump.
[Wafaa M Abd El kader, Maysa Saber M. Ismail. **Nurses' Awareness Regarding Implementing Smart Pump to Enhance Safety and Error Reduction.** *Life Sci J* 2016;13(1s):152-160]. ISSN 1097-8135 (print); ISSN 2372-613X (online) http://www.lifesciencesite.com. 16. doi:10.7537/marslsj1301s1616.

Keywords: Awareness, Safety, Smart Pump.

1. Introduction

Medications are the most common treatment intervention used in healthcare around the world. When used safely and appropriately, they contribute to significant improvements in the health and well-being of patients. Medication safety is defined as freedom from preventable harm with medication use. Medication safety issues can impact health outcomes, length of stay in a healthcare facility, readmission rates, and overall costs. (1)

Medication safety has long been recognized to be important in the provision of patient care. With the evidence now pointing to medication errors as one of the leading causes of avoidable complications and deaths, medication safety is the responsibility of all members of the healthcare team. Reducing error and harm from medicines through safe and quality use is an important element of health care system which helps achieve safety and quality improvements in health care. (2)

As a patient safety initiative, effective use of smart pump technology is dependent not only on the design of the pump itself but also on the way it is implemented at the clinical settings. Therefore, smart pump system implementation must be viewed and approached as a patient safety initiative, rather than a pump replacement initiative in medication administration process. (3)

The administration of medications intravenously is an important part of the management of patients in pediatric settings. Due to the frequency of high-risk-of-harm medications given intravenously and the rapid onset of infusion medications, medication errors that occur in this method of therapy have great potential for patient harm especially pediatric patients (4,5). In an attempt to reduce medication errors at the administration stage, manufacturers have introduced intravenous (IV) infusion pumps (smart pumps). (6)

Intravenous (IV) infusion pumps are medical devices with medication safety software that deliver medication and fluids more accurately, efficiently, and safely, than adjusted gravity systems (7). However, the improper use of IV pumps can also contribute to patients suffering complications (8). Several new infusion pumps incorporate software functions designed to reduce incorrect dosage errors by helping with dosage calculations as part of integrated software. Newer infusion pumps tend to incorporate advanced, automated features intended to decrease the user's cognitive workload, reduce programming errors, and increase efficiency (9).

In a systematic review of UK studies using structured observation of medication administration, errors were five times more likely in intravenous than non-intravenous doses. (10) Published error rates vary from 18% to 173% of intravenous doses given. (11) While many of these errors do not result in patient harm, all can cause anxiety for staff and patients, and reduce patients' confidence in their care. (12) Therefore, administration of intravenous medication has been identified as a significant topic of concern by regulators, manufacturers and healthcare providers. (13)

The role of smart infusion pumps in safety and error reduction:

Smart infusion pumps represent transformational clinical tools that can greatly play a very important role in reducing errors associated with intravenous infusions in pediatric hospitals, through incorporating dose error reduction software which includes features for administration error prevention and data collection. (6) This software also, checks programmed infusion rates against preset limits for each drug and clinical location, using customizable 'drug libraries', to reduce

the risk of infusion rates that are too high or too low. [14-15]

Although such technology can potentially identify and prevent some kinds of medication errors, it cannot prevent all possible errors. Smart pump use also comes at a cost, both financial and in terms of changes to practice needed to make their use effective. [16]

According to a recent systematic review identified 21 quantitative studies of smart pumps, [17] the majority of which studied the over-rides recorded in the smart pump logs and/or used unreliable methods of identifying medication errors and adverse drug events such as incident reports. The authors concluded that smart pumps can reduce but not eliminate error, and that the picture was far from conclusive. [18]

Since, administering medications is a common process in pediatric hospitals, a routine nursing practice, and a significant cause of preventable adverse drug event. However, medication administration is much more than a simple psychomotor skill. The process involves coordination between multiple providers to order, transcribe, prepare, dispense, and deliver the medication. [19]

Although intravenous medications are vital during inpatient management and are important therapeutic tools in health care, creating safe medication processes is challenging. Pediatric nurses need to recognize the challenges they face when administering medications to their patients. Because nurses consistently administer medications, they're well positioned to prevent medication errors. Nurses must be prepared to not only catch their own errors, but also the errors of healthcare providers, pharmacists, and others in the chain of medication administration. [20] Therefore, the present study aims to assess nurses' awareness regarding implementing smart pump to enhance safety and error reduction.

Patient Safety and Error Reduction

Technology has had a vast impact on the approach that registered nurses take to do their work to improve patient safety and error reduction. [21] Perceptions of smart infusion pump technology in the patient care environment can influence patient safety and error. [22]. Locsin's (2005) conceptual model of technological competency as caring in nursing guided the study. Research questions and hypotheses were developed for the study and a suitable method and design selected. This quantitative, descriptive correlational study sought to assess if relationships exist between the variables of pediatric nurses' perceptions of smart infusion pump technology, patient safety, and error reduction.. [23]

Patient safety and error reduction are essential to improve patient care, and new technology is expected to contribute to such improvements while reducing costs and increasing care efficiency in health care organizations.. [24,25] Smart infusion pump (SIP) is an infusion device used by pediatric nurses to reduce medication administration errors; because health care organizations are purchasing these or similar pumps to promote safety, it is important to know how nurses who work with these pumps regard them. These pumps are equipped with safety features such as user-alerts that are activated when clinicians set the parameter of the pump outside a specified safety limit, or when there is a risk of an adverse drug interaction. [26,27]

Nurses make up the largest workforce in the health care Patient care is heavily dependent on nurses on a 24-hour basis. [28] The nurses ' scope of practice defines safe, quality care provided to patients. [29] The pediatric nurses have responsibilities that include patient assessment, patient activity management, medication administration, and physician orders evaluation. [30] Technology is used by pediatric nurses to improve nursing practices and patient care management . [31] Acceptance of technology by nurses is gained from its ease of use, usefulness, and ability to improve workflow processes. [32,33]

Health care organizations have adopted the SIP technology to decrease errors in medication administration. The built-in safety features of the SIP technology serve as an additional double check system in medication administration. Proper use of the SIP technology yields benefits that include enhanced workflow for nurses and error reduction from medication administration. [22] The SIP technology has built-in software applications that support the creation of specific drug libraries, including parameters for medication dosing specific to pediatrics. [32] Appropriate use and programming of the SIP technology activates these safety features.

The use of smart, software-based, networked devices is clearly becoming a major trend in future healthcare. An important factor for the adoption of medical grade devices in clinical practice and for cost reimbursement from insurance is the proof of their medical efficacy. There are formal conditions for approval, set by the respective authorities. [33,34] However, even clinical trials are of limited value, as such devices act as complex Cyber-Physical Systems, that is, they interact intensively with the varying environment and are dependent on numerous humans who have various skills and mindsets. Due to software upgrades, the devices evolve themselves. Therefore constant monitoring of their behavior is necessary. Fortunately, these devices produce an immense quantity of data that beyond assuring direct patients' care, can be reused for quality assurance and medical research. [35,36] Ideally, this process should be supported by open platforms for system integration

and data exchange. In the real case, we have to make it a common goal for various stakeholders with differing interests. Among the potential technical problems we can name, privacy protection is one that can be reasonably assured by a blend of technical and organizational measures. Another one is data analysis, which, due to the constantly evolving conditions, is a challenging problem. [37,38]

The aim of this study is to:

Assess the relationship between awareness of pediatric nurses' regarding implementing Smart Pump, patient safety and error reduction.

Compare between awareness of pediatric nurses' regarding implementing Smart Pump, patient safety and error reduction in both setting.

Research Question:

1. What is the relationship between pediatric nurses' awareness regarding implementation of Smart Pump, patient safety and error reduction?
2. What is the comparison between pediatric nurses' awareness regarding implementing Smart Pump, patient safety and error reduction in both setting?

2. Materials and Method

Materials

Research design:

A comparative study was used to accomplish this study.

Setting:

The study was conducted at the Pediatric Intensive Care Unit (PSICU) at Alexandria University Children's Hospital (AUCH) in El Shatby and Damanhour National Health Institute.

Subjects:

All nurses working in the Pediatric Intensive Care Unit (PSICU) constituted the subjects regardless their age, sex, and years of experience. Their number was 56.

Tools:

Tool I:

Personal data regarding nurses working in PICU e.g. nurse's age, education, position, and years of experiences.

Tool II:

Nurses' Awareness Regarding Smart Pump technology:

The Infusion System Awareness Scale (Infusion System Pump Survey for Nurses) includes 30 questions on a five-point Likert scale (strongly disagree = 1 to strongly agree = 5) used to collect data, and to measure pediatric nurses' awareness of smart infusion pump technology and patient safety.

It contained the following items:

Nurse roles, **relationships with others**, **support teams**, **personal feelings**, **use of time**, daily **routines**, **reporting of medication errors, job satisfaction**.

METHOD

1. Permission to conduct the study was obtained from the responsible authorities of the PSICU after explanation of the aim of the study.
2. Personal communication with the attending nurses was necessary to gain their cooperation while conducting the study.
3. Tools of the study were developed by the researcher and were tested for its content validity by five experts in the pediatric nursing field.
4. The reliability of the used tools was asserted through their internal consistency by using Cronbach's alpha test, it was $\alpha = 0.801$.
5. Confidentiality and anonymity of individual response were guaranteed by a statement in the cover letter of tool I.
6. A pilot study was carried out by the researcher on five nurses to test the clarity and feasibility of both tools (I and II); consequently necessary modifications were done. Those nurses were excluded from the study.
7. Every nurse was asked to fill in the questionnaire during their breaks and submit it to the researcher.

Statistical analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (2) Qualitative data were described using number and percent Quantitative data were described using range (minimum and maximum), mean, and standard deviation. Significance of the obtained results was judged at the 5% level.

The Infusion System Awareness Scale was used to measure the pediatric nurses' awareness of the use of the smart infusion pump technology (predictor variable) and patient safety (criterion variable), and electronic data reports obtained from the smart infusion pump technology were used to measure error reduction (criterion variable).

The predictor variable and the criterion variables were operationalized by translating them into numerical values that were quantitatively measured using ordinal level of measurement. The responses from the existing survey might facilitate the measurement of the degree of relationship between the predictor variable and the criterion variable.

The correlation design was used to assess possible relationships between the variables of pediatric nurses' awareness of smart infusion pump technology, patient safety, and error reduction through statistical analysis. A potential relationship existed between the predictor variable and the criterion variables from the correlation coefficient, a number

between +1 (positive correlations) and -1 (negative correlation); no relationship between the variable is a correlation of zero.

Pediatric nurses' awareness calculated:

Computed pediatric nurses' awareness of the smart pump technology = sum (*Nurses roles* – question #3, I like using technology to administer medications; question 4, the smart infusion pump (SIP) takes away my control over giving medications; question 5, the technical aspects of the SIP will limit my ability to make autonomous nursing decisions; *Relationship with others* – question 8, the SIP decreases patient concerns about medications; question 9, the SIP increases the confidence that patients or families have in the care provided; *Support teams* – question 10, the SIP drug library and medication limits enhance my ability to provide high quality nursing care; question 11, I rely less on the pharmacy staff for assistance with medication administration; question 12, I rely less on my other nurses for advice when giving medications; *Personal feelings* – question 13, the SIP increases my self-confidence; question 14, I believe reporting of medication errors is less punitive; question 16, the SIP feels like someone is always watching me when I give medications; question 17, the SIP causes anxiety among patients and families; Use of my time – question 18, the SIP increases my workload; question 19, my time is too busy to add the SIP to what I have to do; question 20, the SIP is easy to use, question 21, I have to override the alerts too often; Daily routines – question 22, the SIP makes my daily routine easier, question 23; It takes too much time and effort to add the SIP to my work schedule; Reporting of medication errors – question 24, I feel that I can be very honest about reporting medication errors on the unit where I work; Job satisfaction – question 28, the SIP increases how satisfied I am with my job; question 29, the SIP increases how satisfied I am with the nursing care that I provide; and question 30, training in the use of the SIP was adequate for me to use the equipment effectively.

Patient safety calculated:

Computed patient safety = sum (question 1, the smart infusion pump (SIP) is designed to promote safe and effective nursing practice; *Nurse role* – question 2 – the SIP increases the safe administration of medications; question 6 – I am concerned that the SIP is not always accurate, causing more errors; *Relationship with others* – question 7, the SIP causes concern about safety among the nurses with whom I work; *Personal feelings* – question 15, I feel anxious about making medication errors; *Reporting of medication errors* – question 25, I believe nurses are very honest about reporting medication errors; question 26, If I report a medication error, I will be formally reprimand for making the error; and question 27, I believe there are many more medication errors that are made, than are reported.

Error reduction:

Error reduction was captured as the measure of the number of times adjustments were made to the smart infusion pump technology to reduce errors. Since the data could not be captured on an individual level, for example, it was not possible to identify each nurse who made each adjustment; these data were captured on a nursing unit level over the course of 4consecutive weeks. The smart infusion pump data were scored by examining (a) the number of times an alert of the guardrails (smart limit and hard limit) resulted in reprogramming of the smart infusion pump, (b) number of times the pumps were programmed above the maximum limit, and (c) the number of times the pumps were programmed below the minimum limit. The data retrieved from the smart infusion pumps were summed to generate a score for the variable error reduction. (_)

The following statistical measures were used:

1 - Chi-square test

For categorical variables, to compare between different groups

2 - Fisher's Exact or Monte Carlo correction

Correction for chi-square when more than 20% of the cells have expected count less than 5.

3 - Pearson coefficient

To correlate between two normally distributed quantitative variables.

3. Results

Part I: Socio-demographic characteristics of the studied nurses.

Table (I) illustrates the socio-demographic characteristics of the studied nurses. Regarding nurses' age, it was found that less than half of the nurses (47.8%) were aged between 30-40 years in Alexandria, while slightly more than half of Damanhur nurses (54.5%) were less than 30 years old.

Statistically significant differences were found between nurses' sex, all nurses (100%) were female in Alexandria compared to 66.7% females and 33.3% males in Damanhur. ($P \leq 0.05$).

Regarding nurses' level of education, it was clear that slightly more than half of the nurses (56.5%) held a technical nursing institute certificate in Damanhur, compared to 60.6% who completed their university education in Alexandria.

Concerning nurses' occupation, it was observed that slightly less than three quarters of them (65.2%) were bedside nurses, while the nearly have of nurses (51%) were supervisors in Alexandria.

Years of experience of 47.8% of the nurses were more than 15 years in Damanhur, while years of

experiences among nearly one quarter of Alexandria nurse (36.4%, 33. %) ranging between 10 to less than 15 years and less than 5 years respectively.

According to the table, all nurses (100%) were working in Intensive care for children in both settings.

Part (II): Comparison between the two studied groups according to nurses' awareness regarding implementing smart pump to enhance safety and error reduction.

Table (1): Comparison between the two studied groups according to demographic data for nurses

Characteristics	Alexandria (n=23)		Damanhour (n=33)		Test of sig.	P
	No.	%	No.	%		
Age						
<30	8	34.8	18	54.5		
30 – <40	11	47.8	9	27.3		0.253
≥40	4	17.4	6	18.2		
Mean ± SD.	32.96 ± 7.04		30.12 ± 8.69		t=1.295	0.201
Sex						
Male	0	0.0	11	33.3		^{FE}p=
Female	23	100.0	22	66.7		0.002*
Level of education						
Nursing Bachelor	7	30.4	20	60.6		^{MC}p=
Technical Nursing Institute RNs	13	56.5	9	27.3		0.066
Secondary Nursing School	3	13.0	4	12.1		
Occupation						
Head nurse	1	4.3	3	9.1		^{MC}p=
Supervisor	7	30.4	17	51.5		0.158
Nurse	15	65.2	13	39.4		
Years of experience						
<5	5	21.7	12	36.4		
5 – <10	2	8.7	11	33.3		0.027*
10 – <15	5	21.7	4	12.1		
≥15	11	47.8	6	18.2		
Mean ± SD.	13.78 ± 7.49		9.45 ± 8.62		t=1.949	0.057
Unit						
Intensive care for children	23	100.0	33	100.0	-	-

χ^2, p: χ^2 and p values for **Chi square test** for comparing between the two groups
^{MC}p: p value for **Monte Carlo** for Chi square test for comparing between the two groups
^{FE}p: p value for **Fisher Exact** for Chi square test for comparing between the two groups
t, p: t and p values for **Student t-test** for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

Table (2) portrays the comparison between the two studied groups according to nurses' awareness. The percent score of using SIP were nearly equal in Alexandria and Damanhur (88.04 ± 18.26 and 82.58 ± 14.64 respectively).

No statistical significance difference was found between percent score regarding nurse Roles in both groups (61.52 ± 13.01 and 63.64 ± 13.30 respectively).

The percent scores were nearly equal concerning relationships with others in Alexandria and Damanhur (58.70 ± 17.49 and 64.39 ± 13.70 respectively). Unfortunately, no statistically significant difference was found.

Nearly equal percent of nurses had percent score between (74.28 ± 18.45 and 78.54 ± 11.42 respectively) in both groups regarding Support Teams.

On the other hand, the difference was statistically significant between Alexandria and Damanhur nurses' percent score in relation to Personal Feelings and Use of their Time where ($P \leq 0.05$ for each previously mentioned items).

Studying nurses' Daily Routines between nurses' at Alexandria and Daman hour the table revealed that there was no statistically significant difference between nurses' total percent score. As for reporting of medication Errors by the nurses' at Alexandria and Damanhour, the nurses' percent score were nearly

equal (66.30 ± 15.62 and 64.39 ± 15.82). The difference was not statistically significant.

No significant differences was evident between nurses' at Alexandria and Damanhour in Job Satisfaction.

Table (3) The comparison between the two studied groups according to nurses' awareness regarding implementing smart pump to enhance safety and error reduction. It showed no statistical significance difference between nurses' total percent score at Alexandria and Damanhour and Patients safety, medication error and nurses' awareness.

Table (4) highlights Correlation between patient safety with errors reduction in each group. The table showed that there was statistical significance difference between nurses' in Damanhur setting only.

Table (5) portrays correlation between patient safety with nurses' awareness in each group; It was obvious from the table that there was statistical significance difference correlation between patient safety with awareness in at Alexandria and Damanhour.

Table (2): Comparison between the two studied groups according to nurses' awareness regarding implementing smart pump to enhance safety and error reduction

		Alexandria (n=23)	Damanhour (n=33)	T	p
SIP use	**Total score** **Percent score**	4.52 ± 0.73 88.04 ± 18.26	4.30 ± 0.59 82.58 ± 14.64	1.242	0.220
Nurse Roles	**Total score** **Percent score**	17.30 ± 2.60 61.52 ± 13.01	17.73 ± 2.66 63.64 ± 13.30	0.591	0.557
Relationships with others	**Total score** **Percent score**	10.04 ± 2.10 58.70 ± 17.49	10.73 ± 1.64 64.39 ± 13.70	1.366	0.178
Support Teams	**Total score** **Percent score**	11.91 ± 2.21 74.28 ± 18.45	12.42 ± 1.37 78.54 ± 11.42	1.067	0.291
Personal Feelings	**Total score** **Percent score**	16.39 ± 2.13 56.96 ± 10.63	20.0 ± 2.29 75.0 ± 11.46	5.969*	<0.001*
Use of My Time	**Total score** **Percent score**	15.35±3.45 70.92±21.54	12.76±1.89 54.73±11.80	3.278*	<0.001*
Daily Routines	**Total score** **Percent score**	8.0±1.65 75.0±20.64	7.36±1.45 67.05±18.17	1.524	0.133
Reporting of medication Errors	**Total score** **Percent score**	14.61 ± 2.50 66.30 ± 15.62	14.30 ± 2.53 64.39 ± 15.82	0.477	0.657
Job Satisfaction	**Total score** **Percent score**	11.43 ± 2.45 70.29 ± 20.39	10.82 ± 1.53 65.15 ± 12.75	1.161	0.251
Overall	**Total score** **Percent score**	109.57 ± 12.16 66.30 ± 10.13	110.42 ± 11.20 67.02 ± 9.33	0.273	0.786

t, p: t and p values for **Student t-test** for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

Table (3): Comparison between the two studied groups according to nurses' awareness regarding implementing smart pump to enhance safety and error reduction

		Alexandria (n=23)	Damanhour (n=33)	T	p
Patients safety	**Total score** **Percent score**	25.26±3.93 65.22±14.05	26.39±3.11 69.26±11.11	1.202	0.235
Errors	**Total score** **Percent score**	7.30±1.61 66.30±20.10	7.12±1.19 64.02±14.91	0.464	0.645
Awareness	**Total score** **Percent score**	76.83±8.41 66.46±10.01	76.67±8.02 66.27±9.55	0.072	0.943

t, p: t and p values for **Student t-test** for comparing between the two groups
*: Statistically significant at $p \leq 0.05$

Table (4): Correlation between patient safety with errors reduction in each group

	R	P
Alexandria (n=23)	0.260	0.231
Damanhour (n=33)	0.736*	<0.001*
Total sample (n = 56)	0.461*	<0.001*

r: Pearson coefficient
*: Statistically significant at $p \leq 0.05$

Table (5): Correlation between patient safety with nurses' awareness in each group

	R	P
Alexandria (n=23)	0.733*	<0.001*
Damanhour (n=33)	0.751*	<0.001*
Total sample (n = 56)	0.727*	<0.001*

r: Pearson coefficient
*: Statistically significant at $p \leq 0.05$

Table (6) presents the Correlations between errors reduction with nurses' awareness in each group. Statistical significance differences were found between the correlations in at Alexandria and Damanhur.

Table (6): Correlation between errors reduction with awareness in each group

	R	P
Alexandria (n=23)	0.495*	0.016*
Damanhour (n=33)	0.393*	0.024*
Total sample (n = 56)	0.440*	0.001*

r: Pearson coefficient
*: Statistically significant at $p \leq 0.05$

4. Discussion

The use of infusion pumps that incorporate "smart" technology (smart pumps) can reduce the risks associated with receiving IV therapies. Smart pump technology incorporates safeguards such as a list of high-alert medications, soft and hard dosage limits, and a drug library that can be tailored to specific patient care areas. Its use can help to improve patient safety and to avoid potentially catastrophic harm associated with medication errors. (39)

The current study showed that about two thirds of nurses in both groups congruent with Rosenkoetter M (2008) whore ported that the majority of the nurses were aware that the pump was designed to promote safe and effective nursing practice and perceived that it actually increased the safe administration of medication. (44)

The use of smart pumps increased nurse job satisfaction by increasing self-confidence, increasing ease of daily nursing care and decreasing anxiety of making IV medication errors. Rosenkoetter M (2008) ascertained that nurses reporting increased job satisfaction positively perceived the role of the pump in increasing patient/families confidence, self-confidence, feelingless anxious about making errors, and making daily routines easier. Finding of the current study confirmed the previously mentioned results. (44)

Overall, we found that nurses' ability to safely administer medications was enhanced when using the smart pump. Thus, effective use of pump technology is dependent not only on the design of the pump itself but also on the way it is implemented into the institution. The present study adds to the literature by explicitly comparing and quantifying the effects of using smart pump technology on nurses' ability to safely administer IV medication, and by identifying errors that are not addressed by any of the current IV pump technologies. (40)

The findings of the study indicate a statistically significant relationship existed between pediatric nurses' awareness of smart pump technology and patient safety. The findings were consistent with previously published studies. The findings supported the literature in which studies have shown technology such as the smart infusion pump plays an important role inpatient safety and error reduction. (21- 23)

In agreement with the literature, the findings from this study revealed when the smart infusion pumps were properly used by pediatric nurses during patient management, the nurses' perceived the pumps to have a positive impact in the delivery of medications and nutritional therapies to the pediatric patients, and improved care outcomes. [21- 23,26,41] Pediatric nurses perceived the smart infusion pumps are technology that support quality patient care and reduce errors. [42, 43]

Although regarding the relationship between the variables pediatric nurses' awareness of smart infusion pump technology and error reduction was determined, a high correlation between the variables of patient safety and error reduction was revealed. This finding supports the literature that the built-in safety features of the smart infusion pump technology were perceived as lessening medication errors. [21, 43].

References

1. Canadian patients' safety institute. Medication safety.2016. available at http://www.patientsafetyinstitute.ca/en/Topic/Pages/Medication-Safety.aspx.
2. Prof K Satku. Medication safety practice guidelines and tools. Ministry of health singafors. 2006.
3. Smart Medication Delivery Systems: Infusion Pumps. Healthcare Human Factors Group Centre for Global e Health Innovation University Health Network Toronto, ON, Canada 2009.
4. Hicks, R., & Becker, S. (2006). An overview of intravenous-related medication administration errors as reported to MEDMARX, a national medication error-reporting program. *Journal of Infusion Nursing, 29*(1), 20-27.
5. Institute For Safe Medication Practices. (2002, February 7). "Smart" infusion pumps join CPOE and bar coding as important ways to prevent medication errors. *ISMP Medication Safety Alert! Acute Care Edition.*
6. Rothwell S. Effect of Dose Error Reduction Software on the Ability of Nurses to Safely and Efficiently Administer Intravenous Medications. A thesis submitted in conformity with the requirements for the degree of Masters of Health Science in Clinical Biomedical Engineering Institute of Biomaterials and Biomedical Engineering University of Toronto.
7. Emergency Care Research Institute. (2002). New perspectives on general-purpose infusion pumps: Advances in technology, changes in our ratings. *Health Devices, 31*, 355-384.
8. Weinger, M. (1999). Anesthesia equipment and human error. Journal of Clinical Monitoring and Computing, 15, 319–323.
9. Institute of Medicine. To err is human: building a safer health system. Report of the Committee on Quality of Health Care in America, Institute of Medicine. Washington: National Academy Press, 2000.
10. McLeod MC, Barber N, Franklin BD. Methodological variations and their effects on reported medication administration error rates. BMJ Qual Saf 2013;22:278–89.
11. McLeod MC, Barber N, Franklin BD. Methodological variations and their effects on reported medication administration error rates. BMJ Qual Saf 2013;22:278–89.
12. Franklin BD, Taxis K, Barber N. Parenteral drug errors: reported error rates are likely to be underestimation. BMJ 2009;338:b1814.
13. Ann Blandford,1 Dominic Furniss,1 Imogen Lyons,1 Gill Chumbley,2 Ioanna Iacovides,1 Li Wei,3 Anna Cox,1 Astrid Mayer,4 Kumiko Schnock,5. Exploring the Current Landscape of Intravenous Infusion Practices and Errors (ECLIPSE): protocol for a mixedmethods observational study. BMJ Open 2016;6:e009777. doi:10.1136/bmjopen-2015-009777.
14. Murdoch LJ, Cameron VL. Smart infusion technology: a minimum safety standard for intensive care? Br J Nurs 2008;17:630–6.
15. Department of Health. An organisation with a memory. London: Stationery Office, 2000.
16. Ann Blandford,1 Dominic Furniss,1 Imogen Lyons,1 Gill Chumbley,2 Ioanna Iacovides,1 Li Wei,3 Anna Cox,1 Astrid Mayer,4 Kumiko Schnock,5. Exploring the Current Landscape of Intravenous Infusion Practices and Errors (ECLIPSE): protocol for a mixed methods observational study. BMJ Open 2016;6:e009777. doi:10.1136/bmjopen-2015-009777.
17. Ohashi K, Dalleur O, Dykes PC, et al. Benefits and risks of using smart pumps to reduce medication error rates: a systematic review. Drug Saf 2014;37:1011–20.
18. Brock TP, Franklin BD. Differences in pharmacy terminology and practice between the United Kingdom and the United States. Am J Health Syst Pharm 2007;64:1541–6.
19. Forni, A., Chu, H.T. & Fanikos, J. (2010). Technology utilization to prevent medication errors. Current Drug Safety. 5 (1), 13–18. doi:10.2174/157488610789869193.
20. Harding L, Petrick T. Nursing student medication errors: a retrospective review. J Nurs Educ. 2008;47(1):43–47. Internet Resources Bibliographic Links [Context Link].
21. Bowcutt M., Rosenkoetter M., Chernecky C., Wall J, Wynn D., & Serrano C. Implementation of an intravenous medication infusion pump

system: Implications for nursing. Journal of Nursing Management, 16(2), 188-197, 2008.
22. Carayon P., Hundt S., & Wetterneck B. Nurses' acceptance of smart IV pump technology. International Journal of Medical Informatics, 79(6), 401-411, June 2010.
23. Locsin, R. C. (2005). Technological competency as caring in nursing: A model for practice. Indianapolis, IN: Sigma Theta Tau International.
24. Jensen, T. B., & Aanestad, J. (2007). How healthcare professionals "make sense" of an electronic patient record adoption. Information Systems Management, 24, 29–42.
25. Longest, B. B., & Darr, K. (2008). Managing health services organizations & systems (5th ed.) Baltimore, MD: Health Professions Press.
26. Nymark, M. (2007). Patient's safety, privacy and effectiveness – A conflict of interest in health care information systems? Medicine & Law, 26, 245–255.
27. Cummings, K., & McGowan, R. (2011). Device safety: "Smart" infusion pumps are electively intelligent. Nursing, 41, 58–59.
28. Health Resources & Services Administration. (2010). HRSA study finds nursing workforce is growing. Washington, DC: U. S. Department of Health and Human Services.
29. American Academy of Pediatrics. (2011). Principles of pediatric patient safety: Reducing harm due to medical care. Pediatrics, 127, 1199–1210.
30. American Nurses Association. (2004). Nursing: Scope and standards of practice. Washington DC.
31. Barnard, A., & Locsin, R. (2007). Technology and nursing practice: Practice, concepts and issues. Herefordshire, UK: Palgrave MacMillan.
32. Morgan L., & Siv-Lee L. Intelligent infusion. Nursing Management. February 2009, Volume:40 Number 2, p20 – 24.
33. Erlen, J. A. (2007). Patient safety, error reduction, and ethical practice. *Orthopedic Nurse, 26*(2),130-133.
34. Eur Spine J. Healthcare technology and technology assessment. Eur Spine J (2007) 16:1293–1302.
35. Bacin A, Stratton K, Burke S. (2006) Committee on the assessment of the U.S. drug safety system report: the future of drug safety: promoting and protecting the health of the public. National Academies, Washington http.
36. Aaron S, Prashant V. Regulating incremental innovation in medical devices. BMJ Clinical Research -September 2014.
37. Stephens JM, Handke B, Doshi JA And Behalf Of ISPOR. International survey of methods used in health technology assessment (HTA): does practice meet the principles proposed for good research? Comparative Effectiveness; 2012;2:29-44.
38. Henshall C, Mardhani-Bayne L, Frønsdal K et al. Interactions between health technology assessment, coverage, and regulatory processes: Emerging issues, goals, and opportunities. International Journal of Technology Assessment in Health Care, 27:3 (2011), 253–260.
39. Andrew D. Increasing the Use of 'Smart' Pump Drug Libraries by Nurses: A Continuous Quality Improvement Project One hospital's efforts to reduce the risk of medication errors. AJN. January 2012, Vol. 112, No. 1.
40. Healthcare Human Factors Group Centre for Global e Health Innovation. Smart Medication Delivery Systems: Infusion Pumps. University Health Network Toronto, ON, Canada April, 2009.
41. McDaniel G, Travis S. Embracing technology. J Gerontol Nurs. 2010 Mar;36(3):3–4. https://doi.org/10.3928/00989134-20100202-08 PMID:20302251.
42. Institute of Safe Medication Practices. Smart pumps are not smart on their own. ISMP Medication Safety Alert! Nurse Advise-ERR. 2009;7(1):1–4.
43. U. S. Food and Drug Administration. (2010). what is an infusion pump? U.S. Department of Health and Human Services. Washington, DC.
44. Rosenkoetter M., Khasanshina E,. Chernecky C. Perception of impact of Smart Pump on nurses and nursing care provided. JAVA Vol 13 No 2 (2008).

1/25/2016