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Medication safety through nursing-pharmacy collaborative management of smart infusion pump technology: A comprehensive review

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Abstract
Background: Medication errors remain a significant challenge in healthcare, with intravenous (IV) administration being particularly prone to mistakes. The introduction of smart infusion pump technology aims to enhance medication safety by mitigating these errors through advanced programming and alerts.
Methods: This review synthesizes literature from 2000 to 2018, utilizing databases such as Scopus, PUBMED, and Web of Science. Studies were selected based on their focus on smart pump technology, including its benefits and challenges in clinical practice. Metrics assessed included error rates, adherence to drug libraries, and the effectiveness of Dose Error Reduction Systems (DERS).
Results: The evidence indicates that smart infusion pumps can reduce medication administration errors significantly, with some studies reporting an 80% decrease in infusion-related mistakes. Implementation of smart pump technology in critical care settings has averted numerous potential adverse events. However, challenges remain, including alert fatigue, compliance with drug libraries, and the need for continuous staff education to maximize efficacy.
Conclusion: While smart infusion pump technology has demonstrated potential to improve medication safety, its effectiveness is contingent on proper integration within healthcare systems. Ongoing education, regular updates to drug libraries, and strategies to mitigate alert fatigue are essential for optimizing the benefits of this technology. Future research should focus on enhancing the usability and integration of smart pumps in diverse healthcare settings to further minimize medication errors.

Keywords: Medication errors, smart infusion pumps, patient safety, intravenous therapy, dose error reduction systems

Introduction

Reducing medical mistakes is a primary objective for contemporary healthcare institutions. The 1999 admonition from the Institute of Medicine (IOM) has prompted healthcare institutions to embrace a more conservative strategy in addressing mistakes, seeing them as systemic failures rather than individual shortcomings [1]. Pharmaceutical mistakes may occur at any stage of pharmaceutical management, namely when prescribing, transcribing, dispensing, and delivering the medicine. The most recent phase requires appropriate attention. Technology has been significantly integrated in the first three stages. Computerized provider order entry (CPOE) was used to reduce prescription mistakes, while a robotic medicine dispenser addressed dispensing issues [2].

Moreover, much study has been undertaken about the prevalence of mistakes and the methods that might aid in mitigating and diminishing them throughout the first three stages. Nonetheless, monitoring drug delivery is challenging, since it often occurs at the patient's location. Nonetheless, the medication administration record (MAR) including bar-code identification of medicine (MAR-BC) has enhanced patient safety for hospitalized

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individuals. Medication mistakes may be exacerbated in certain patient populations (Pediatrics, renal insufficiency, and other concomitant conditions) and with crucial drugs (narrow therapeutic index and parenteral pharmaceuticals). Intravenous drug delivery may significantly harm 60% of individuals [1, 3]. This sort of inaccuracy is often life-threatening. This method of administration must not be tolerated, since it is reserved for essential medications that will effectively reach the patient. Infusion pump technology was introduced to healthcare 45 years ago to regulate the pace and volume of intravenous pharmaceuticals, hence improving safety in the administration of cardiovascular drugs. The main purpose of the smart pump is to provide the correct dosage.

In 2018, 89.5% of hospitals in the United States used smart pump technology, as reported by a study conducted by the American Society of Health-System Pharmacists (ASHP). The use of smart pump technology varied according to hospital bed capacity, being fully implemented in hospitals with 600 or more beds [4]. The smart pump has dosage error reduction software (DERS), a critical application designed to avert discrepancies in infusion programming and alert users by adhering to drug library requirements. A drug library comprises medication properties, dosage limits (minimum and maximum doses), duration rates, and accessible concentrations. A discrepancy in the prescribed dosage may trigger a soft alert, allowing the nurse to disregard the notification (soft limit), or a hard alarm, which prohibits medicine administration and cannot be overridden [5]. Drug libraries differ across healthcare organizations according to their specific requirements and practices [2]. Introducing smart infusion pump technology to hospitals may be daunting: smart IV pumps must be sophisticated, need ongoing user education, and maintain an accurate medication library [6].

While some research corroborates the efficacy of smart pump technology in mitigating intravenous drug mistakes, the effectiveness rates of smart pump systems vary. Decreased adherence to the medication library results in more frequent notifications [8]. This review study is significant as it evaluates the current state of smart pump technology, assesses its benefits and challenges, suggests tactics to enhance advantages and mitigate bad occurrences, and outlines solutions for smart pump technology issues.

Methods

A comprehensive review of pertinent literature was conducted from 2000 to 2019 utilizing various scientific databases (Web of Science, Scopus, ScienceDirect, and PubMed) through distinct search strategies, specifically employing medical subject headings (MeSH) terms and keywords (‘smart-intravenous pumps’ OR ‘smart pump technology’ OR ‘smart pump’ OR ‘IV-smart pump’ OR ‘smart pump safety’ OR ‘smart pump errors’ OR ‘smart infusion pumps’). Only research conducted in English was considered.

Advantages of Employing Smart Pump Technology

Smart pump infusion technology can mitigate mistakes such as wrong dosage, rate, and pump malfunction. Research revealed an 80% decrease in infusion-related medication mistakes [9]. A two-year research study conducted by Larsen *et al*. assessed the efficacy of smart pumps equipped with a pharmaceutical library and Dose Error Reduction Systems (DERS) in the adult critical care unit (ICU). It has averted 1,136 mistakes and has the potential to prevent at least 300 adverse events in the ICU; 74 errors were classified as the most serious, posing the greatest risk of patient damage [10]. Larsen *et al*. identified a 70% decrease in reporting inaccuracies associated with fundamental medication infusions [11].

The influence of smart pumps on adverse medication responses: Research conducted by Prewitt *et al*. evaluated the adverse events associated with patient-controlled analgesia (PCA) before and after the deployment of smart IV pumps, resulting in a significant reduction in adverse drug reactions [12]. A randomized clinical study (RCT) conducted by Rothschild *et al*. evaluated the effect of smart infusion technology to treat adverse outcomes. The decrease was 0.18 for every 100 pumps daily. Nonetheless, the occurrence of managing adverse medication events did not exhibit a statistically significant decrease with the use of smart infusion technology [13].

Smart pump technology in home healthcare: In contrast to the smart infusion pumps used in hospitals, home healthcare practitioners rely on conventional infusion pumps that lack a drug library and drug-safe software. Consequently, the effects of the smart pump infusion remain contentious. Nonetheless, educating home healthcare professionals on ambulatory infusion pumps and using a specific medication library by doctors was effective for home infusion [14]. Consequently, patients expressed satisfaction and were able to react to notifications without the need to call home healthcare providers [14].

Challenges with the Smart Pump Infusion

Smart pump technology cannot prevent all drug-related infusion mistakes and may introduce new forms of errors. Smart pump technology is ineffective without the use of DERS. Before and during the trial, there was almost an 80% reduction in mistakes when using the DERS; however, the difference was not statistically significant in its absence [9]. The most often reported types of intravenous administration mistakes included: undispensed medicine (23%) mostly owing to open tubing failures during secondary infusion, inappropriate pump rate (about 20%), erroneous drug (17%), or incorrect dosage (14%) [15].

In an observational study of intravenous preparation and medication administration in an intensive care unit of a teaching hospital, the predominant mistakes were bolus doses being provided at rates above the acceptable guidelines. A separate investigation into intravenous medication delivery revealed that bolus administration was associated with a 31% increased chance of mistake [16]. The fundamental infusion profile accounted for almost fifty percent of smart pump infusions. Basic infusion enables practitioners to circumvent pharmaceutical restrictions by omitting the medicine's name. Continuous infusions cannot provide notifications if medication restrictions are exceeded. A nurse shift change is a risk factor for infusion alarms. The likelihood of infusion rates with alarms was 1.3 times higher than those during the day shift [17]. The majority of secondary medicine delivery is designed to enable the main infusion to resume after the secondary infusion [18].

It is typical for wireless drug library updates for smart pumps to be delayed, potentially jeopardizing patient safety if a pump is configured with incorrect limit parameters during medication administration. A retrospective study was

conducted to assess delays in updating the pharmaceutical library over two years among 49 hospitals using 12 health systems. Eleven health systems had significant modifications to their medication libraries, ranging from 22 to 192 days [19]. Health systems must recognize the importance of delays in smart-pump updates to mitigate adverse occurrences. The bypassing library may vary depending on the medicine in question. In the randomized controlled trial conducted by Prewitt *et al.*, nurses overlooked the drug library in around 70% of propofol infusions and around 60% of insulin infusions, with a bypass rate of 25% [12].

The majority of notifications are disregarded at the point of care, exacerbating the issue of alert fatigue. Despite the potential for high alert medicines (HAD) to pose considerable risks, research revealed that 75.8% of alarms are disregarded across 15 hospital systems. Bypassed signals did not diminish intravenous drug errors since they did not modify the planned medication delivery.

Strategies to Mitigate the Adverse Effects of Smart Pump Technology

Improving adherence to the drug library is essential for safety; however, non-compliance may adversely affect results, efficacy, and quality of interest. Compliance with the drug library was assessed by the reporting of real-time applications. Consequently, pharmacists and nurses were acutely aware of any planned infusions absent from the medication library, enabling them to contribute effectively to success. The use of real-time units achieved complete compliance by using the drug library across all six ICUs. Nonetheless, data from other departments circumvented the drug library 34% of the time. The reasons for neglecting the drug library were identified. Certain infusion limits were identified as excessive constraints, prompting a revision of the pharmaceutical library to mitigate alert weariness and enhance drug adherence. Furthermore, training on the use of the medication library during annual skills authorization is crucial for documenting a consistent increase in organization-wide medication library compliance and a comprehensive decrease in alert frequency [8].

Notifications from the smart pump provide a warning if a nurse attempts to establish limitations outside the parameters of hospital dosage protocols. Alert fatigue results from an excessive frequency of notifications, leading professionals to disregard caution. In research, the warning frequency during the initiation of a new smart pump technology was around 4%; over half of the medications in the library triggered alarms, but this rate decreased to 1.16% over the subsequent three months [19]. The first three months of using smart pumps were dedicated to identifying elevated alert frequencies and implementing suggestions to reduce alerts and improve drug library adherence. For example, increasing the soft limit of heparin units from 1500 to 1800 per hour lowers around 55% of associated overrides. Two override concerns have been detected. The primary concern is the selection mistake, namely choosing an incorrect medicine entry when many options exist for the same infusion. The second concern is to bolus dosage, which elevated the infusion rate rather than leveraging the bolus benefit to establish safe parameters. This exemplifies the optimization of patient safety within the medication library [8].

Addressing and rectifying alarms may streamline the verification process for nurses or enable them to amend programming errors. The reduced frequency of adjustments indicates the appropriate dosage by the nurses. Prominent smart pump infusions for dosage correction are heparin, phenylephrine, and potassium chloride piggyback. Thirteen dosage adjustments of heparin were made due to both over-dosing and under-dosing. The medication might inflict damage on the patient and result in expensive repercussions for the hospital if dosage adjustments are not made. The thirteen corrective dosages resulted in savings of $113,750 [8].

Discussion

The smart pump is a device that mitigates the adverse effects associated with the administration of intravenous medications, which may be detrimental. During the administration phase, mistakes may occur with smart pumps, including patient identification issues, documentation errors, or labeling errors on intravenous medications [18, 20]. The organization and preparation of medication phases are critical elements in the use of smart pumps. A reduced compliance rate with the drug library might hinder the effectiveness of smart pumps. A significant frequency of alerts, occurring once in every three uses of smart pumps, results in about 106 hours of alarms monthly for a single healthcare facility [17]. Circumventing alarms from the medication library is an additional concern that may diminish the safety benefits of the smart IV pump. Research has identified factors contributing to the excessive use of medication libraries, including a misguided sense of low risk, an inability to update the medication library when alerts are deemed unreliable, and the need for substantial effort to use smart pump technology, with work-related stress and crises [20]. Nevertheless, recent research has sought to provide solutions for issues associated with smart pumps, which need meticulous and methodical deployment. Alert reduction is essential to prevent alert fatigue, which may lead doctors to ignore signals or improperly modify alarm thresholds beyond acceptable limits to reduce the frequency of alarms.

Giuliano has affirmed the necessity for innovation in smart pump technology, which encompasses auto-programming, allowing for immediate transmission of drug orders from the pharmacy information system to the infusion pumps, followed by clinician approval before infusion initiation; and auto-documentation of the infusion smart pump program within electronic information systems [15]. System integration in information technology for ordering and standardization control is essential to mitigate misunderstandings and fluctuations in product function interpretation from diverse sources. Additionally, enhancements to screen visibility and size are necessary improvements for the smart pump to assist clinicians in effectively monitoring infusion transmission. Additionally, smart pump devices must be lightweight, compact, and portable. Table 1 represents the summary of findings, benefits, and challenges of smart infusion pump technology in medication safety.

Table 1: Summary of Findings, Benefits, and Challenges of Smart Infusion Pump Technology in Medication Safety

Category	Findings	Benefits	Challenges
Reduction in Errors	Decreased medication errors by 60-80% in some studies.	Fewer instances of wrong drug selection and incorrect dosages.	Non-compliance with updated drug libraries in 20-30% of cases limits the potential for error reduction.
Improved Patient Safety	Fewer adverse drug events (ADEs) were reported in high-risk areas like ICUs and surgical units.	Real-time alerts reduce the administration of potentially harmful medications.	Alarm fatigue among staff leads to ignored or overridden alerts, which can compromise safety.
Implementation Challenges	Widely adopted in larger hospitals, with an 89.5% adoption rate in U.S. hospitals, but slower adoption in rural areas.	Improves standardization across different healthcare settings.	Smaller facilities face high costs for implementation and maintaining drug libraries.
Cost-Efficiency	Reduction in preventable ADE costs by up to $6,000 per event in ICU settings.	Long-term savings from error prevention outweigh initial investment costs.	High upfront costs for purchasing and maintaining smart infusion pump systems deter smaller healthcare centers.
User Interaction	Enhanced confidence among nurses and pharmacists during high-risk infusions.	Real-time support for interdisciplinary teams ensures better collaboration and reduces errors during administration.	Complexity in training and ensuring that all users fully understand smart pump features leads to suboptimal use.
Interdisciplinary Collaboration	Pharmacists and nurses effectively update drug libraries for new protocols.	Promotes shared accountability between pharmacy and nursing teams.	Communication gaps in cross-department workflows can delay updates or error reporting processes.
Education and Training	Staff training programs enhance knowledge of smart infusion pump functions.	Training improves compliance with drug library settings and the use of advanced safety features.	Inconsistent training schedules lead to variability in staff proficiency.
Technology Limitations	Drug libraries reduce variability in medication programming.	Data logging and error reporting features provide actionable insights for continuous improvement.	Systems require frequent updates to keep up with new drugs and protocols, which can disrupt workflows.

Conclusions

The existing literature evaluation indicates that smart pump technology enhances the safe delivery and avoidance of infusion mistakes. The findings indicate an improvement in smart pump technology. Smart pumps may reduce programming error rates; nevertheless, some mistakes still occur with the implementation of smart pump technology in hospitals, such as medicine delivery problems and inaccurate patient information. The lack of connectivity with hospital systems may diminish the efficacy of smart pumps since adherence to the medication library is essential for effective smart pump infusions.

Each hospital must improve compliance rates by using pump technology and the pharmaceutical library to align with the stated techniques for advancement, enhancement, and creation of medication libraries. Consequently, maintaining an up-to-date medicine library is advisable to minimize mistakes, prevent delays in drug updates, and mitigate alert fatigue that may arise from several sources, including alarm desensitization. Smart pump technology is advancing swiftly as new advantages emerge, such as the adaptation of a medicine library for home utilization and a program aimed at minimizing alerts. Nonetheless, there is a need for innovation in smart IV pump technology, including auto-programming and auto-documentation, as well as a reduction in the size of the device to enhance portability.

References

1. Schnock KO, Dykes PC, Albert J, *et al*. The frequency of intravenous medication administration errors related to smart infusion pumps: A multihospital observational study. BMJ Qual Saf. 2017;26:131-140.
2. Ohashi K, Dalleur O, Dykes PC, Bates DW. Benefits and risks of using smart pumps to reduce medication error rates: a systematic review. Drug Saf. 2014;37:1011-1020.
3. Shah PK, Irizarry J, O'Neill S Strategies for managing smart pump alarm and alert fatigue: A narrative review. Pharmacotherapy. 2018;38:842-850.
4. PJ, Pedersen CA, Scheckelhoff DJ. ASHP national survey of pharmacy practice in hospital settings: dispensing and administration-2017. Schneider The Bulletin of the American Society of Hospital Pharmacists. 2018 Aug 15;75(16):1203-26.
5. Walroth TA, Smallwood S, Arthur K, Vance B, Washington A, Staublin T, *et al*. Development of a standardized, citywide process for managing smart-pump drug libraries. The Bulletin of the American Society of Hospital Pharmacists. 2018 Jun 15;75(12):893-900.
6. Makic MB. Maximizing smart pump technology to enhance patient safety. Clin Nurse Spec. 2015;29:195-197.
7. Mansfield J, Jarrett S. Optimizing smart pump technology by increasing critical safety alerts and reducing clinically insignificant alerts. Hosp Pharm. 2015;50:113-117.
8. Wetterneck TB, Skibinski KA, Roberts TL, Kleppin SM, Schroeder ME, Enloe M, *et al*. Using failure mode and effects analysis to plan implementation of smart iv pump technology. American Journal of Health-System Pharmacy. 2006 Aug 15;63(16):1528-1538.
9. Rebecca KY Pang, David CM Kong, Jan-Marie de Clifford, Skip S Lam. Infusion pumps reduce intravenous medication administration errors at an Australian teaching hospital. Smart. J Pharm Pract Res. 2011;192:95.
10. Manrique-Rodríguez S, Sánchez-Galindo AC, Fernández-Llamazares CM, Calvo-Calvo MM, Carrillo-Álvarez Á, Sanjurjo-Sáez M. Safe intravenous administration in pediatrics: A 5-year Pediatric Intensive Care Unit experience with smart pumps. Medicina Intensiva (English Edition). 2016 Oct 1;40(7):411-21.
11. Larsen GY, Parker HB, Cash J, O'Connell M, Grant MC. Standard drug concentrations and smart-pump technology reduce continuous-medication-infusion errors in pediatric patients. Pediatrics. 2005;116:0.

12. Prewitt J, Schneider S, Horvath M, *et al*. PCA safety data review after clinical decision support and smart pump technology implementation. J Patient Saf. 2013;9:103-109.
13. Rothschild JM, Keohane CA, Cook EF, *et al*. A controlled trial of smart infusion pumps to improve medication safety in critically ill patients. Crit Care Med. 2005;33:533-540.
14. Brown TD, Michael M, Grady DS. Implementation of smart pump technology with home infusion providers: an assessment of clinician workflow and patient satisfaction. J Infus Nurs. 2018;41:344-349.
15. Giuliano KK. Intravenous smart pumps: usability issues, intravenous medication administration error, and patient safety. Crit Care Nurs Clin North Am. 2018;30:215-224.
16. Westbrook JI, Rob MI, Woods A, *et al*. Errors in the administration of intravenous medications in hospitals and the role of correct procedures and nurse experience. BMJ Qual Saf. 2011;20:1027-1034.
17. Yu D, Hsu K-Y, Kim JH, *et al*. Infusion pump informatics approach to quantify the impact of alerts and alarms on healthcare delivery. Proc Hum Factors Ergon Soc Annu Meet. 2017;61:681-685.
18. Schnock KO, Dykes PC, Albert J, Ariosto D, Call R, Cameron C, *et al*. The frequency of intravenous medication administration errors related to smart infusion pumps: A multihospital observational study. BMJ Quality & Safety. 2017 Feb 1;26(2):131-40.
19. DeLaurentis P, Hsu KY, Bitan Y. Prevalence of wireless smart pump drug library update delays. Am J Health Syst Pharm. 2018;75:1140-1144.
20. Hertzel C, Sousa VD. The use of smart pumps for preventing medication errors. J Infus Nurs. 2009;32:257-267.

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سلامة الأدوية من خلال الإدارة التعاونية بين التمريض والصيدلة لتقنية مضخة التسريب الذكية: مراجعة شاملة

الملخص

الخلفية :لا تزال أخطاء الأدوية تمثل تحديًا كبيرًا في الرعاية الصحية، حيث تكون الإدارة الوريدية (IV) عرضة بشكل خاص للأخطاء. تهدف تقنية المضخات الذكية إلى تعزيز سلامة الأدوية من خلال التخفيف من هذه الأخطاء من خلال البرمجة المتقدمة والتنبيهات.

الطرق :تستعرض هذه المراجعة الأدبيات من 2000 إلى 2018، باستخدام قواعد بيانات مثل Scopus و PUBMEDو Web of Science. تم اختيار الدراسات بناءً على تركيزها على تقنية المضخات الذكية، بما في ذلك فوائدها وتحدياتها في الممارسة السريرية. تضمنت المقاييس التي تم تقييمها معدلات الأخطاء، والامتثال لمكتبات الأدوية، وفعالية أنظمة تقليل أخطاء الجرعات(DERS)

النتائج :تشير الأدلة إلى أن المضخات الذكية يمكن أن تقلل بشكل كبير من أخطاء إدارة الأدوية، حيث أبلغت بعض الدراسات عن انخفاض بنسبة 80% في الأخطاء المتعلقة بالتسريب. لقد حال تنفيذ تقنية المضخات الذكية في بيئات الرعاية الحرجة دون حدوث العديد من الأحداث السلبية المحتملة. ومع ذلك، لا تزال هناك تحديات قائمة، بما في ذلك تعب التنبيهات، والامتثال لمكتبات الأدوية، والحاجة إلى التعليم المستمر للموظفين لتعظيم الفعالية.

الخاتمة :بينما أظهرت تقنية المضخات الذكية إمكانية لتحسين سلامة الأدوية، فإن فعاليتها تتوقف على التكامل الصحيح ضمن نظم الرعاية الصحية. التعليم المستمر، وتحديثات منتظمة لمكتبات الأدوية، واستراتيجيات التخفيف من تعب التنبيهات هي أمور ضرورية لتحسين فوائد هذه التقنية. يجب أن تركز الأبحاث المستقبلية على تعزيز سهولة استخدام المضخات الذكية ودمجها في بيئات الرعاية الصحية المتنوعة لتقليل الأخطاء في إدارة الأدوية بشكل أكبر.

الكلمات المفتاحية :أخطاء الأدوية، المضخات الذكية، سلامة المرضى، العلاج الوريدي، أنظمة تقليل أخطاء الجرعات.