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Internet of Things as support to reduce hospital errors related to medication administration

Internet das Coisas como suporte para redução de erros hospitalares relacionados à administração de medicamentos

Internet de las Cosas como apoyo para reducir los errores hospitalarios relacionados con la administración de medicamentos

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Abstract
Objective: The high potential of digital technologies to reduce medication errors in patients hospitalized or under hospital care was explored in this investigation. The study identifies common types of medication errors and their probable causes. Furthermore, examines the technological innovation solutions available that have not yet been applied in this context, specifically the Internet of Things usage to reduce medication errors through a practical example. Methods: A rapid review was applied, exploring the papers from two databases. The analysis was limited to the period from 2017 to 2021, resulting in 147 articles from the VHL Regional Portal – Virtual Health Library and 257 articles from the PubMed database. Results: There were analyzed 40 studies. An error mapping related to the theme was made. Also, the technology application and their effectiveness were identified in the studies. According to the research, inattention or distraction due to the excessive journey of work was pointed out as the main reason that leads to medication errors with the systems employed. Conclusion: There are several opportunities to improve hospital procedures with new technological approaches. By implementing innovative technologies, hospital medication errors can be managed more efficiently and reduce costs and waste with errors medication.
Keywords: Medication errors; Internet of things; Patient safety; Health sciences, technology, and innovation management.

Resumo
Objetivo: O alto potencial das tecnologias digitais para reduzir erros de medicação em pacientes hospitalizados ou sob cuidados hospitalares foi explorado nesta investigação. O estudo explora tipos de erros comuns na manipulação de medicação e suas prováveis causas. Além disso, investiga as soluções com o uso da Internet das Coisas para reduzir erros de medicação apresentando um exemplo prático de uso. Métodos: Foi aplicada uma revisão rápida, explorando os artigos de duas bases de dados. A análise limitou-se ao período de 2017 a janeiro de 2022, resultando em 147 artigos do Portal Regional da BVS – Biblioteca Virtual em Saúde e 257 artigos da base de dados PubMed. Resultados: Foram analisados ao final 40 estudos. Foi feito um mapeamento de erros relacionados ao tema. Além disso, foram identificadas a aplicação da tecnologia e sua eficácia relatada nos estudos. Segundo a pesquisa, a desatenção ou distração devido à jornada excessiva de trabalho foi apontada como o principal motivo que leva a erros de medicação com os sistemas utilizados nos hospitais. Conclusão: Existem várias oportunidades para melhorar os procedimentos hospitalares com novas abordagens tecnológicas, como é o caso de Internet das Coisas. Ao implementar tecnologias inovadoras, os erros de medicação hospitalar podem ser gerenciados com mais eficiência proporcionando melhor atendimento e redução de gastos com o uso tecnológico eficiente.
Palavras-chave: Erros de medicação; Internet das coisas; Segurança do paciente; Gestão de ciência, tecnologia e inovação em saúde.

Resumen

Objetivos: Esta investigación muestra una visión sobre el potencial de las tecnologías digitales para reducir los errores de medicación en pacientes hospitalizados o bajo atención hospitalaria. Este estudio expone los tipos de errores más comunes en el manejo de medicamentos y sus posibles causas. Además, investiga soluciones utilizando las técnicas de Internet de las Cosas para reducir los errores de medicación, presentando un ejemplo práctico de uso. Métodos: Se aplicó una revisión rápida, utilizando artículos de dos bases de datos. El análisis se limitó al período de 2017 a enero de 2022, resultando en 147 artículos del Portal Regional de la BVS – Biblioteca Virtual en Salud y 257 artículos de la base de datos PubMed. Resultados: Al final, se analizaron 40 estudios. Se realizó un mapeo de errores relacionados con el tema. Además, se identificó la aplicación de la tecnología y su efectividad reportada en los estudios. Según la investigación, la desatención o distracción por exceso de jornada laboral fue identificada como principal motivo que conduce a errores de medicación con los sistemas utilizados en los hospitales. Conclusión: Existen varias oportunidades para mejorar los procedimientos hospitalarios con nuevos enfoques tecnológicos, como la Internet de las Cosas. Mediante la implementación de tecnologías innovadoras, los errores de medicación hospitalaria se pueden gestionar de manera más eficiente, brindando una mejor atención y ahorro de costos mediante el uso eficiente de la tecnología. Además de asegurar la salud de los pacientes, las tecnologías pueden ayudar a reducir los costes que resultan de la aplicación equivocada de medicamentos a pacientes, así como permite reducir costos de internación, mejorar la tasa de ocupación y tiempo de alta Hospitalar, mejorar la productividad de los empleados del hospital, así como evitar procesos judiciales consecuentes.

Palabras clave: Errores de medicación; Internet de las cosas; Seguridad del paciente; Gestión de ciencia, tecnología e innovación en salud.

1. Introduction

Several factors may contribute to increasing the complexity of hospital operations, including the diversity of patients and their health conditions, as well as the high number of people assisting patients in medical procedures, leading to an increased proportion of operations being performed incorrectly. These issues can result in an aggravation of the health conditions of patients already debilitated by some disease (Kim et al., 2020). The scientific literature identified different records of hospital errors related to patients. Overall the years' several researchers in the medical and nursing area have tried to get to the true causes and propose solutions for their mitigation (Prado & Vilela, 2019). With regards to clinical biomedical engineering concepts and new technologies, this work contributes to the conversation about how new paradigms might be applied. In this context, the Internet of Things (IoT) can be used to improve health services, especially hospital care. Through the Internet of Things infrastructure, electronic devices, and distributed cloud systems can be accessed to enhance health assistance through communications resources and other technologies. (Firouzi et al., 2018). There are several opportunities to develop innovative solutions with the IoT. In the hospital setting, for example, the development of new tools and instruments to improve medical decision-making is just one example (Morales et al., 2021). Hence, medication errors can be reduced. Concerning patient care, several issues have been reported within the scope of organizational losses, such as day-to-day situations, and human restrictions that can eventually result in errors in the treatment of patients that can produce temporary or permanent negative effects on their health. As a highly complex system, health care involves several critical situations with potentially life-threatening consequences. Recently, in the COVID-19 pandemic, the multidisciplinary health professionals' teams were exposed to the infection risks and distress situation reported in some papers including nurse's suicides in Italy (Lupia et al., 2020). These features can lead to errors during patient care (Rosa & Perini, 2003). In addition, the overload of the health system suffered in recent years has aggravated the situation, considering the inadequate working conditions and stress sorrowed by health workers in this period (Salazar de Pablo et al., 2020).

Medications are essential to health care and have been used directly in the handling of patients. However, the pharmaceutical's inadequate management can cause significant adverse reactions, or simply be innocuous for the treatment, resulting in different conditions from those foreseen in the medical treatment prescript (Rabelo Néri et al., 2011). Medication errors in health care have been constantly discussed in the context of hospital care, reported negative consequences of short-term impact and result in high human damage which is very difficult to quantify, both for the patient and for the professionals and

institutions involved (Dalmolin, 2012; Henry, 2014; Lichtner et al., 2018; Vilela et al., 2017).

This way, the purpose of this study is present a solution using the IoT-based system to improve the management and use of medicines. The work is organized into five sections. Section 2 presents the rapid review methodology. The results are reported in Section 3. Section 4 brings forward the discussions. Following the final considerations and references.

2. Methodology

The rapid review methodology has been applied to a variety of works over the years. Based on this kind of methodology, some of the results were presented in the scoping review (Tricco et al., 2015). In rapid reviews, some components of a systematic review are simplified or omitted in order to produce information faster. The rapid review process has proven to be useful for getting evidence to decision-makers as quickly as possible (King et al., 2022). Some important points to this methodological approach employed in this work: time is the sources and searches are limited due to the time and the resources are restricted and take approximately 5 weeks to its development. We used a narrow question and didn't apply PICO strategy. Due to the limited time, the evaluation was strict and two databases were investigated. To document the full search strategy for two electronic databases used in this report, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards were used (Moher et al., 2009). For the purposes of a discussion regarding the technologies and innovation deployment, as well as the capability to improve the safety of patients concerned with medication errors, we categorized some results.

2.1 Scope of study

Two research questions were employed in the rapid review methodology:

RQ1 - What are the frequent errors medication reported in the studies?

RQ2 - What types of technologies have been engaged? In this context, have IoT-based systems been considered?

The descriptors used were “medication AND error AND hospital AND technology”, the period was limited from 2017 to 2022, resulting in 147 articles from the VHL Regional Portal – Virtual Health Library (https://bvsalud.org), and 257 articles from the PubMed database (https://pubmed.ncbi.nlm.nih.gov) explored at 2022, January 10th. The Parsival tool was used to organize the articles, select and analyze their outcomes. Table 1 presents the inclusion and exclusion criteria for the review process.

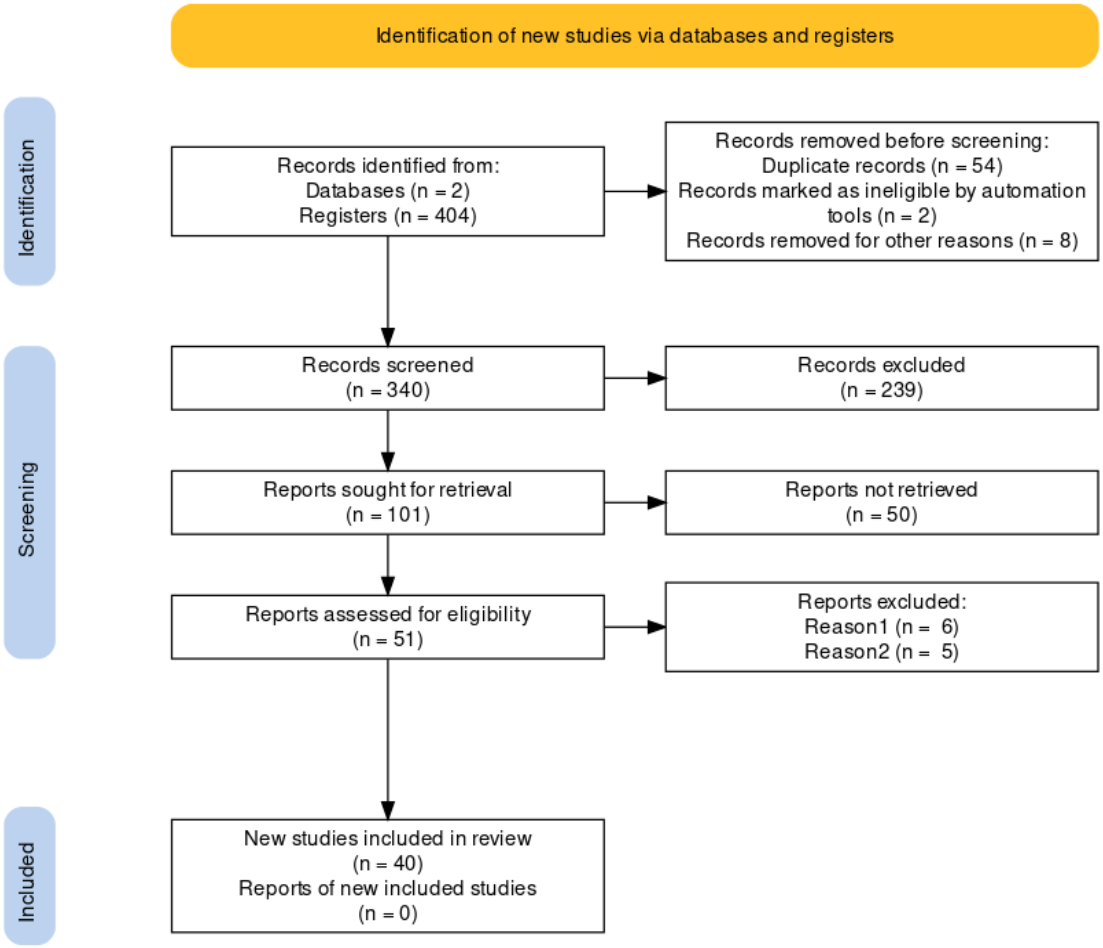
Table 1 - Inclusion and exclusion criteria.

Inclusion Criteria
Full articles published between 2017 and 2021.
Articles published in journals and peer reviewed.
Articles available in its full version.
Articles describing results of applications of technologies for medication errors
Exclusion Criteria
Duplicate articles
Articles that present systematic reviews or systematic mappings
Articles that do not have free access
It is not an article, although it is classified as such in a journal (editorials, book reviews, etc.).
Articles outside the scope of the search

Source: Authors.

The inclusion and exclusion selection criteria were applied and quantified according to the PRISMA (https://prisma-statement.org) diagram in Figure 1. Articles related to primary care were selected, considering works related to very specific areas and/or high complexity due to the research objective outside the research topic. There were selected 40 studies.

Figure 1 – PRISMA diagram.



Source: Authors.

3. Results

3.1 Answer to RQ1

According to an article published by Schwendimann et al (2018), based on data analysis from twenty-seven countries related to "Adverse Events", or EA's, in hospitals, it would have been possible to avoid 50% of the damage due to hospital errors (Schwendimann et al., 2018). In a more recent publication, adverse events are described as situations accompanied by a series of conditions that generate insecurity in patient care. However, studies related to the subject point to psychological and behavioral issues (M. C. Hsieh et al., 2021; Risør et al., 2017; Ting et al., 2020), leaving aside many issues related to management and organizational problems (Cabilan et al., 2017; Oliveros et al., 2017). Errors can occur during the medication process administration, such as stress by health professionals, and it represents an overload in the health system involving social and financial issues that affect everyone (M.-C. C. Hsieh et al., 2021). For example, coping with the COVID-19 pandemic in the world health system (Burlea-Schiopoiu & Ferhati, 2020). The investigated articles found distinct types of medication-related

errors (Risør et al., 2017). The rapid review enables the organization of Table 2 highlighting the importance to identify the most recurrent drug administration errors in hospital environments as an outcome of this work.

Table 1 – Medication errors and classes found in the review that are mentioned in several references.

Clinical errors	***Prescription-related errors and patient safety care***
Ref. (Küng et al., 2021),Ref. (M. C. Hsieh et al., 2021), Ref. (Burkoski et al., 2019), Ref. (Mohan et al., 2019), Ref. (Van Der Veen et al., 2018), Ref. (Cabilan et al., 2017), Ref. (Risør et al., 2017), Ref. (Spat et al., 2017), Ref. (Vélez-Díaz-Pallarés et al., 2017).	Incorrect medicine
	Omission of the prescribed dose
	Incorrect drug replacement
	Incorrect dose
	Incorrect patient
	Omission
	Lack of information with patient history
	Unidentified allergic reaction in prescription
	Incomplete documentation
Procedure errors	***Errors regarding the administration and preparation of medicines in the hospital environment***
Ref. (Barakat & Franklin, 2020), Ref. (Sessions et al., 2019), Ref. (Van Der Veen et al., 2018), Ref. (Cabilan et al., 2017), Ref. (Risør et al., 2017), Ref. (Lu et al., 2017), Ref. (Vélez-Díaz-Pallarés et al., 2017).	Incorrect dosage per unit
	Incorrect administration period
	Identification of the patient in the medicine box
	Patient identification control
	Incorrect barcode reading
	Distraction of the health care team
	Incorrect use of drug automation systems
	Inadequate monitoring
	Error in the packaging of the medicine
	Incorrect route administration
	Psychological issues
Organizational management errors	***Errors related to organizational conduct and management that affect patient care and safety***
Ref. (Chien et al., 2021), Ref. (Lawal et al., 2020), Ref. (Cabilan et al., 2017), Ref. (Vicente Oliveros et al., 2017)	Number of professionals to assist patients
	Excess hours in the workday of health professionals
	Lack of medication
	Logistics error
	Hospital policies
	Equipment reading
	Lack of adequate training for health professionals in hospital information systems
	Errors related to data entry in information systems

Source: Authors.

3.2 Answer to RQ2

Table 3 summarizes the types of technologies reported in the studies. Some articles refer to mobile devices (smartphones) and apps. In many cases, experimental solutions with machine learning and fuzzy appear, and in some cases consider other types of technology as analytical solutions for data analysis.

Table 3 – Types of technologies reported in the studies.

Technologies	Related articles
Barcode Medication Administration – BCMA	Refs. (Barakat & Franklin, 2020; Burkoski et al., 2019; Cabilan et al., 2017; González-Bueno et al., 2021; Kennedy & Massey, 2019; Küng et al., 2021; Mulac et al., 2021; Risør et al., 2017; Van Der Veen et al., 2018)
Electronic Health System – HER	Refs. (Amato et al., 2017; Biltoft & Finneman, 2018; Debono et al., 2017; Griffon et al., 2017; Jurado et al., 2018; Kirkendall et al., 2020; Pontefract et al., 2018; Reinhardt et al., 2019; Shah et al., 2021; Vélez-Díaz-Pallarés et al., 2017; Vicente Oliveros et al., 2017).
Health Information System – HIS	Refs. (Chien et al., 2021; Lu et al., 2017)
Mobile and Web App	Refs. (Ben Souissi et al., 2019; Ehrler & Siebert, 2020; Froese et al., 2021; Keyworth et al., 2017; Liao et al., 2019; Siebert et al., 2017; Spat et al., 2017; Ting et al., 2020)
Internet of Things	Refs. (Roh et al., 2021), (Wang et al., 2019)

Source: Authors.

Two articles presented IoT and cloud computing issues Refs. [33] and [34]. One of them presents an IoT-based solution, denominated Medication Behavior Monitoring System (MBMS). In this case, it is necessary configuration by the doctor to input the cycles of the medication into the MBMS device first. After, the medication will be administered by the patient himself. The system sends an alarm to the patient's smartphone or emits an alarm at the time of taking the medicine. When a patient hears the alarm and approaches the device, the camera records the video based on the motion detected around the motion detection sensors and stores the behavior of the patient's medication. The system uses OpenPose, the human activity recognition part analyzes the patient's behavior in relation to recorded images and identifies the act of raising the arm to drink water. After detecting the action, the device discards the right amount of medication to easily provide the patient with medication. The weight of the drug is checked according to the doses taken by the patient. If the patient's behavior is compatible with the act of taking water and the weight of the drug converges to zero, it is considered that the drug was taken at the right time. The device sends weekly results to the doctor, allowing the monitoring of the patient's behavior and the patient's health status. The device uses the MQTT protocol to send the information. Furthermore, information to assist in disease management, such as foods that may or may not be ingested, is performed through a monitor connected to the device (Roh et al., 2021). The second article in the IoT-based system context is not exactly for medication administration but is a device that predicts patient safety. It is a wearable device for blood pressure monitoring, which analyzes in real time and predicts the occurrence of strokes through machine learning algorithms. The device can be integrated into a hospital system architecture allowing monitoring through a panel that displays the graphics of the device's monitoring and can be accessed through a web page (Wang et al., 2019).

The implementation of barcodes in the administration of medicines (Barcode Medication Administration - BCMA) associated with electronic registration systems for label of adverse medication events was explored by nine studies. The studies reported satisfactory results, but pointing out problems related to the use of technology as one of the notification of health teams. Between the difficulties presented it was mentioned the information system manipulation during the daily activities. Another technology cited, which resulted satisfactory consequences, is the use of Electronic Health Records (EHR). In some cases, the use of electronic registration was associated with BCMA technology Refs. (Cabilan et al., 2017; Küng et al., 2021; Mulac et al., 2021; Risør et al., 2017). Health Systems, or Health Information System (HIS), are mentioned in two studies Refs.(Chien et al., 2021; Lu et al., 2017). Several studies were analyzed, about thirteen articles reported results, some of them were integrated with other types of technologies, such as BCMA and EHR system Refs. (Kennedy & Massey, 2019; Lu et al., 2017; Shah et al., 2021).

4. Discussion

During the investigation, two papers were encountered in the rapid review belonging to the IoT context. It is essential emphasizing IoT ecosystems allow the exchange of information through shared systems remotely, regardless of their distance and geographical location (Atzori et al., 2010). When the new paradigm is associated with the health area, several opportunities can be explored, and it has been possible to find different definitions of health involving this concept: Internet of Medical Things, Internet of Things Healthcare, Smart Healthcare, Healthcare 4.0, Smart Hospital, etc. In the literature, existing many terms related to the suitability of these new technologies in the health area. Furthermore, there are several new types of research explored in this theme, new sensors, biomarkers, devices, microprocessors, and new machine learning approaches specifically to healthcare (Al-Turjman et al., 2020; Habibzadeh et al., 2020; Qadri et al., 2020; Scarpato et al., 2017). In general, the IoT allows the combination of various areas of knowledge and applications, such as data acquisition, communication, data analysis, and uninterrupted connectivity. This allows objects (or things) to store, exchange, and combine data that results in useful information for human decision-making. Until this moment, there is no international standardization of use for the IoT-based system architecture applied to health (Morales et al., 2021). There is not even a consensus on the distribution of the number of layers needed for your deployment, but usually, they have very similar functions. There is a challenge to improve security and privacy issues, specifically in the health context.

4.1 Employing IoT to Reduce Medication Errors

An IoT-based system is proposed to help reduce medication errors. Three-layer IoT requires wrist wearables, smart medicine cases, and interactive displays that record events automatically and provide access to the database with respect to the patient's identity. Figure 3 illustrates an IoT-based system proposal.

Figure 2 - Interaction of devices in the nurse-patient system.

Source: Authors.

One of the essential points to avoiding medication errors is related to the identification system, for both patient and the nurse. There are several types of medication errors, including incorrect information about names, health conditions, allergies, and other information that the nursing team may need to evaluate the medication administration process. Among the attributes of an IoT-based system is the ability to gather data, so patients and health workers should wear wristbands with an electronic microprocessor, a small memory, and a wireless communication interface. In addition to being comfortable for the patient or

care professional, the wristbands need to be adjustable, for instance, on the wrist, leg, or on the body in the appropriate place. Various colors can be used to indicate standardized relevant information, such as allergies or chronic diseases. Nowadays, it is used today is a plasticized paper tape with printed identification and a barcode. This solution, although practical and inexpensive. It does not allow the inclusion of other information and it needs a portable barcode reader to integrate with the computer system. Furthermore, it is impossible to add or update the information. The barcodes increase the likelihood of errors occurring in the process. Electronic wristbands holding integrated electronics enable the updating of information automatically, including medication received, food, hygiene and other, i.e., the registration of care by nursing staff. The medication box may also include wireless communication to store information related to the drugs included in it. For example, it is possible showing information about the pharmacy sector, the name of the physician, the pharmacist, the nurse, and the patient, as well as to detail each of the medications along with the time and the way of handling and administration of medicine. In the pharmacy data load, the system automatically checks allergies or antagonistic conditions with the selected substances, and it will alert the pharmacist or the nurse. Most of the information is automatically captured, including the electronic signature of the pharmacy professional at the time of release for administration. For the drugs, RFID tags should be used to aid in automating the process. A hospital tablet in each bed, fixed to the wall or the hospital bed, detects the arrival of the professional and the box of medications and checks that they agree with the identification of the patient corresponding to that bed, issuing authorization or verification alerts. This element records the event and forwards it to the cloud to be part of the data collection and record. The approach would be employed by hospital management for other applications around costs and control of drug use. Other communication elements spread throughout the various sectors of the hospital would record the movement of patients and nurses during the 24 hours, seven days a week. As shown in the Table 3, IoT-based systems enhance medication administration security.

Table 1 - Rules that the IoT-based system could follow to ensure patient safety while administering drugs process.

Rules	Patient Safety
Correct medicine (clinical error)	Check the dispensing in the pharmacy and administration in the room.
Correct patient (clinical error)	Automatic identification in the bed of medicines, room and patient, even in rooms of multiple beds.
Correct route (procedure error)	Indicated the procedure on the display. The nurse should tap the screen to confirm the route.
Correct dosage (procedure error)	Checked in the pharmacy and checked by the nurse in the room through the smart viewfinder. The nurse should tap the screen to confirm the dosages.
Correct time (clinical error)	Automatic event logs and prescription-related views. Generation of notifications about possible delays.
Registration of administered medications (organizational administration error)	Confirmation from the nurse.
Inform and instruct the patient about the medications he receives	Electronic systems are able to speak aloud and even send this information by electronic message, for example, to a patient's or family's smartphone.
Check that the patient is not taking any medication sofa to the prescribed (clinical error)	It's a point to be analyzed. The viewfinder has video camera, which can be used. However, there are practical, ethical and cultural considerations to take into account.
Investigate whether the patient suffers from allergies and rule out pharmacological interactions (clinical error)	Known allergies are stored in the cloud. The color of the bracelets may evidence allergies, diabetes, and other conditions. However, unknown allergies should be evaluated by conventional means.
Wash hands before preparing and administering a medicine (procedure error)	The presence of the nurse in hand washing can be detected, however it is difficult to address all situations, other than the issuance of an alert message on the display, remembering this standard and requesting confirmation that it was met.

Source: Authors.

5. Final Considerations

This paper presented a rapid review of medication errors with technology usage in hospital environments. The results obtained help to mapping a set of medical errors and information technologies in the care of patients in hospitals. This study is based on the development of the research proposal and directed the search for technologies that could help reduce adverse effects in hospitals, specifically medication errors. The potential of information technologies and specifically IoT-based systems have not yet found its place in hospital care, as observed in the results that point out only two works in this context. However, there is increasing interest in researching and evaluating the use of this resource to improve hospital procedures and processes. This technology may improve the hospital management process. The technology proposed in this article is feasible, available, and can be integrated as a pilot project in any hospital unit.

Finally, we emphasize some suggestions about future works. The scientific community needs to advance how to guarantee privacy for patients and how to include security mechanisms in the Internet of Things Healthcare (Ma et al., 2019; Qadri et al., 2020). There are rare important results about this theme and have been a vital investigation to increase the usage of new technologies in hospital management and safe patient (Ahmadi et al., 2019). Some techniques may be incorporated into the solution before deploying it for field testing, guaranteeing the efficient and correct use of new technologies. Another important issue is related to wearables and materials to employ in hospitals to manage the vital signs of the patient. There are significant approaches and resources to be explored associated with innovation and application of new technologies in healthcare and safe patients (Minh Dang et al., 2019; Prieto-Avalos et al., 2022).

References

Ahmadi, H., Arji, G., Shahmoradi, L., Safdari, R., Nilashi, M., & Alizadeh, M. (2019). The application of internet of things in healthcare: a systematic literature review and classification. In *Universal Access in the Information Society* (Vol. 18, Issue 4). Springer Berlin Heidelberg. https://doi.org/10.1007/s10209-018-0618-4

Al-Turjman, F., Nawaz, M. H., & Ulusar, U. D. (2020). Intelligence in the Internet of Medical Things era: A systematic review of current and future trends. *Computer Communications*, *150*(December 2019), 644–660. https://doi.org/10.1016/j.comcom.2019.12.030

Amato, M. G., Salazar, A., Hickman, T. T. T., Quist, A. J. L., Volk, L. A., Wright, A., McEvoy, D., Galanter, W. L., Koppel, R., Loudin, B., Adelman, J., McGreevey, J. D., Smith, D. H., Bates, D. W., & Schiff, G. D. (2017). Computerized prescriber order entry-related patient safety reports: Analysis of 2522 medication errors. *Journal of the American Medical Informatics Association*, *24*(2), 316–322. https://doi.org/10.1093/jamia/ocw125

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, *54*(15), 2787–2805. https://doi.org/10.1016/j.comnet.2010.05.010

Barakat, S., & Franklin, B. D. (2020). An Evaluation of the Impact of Barcode Patient and Medication Scanning on Nursing Workflow at a UK Teaching Hospital. *Pharmacy (Basel, Switzerland)*, *8*(3), 148. https://doi.org/10.3390/pharmacy8030148

Ben Souissi, S., Abed, M., El Hiki, L., Fortemps, P., & Pirlot, M. (2019). PARS, a system combining semantic technologies with multiple criteria decision aiding for supporting antibiotic prescriptions. *Journal of Biomedical Informatics*, *99*(July), 103304. https://doi.org/10.1016/j.jbi.2019.103304

Biltoft, J., & Finneman, L. (2018). Clinical and financial effects of smart pump-electronic medical record interoperability at a hospital in a regional health system. *Am J Health Syst Pharm*, *75*(14), 1064–1068. https://doi.org/10.2146/ajhp161058

Burkoski, V., Yoon, J., Solomon, S., Hall, T. N. T., Karas, A. B., Jarrett, S. R., & Collins, B. E. (2019). Closed-Loop Medication System: Leveraging Technology to Elevate Safety. *Nurs Leadersh (Tor Ont)*, *32*(SP), 16–28. https://doi.org/10.12927/cjnl.2019.25817

Burlea-Schiopoiu, A., & Ferhati, K. (2020). The Managerial Implications of the Key Performance Indicators in Healthcare Sector: A Cluster Analysis. *Healthcare (Basel, Switzerland)*, *9*(1). https://doi.org/10.3390/healthcare9010019

Cabilan, C. J., Hughes, J. A., & Shannon, C. (2017). The use of a contextual, modal and psychological classification of medication errors in the emergency department: a retrospective descriptive study. *J Clin Nurs*, *26*(23–24), 4335–4343. https://doi.org/10.1111/jocn.13760

Chien, S. C., Chin, Y. P. H., Yoon, C. H., Islam, M. M., Jian, W. S., Hsu, C. K., Chen, C. Y., Chien, P. H., & Li, Y. C. J. (2021). A novel method to retrieve alerts from a homegrown Computerized Physician Order Entry (CPOE) system of an academic medical center: Comprehensive alert characteristic analysis. *PLoS ONE*, *16*(2 February). https://doi.org/10.1371/journal.pone.0246597

Dalmolin, G. R. dos S. (2012). *Erros de medicação no ambiente hospitalar : uma abordagem através da bioética complexa* [Universidade Federal do Rio Grande do Sul]. https://lume.ufrgs.br/handle/10183/60813

Debono, D., Taylor, N., Lipworth, W., Greenfield, D., Travaglia, J., Black, D., & Braithwaite, J. (2017). Applying the Theoretical Domains Framework to

identify barriers and targeted interventions to enhance nurses' use of electronic medication management systems in two Australian hospitals. *Implementation Science*, *12*(1). https://doi.org/10.1186/s13012-017-0572-1

Ehrler, F., & Siebert, J. N. (2020). PedAMINES: A disruptive mHealth app to tackle paediatric medication errors. *Swiss Medical Weekly*, *150*(35–36), 1–10. https://doi.org/10.4414/smw.2020.20335

Firouzi, F., Farahani, B., Ibrahim, M., & Chakrabarty, K. (2018). Keynote paper: From EDA to IoT eHealth: Promises, challenges, and solutions. *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, *37*(12), 2965–2978. https://doi.org/10.1109/TCAD.2018.2801227

Froese, L., Dian, J., Batson, C., Gomez, A., Sainbhi, A. S., Unger, B., & Zeiler, F. A. (2021). Computer Vision for Continuous Bedside Pharmacological Data Extraction: A Novel Application of Artificial Intelligence for Clinical Data Recording and Biomedical Research. *Frontiers in Big Data*, *4*(August), 1–9. https://doi.org/10.3389/fdata.2021.689358

González-Bueno, J., Sevilla-Sánchez, D., Puigoriol-Juvanteny, E., Molist-Brunet, N., Codina-Jané, C., & Espaulella-Panicot, J. (2021). Factors associated with medication non-adherence among patients with multimorbidity and polypharmacy admitted to an intermediate care center. *International Journal of Environmental Research and Public Health*, *18*(18). https://doi.org/10.3390/ijerph18189606

Griffon, N., Schuers, M., Joulakian, M., Bubenheim, M., Leroy, J.-P. P., & Darmoni, S. J. (2017). Physician satisfaction with transition from CPOE to paper-based prescription. *International Journal of Medical Informatics*, *103*(November 2016), 42–48. https://doi.org/10.1016/j.ijmedinf.2017.04.007

Habibzadeh, H., Dinesh, K., Rajabi Shishvan, O., Boggio-Dandry, A., Sharma, G., & Soyata, T. (2020). A Survey of Healthcare Internet of Things (HIoT): A Clinical Perspective. *IEEE Internet of Things Journal*, *7*(1), 53–71. https://doi.org/10.1109/JIOT.2019.2946359

Henry, T. A. (2014). Focusing on new hospital technology. *J Med Assoc Ga*, *103*(3), 8–10. https://pesquisa.bvsalud.org/portal/resource/pt/mdl-25665338

Hsieh, M.-C. C., Chiang, P.-Y. Y., Lee, Y.-C. C., Wang, E. M.-Y. Y., Kung, W.-C. C., Hu, Y.-T. T., Huang, M.-S. S., & Hsieh, H.-C. C. (2021). An investigation of human errors in medication adverse event improvement priority using a hybrid approach. *Healthcare (Switzerland)*, *9*(4), 1–16. https://doi.org/10.3390/healthcare9040442

Hsieh, M. C., Chiang, P. Y., Lee, Y. C., Wang, E. M. Y., Kung, W. C., Hu, Y. T., Huang, M. S., & Hsieh, H. C. (2021). An investigation of human errors in medication adverse event improvement priority using a hybrid approach. *Healthcare (Switzerland)*, *9*(4), 1–16. https://doi.org/10.3390/healthcare9040442

Jurado, C., Calmels, V., Lobinet, E., Divol, E., Hanaire, H., Metsu, D., & Sallerin, B. (2018). The Electronic Pharmaceutical Record: A new method for medication reconciliation. *Journal of Evaluation in Clinical Practice*, *24*(4), 681–687. https://doi.org/10.1111/jep.12942

Kennedy, A. R., & Massey, L. R. (2019). Pediatric medication safety considerations for pharmacists in an adult hospital setting. *American Journal of Health-System Pharmacy*, *76*(19), 1481–1491. https://doi.org/10.1093/ajhp/zxz168

Keyworth, C., Hart, J., Thoong, H., Ferguson, J., & Tully, M. (2017). A technological innovation to reduce prescribing errors based on implementation intentions: The acceptability and feasibility of myprescribe. *JMIR Human Factors*, *4*(3). https://doi.org/10.2196/humanfactors.7153

Kim, M. S., Seok, J. H., & Kim, B. M. (2020). Mediating role of the perceived benefits of using a medication safety system in the relationship between transformational leadership and the medication-error management climate. *Journal of Research in Nursing : JRN*, *25*(1), 22–34. https://doi.org/10.1177/1744987118824621

King, V. J., Stevens, A., Nussbaumer-Streit, B., Kamel, C., & Garritty, C. (2022). Paper 2: Performing rapid reviews. *Systematic Reviews*, *11*(1), 1–10. https://doi.org/10.1186/s13643-022-02011-5

Kirkendall, E., Huth, H., Rauenbuehler, B., Moses, A., Melton, K., & Ni, Y. (2020). The generalizability of a medication administration discrepancy detection system: Quantitative comparative analysis. *JMIR Medical Informatics*, *8*(12), 1–14. https://doi.org/10.2196/22031

Küng, K., Aeschbacher, K., Rütsche, A., Goette, J., Zürcher, S., Schmidli, J., & Schwendimann, R. (2021). Effect of barcode technology on medication preparation safety: A quasi-experimental study. *International Journal for Quality in Health Care*, *33*(1), 1–8. https://doi.org/10.1093/intqhc/mzab043

Lawal, B. K., Aliyu, A. A., Ibrahim, U. I., Maiha, B. B., & Mohammed, S. (2020). Medication safety practices in healthcare facilities in Kaduna State, Nigeria: a study protocol. *Therapeutic Advances in Drug Safety*, *11*, 2042098620927574. https://doi.org/10.1177/2042098620927574

Liao, C. Y., Wu, M. F., Poon, S. K., Liu, Y. M., Chen, H. C., Wu, C. L., Sheu, W. H. H., & Liou, W. S. (2019). Improving medication safety by cloud technology: Progression and value-added applications in Taiwan. *International Journal of Medical Informatics*, *126*(May 2018), 65–71. https://doi.org/10.1016/j.ijmedinf.2019.03.012

Lichtner, V., Westbrook, J. I., & Franklin, B. D. (2018). Pharmacy Interweaving Safety Within Hospital Health Information Technology. *Stud Health Technol Inform*, *252*, 105–111. https://pesquisa.bvsalud.org/portal/resource/pt/mdl-30040691

Lu, Y. H., Lee, L. Y., Chen, Y. L., Cheng, H. I., Tsai, W. T., Kuo, C. C., Chen, C. Y., & Huang, Y. Bin. (2017). Developing an App by Exploiting Web-Based Mobile Technology to Inspect Controlled Substances in Patient Care Units. *BioMed Research International*, *2017*. https://doi.org/10.1155/2017/3195369

Lupia, T., Scabini, S., Mornese Pinna, S., Di Perri, G., De Rosa, F. G., & Corcione, S. (2020). 2019 novel coronavirus (2019-nCoV) outbreak: A new challenge. *Journal of Global Antimicrobial Resistance*, *21*, 22–27. https://doi.org/10.1016/j.jgar.2020.02.021

Ma, X., Yao, T., Hu, M., Dong, Y., Liu, W., Wang, F., & Liu, J. (2019). A Survey on Deep Learning Empowered IoT Applications. *IEEE Access*, *7*, 181721–181732. https://doi.org/10.1109/ACCESS.2019.2958962

Minh Dang, L., Piran, M. J., Han, D., Min, K., & Moon, H. (2019). A survey on internet of things and cloud computing for healthcare. *Electronics (Switzerland)*, *8*(7), 1–49. https://doi.org/10.3390/electronics8070768

Mohan, A., Manikandan, S., Ravikumar, T. S., & Batmanabane, G. (2019). Decreasing medication errors in four intensive care units of a tertiary care teaching hospital in India using a sensitization programme. *Natl Med J India*, *32*(4), 207–212. https://doi.org/10.4103/0970-258X.291294

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Altman, D., Antes, G., Atkins, D., Barbour, V., Barrowman, N., Berlin, J. A., Clark, J., Clarke, M., Cook, D., D'Amico, R., Deeks, J. J., Devereaux, P. J., Dickersin, K., Egger, M., Ernst, E., … Tugwell, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7). https://doi.org/10.1371/journal.pmed.1000097

Morales, A. S., Ourique, F. de O., & Cazella, S. C. (2021). A Comprehensive Review on the Challenges for Intelligent Systems Related with Internet of Things for Medical Decision. *Studies in Fuzziness and Soft Computing*, *410*, 221–240. https://doi.org/10.1007/978-3-030-70111-6_11

Mulac, A., Mathiesen, L., Taxis, K., & Gerd Granås, A. (2021). Barcode medication administration technology use in hospital practice: a mixed-methods observational study of policy deviations. *BMJ Qual Saf*, *30*(12), 1021–1030. https://doi.org/10.1136/bmjqs-2021-013223

Oliveros, N. V., Caro, T. G., Menendez-Conde, C. P., Álvarez-Díaz, A. M., Álvarez, S. M.-A., Vicedo, T. B., & Silveira, E. D. (2017). Effect of an electronic medication administration record application on patient safety. *J Eval Clin Pract*, *23*(4), 888–894. https://doi.org/10.1111/jep.12753

Pontefract, S. K., Hodson, J., Slee, A., Shah, S., Girling, A. J., Williams, R., Sheikh, A., & Coleman, J. J. (2018). Impact of a commercial order entry system on prescribing errors amenable to computerised decision support in the hospital setting: A prospective pre-post study. *BMJ Quality and Safety*, *27*(9), 725–736. https://doi.org/10.1136/bmjqs-2017-007135

Prado, R., & Vilela, B. (2019). *Implantação de tecnologias para prevenção de erros de medicação em hospital de alta complexidade : análise de custos e resultados*. *17*(4), 1–7. https://doi.org/10.31744/einstein

Prieto-Avalos, G., Cruz-Ramos, N. A., Alor-Hernández, G., Luis Sánchez-Cervantes, J., Rodríguez-Mazahua, L., & Guarneros-Nolasco, L. R. (2022). *Wearable Devices for Physical Monitoring of Heart: A Review*. https://doi.org/10.3390/bios12050292

Qadri, Y. A., Nauman, A., Zikria, Y. Bin, Vasilakos, A. V., & Kim, S. W. (2020). The Future of Healthcare Internet of Things: A Survey of Emerging Technologies. *IEEE Communications Surveys & Tutorials*, *c*, 1–1. https://doi.org/10.1109/comst.2020.2973314

Rabelo Néri, E. D., Chaves Gadêlha, P. G., Maia, S. G., da Silva Pereira, A. G., de Almeida, P. C., Martins Rodrigues, C. R., Portela, M. P., & de França Fonteles, M. M. (2011). Erros de prescrição de medicamentos em um hospital brasileiro. *Revista Da Associação Médica Brasileira*, *57*(3), 306–314. https://doi.org/10.1590/s0104-42302011000300013

Reinhardt, H., Otte, P., Eggleton, A. G., Ruch, M., Wöhrl, S., Ajayi, S., Duyster, J., Jung, M., Hug, M. J., & Engelhardt, M. (2019). Avoiding chemotherapy prescribing errors: Analysis and innovative strategies. *Cancer*, *125*(9), 1547–1557. https://doi.org/10.1002/cncr.31950

Risør, B. W., Lisby, M., & Sørensen, J. (2017). Cost-Effectiveness Analysis of an Automated Medication System Implemented in a Danish Hospital Setting. *Value in Health*, *20*(7), 886–893. https://doi.org/10.1016/j.jval.2017.03.001

Roh, H., Shin, S., Han, J., & Lim, S. (2021). A deep learning-based medication behavior monitoring system. *Mathematical Biosciences and Engineering*, *18*(2), 1513–1528. https://doi.org/10.3934/MBE.2021078

Rosa, M. B., & Perini, E. (2003). Erros de medicação: quem foi? *Revista Da Associação Médica Brasileira*, *49*(3), 335–341. https://doi.org/10.1590/s0104-42302003000300041

Salazar de Pablo, G., Vaquerizo-Serrano, J., Catalan, A., Arango, C., Moreno, C., Ferre, F., Shin, J. Il, Sullivan, S., Brondino, N., Solmi, M., & Fusar-Poli, P. (2020). Impact of coronavirus syndromes on physical and mental health of health care workers: Systematic review and meta-analysis. *Journal of Affective Disorders*, *275*(May), 48–57. https://doi.org/10.1016/j.jad.2020.06.022

Scarpato, N., Pieroni, A., Di Nunzio, L., & Fallucchi, F. (2017). E-health-IoT universe: A review. *International Journal on Advanced Science, Engineering and Information Technology*, *7*(6), 2328–2336. https://doi.org/10.18517/ijaseit.7.6.4467

Schwendimann, R., Blatter, C., Dhaini, S., Simon, M., & Ausserhofer, D. (2018). The occurrence, types, consequences and preventability of in-hospital adverse events - A scoping review. *BMC Health Services Research*, *18*(1), 1–13. https://doi.org/10.1186/s12913-018-3335-z

Sessions, L. C., Nemeth, L. S., Catchpole, K., & Kelechi, T. J. (2019). Nurses' perceptions of high-alert medication administration safety: A qualitative descriptive study. *J Adv Nurs*, *75*(12), 3654–3667. https://doi.org/10.1111/jan.14173

Shah, S. N., Seger, D. L., Fiskio, J. M., Horn, J. R., & Bates, D. W. (2021). Comparison of Medication Alerts from Two Commercial Applications in the USA. *Drug Safety*, *44*(6), 661–668. https://doi.org/10.1007/s40264-021-01048-0

Siebert, J. N., Ehrler, F., Lovis, C., Combescure, C., Haddad, K., Gervaix, A., & Manzano, S. (2017). A mobile device app to reduce medication errors and time to drug delivery during pediatric cardiopulmonary resuscitation: Study protocol of a multicenter randomized controlled crossover trial. *JMIR Research Protocols*, *6*(8), e167. https://doi.org/10.2196/resprot.7901

Spat, S., Donsa, K., Beck, P., Höll, B., Mader, J. K., Schaupp, L., Augustin, T., Chiarugi, F., Lichtenegger, K. M., Plank, J., & Pieber, T. R. (2017). A Mobile Computerized Decision Support System to Prevent Hypoglycemia in Hospitalized Patients with Type 2 Diabetes Mellitus. *Journal of Diabetes Science and Technology*, *11*(1), 20–28. https://doi.org/10.1177/1932296816676501

Ting, H. W., Chung, S. L., Chen, C. F., Chiu, H. Y., & Hsieh, Y. W. (2020). A drug identification model developed using deep learning technologies: Experience of a medical center in Taiwan. *BMC Health Services Research*, *20*(1), 1–9. https://doi.org/10.1186/s12913-020-05166-w

Tricco, A. C., Antony, J., Zarin, W., Strifler, L., Ghassemi, M., Ivory, J., Perrier, L., Hutton, B., Moher, D., & Straus, S. E. (2015). A scoping review of rapid review methods. *BMC Medicine*, *13*(1). https://doi.org/10.1186/s12916-015-0465-6

Van Der Veen, W., Van Den Bemt, P. M., Bijlsma, M., De Gier, H. J., & Taxis, K. (2018). Association between workarounds and medication administration

errors in bar code-assisted medication administration: Protocol of a multicenter study. *Journal of the American Medical Informatics Association*, *25*(4), 385–392. https://doi.org/10.2196/resprot.7060

Vélez-Díaz-Pallarés, M., Álvarez Díaz, A. M., Gramage Caro, T., Vicente Oliveros, N., Delgado-Silveira, E., Muñoz García, M., Cruz-Jentoft, A. J., & Bermejo-Vicedo, T. (2017). Technology-induced errors associated with computerized provider order entry software for older patients. *International Journal of Clinical Pharmacy*, *39*(4), 729–742. https://doi.org/10.1007/s11096-017-0474-y

Vicente Oliveros, N., Gramage Caro, T., Pérez Menendez-Conde, C., Álvarez-Díaz, A. M., Martín-Aragón Álvarez, S., Bermejo Vicedo, T., & Delgado Silveira, E. (2017). Effect of an electronic medication administration record application on patient safety. *Journal of Evaluation in Clinical Practice*, *23*(4), 888–894. https://doi.org/10.1111/jep.12753

Vilela, R. P. B., Castilho, V., Jericó, M. de C., & Faria, J. I. L. (2017). Educação permanente: tecnologia para a prevenção do erro de medicação. *CuidArte, Enferm*, *11*(2), 203–208. http://www.webfipa.net/facfipa/ner/sumarios/cuidarte/2017v2/203.pdf

Wang, G., Zhou, S., Rezaei, S., Liu, X., & Huang, A. (2019). An ambulatory blood pressure monitor mobile health system for early warning for stroke risk: Longitudinal observational study. *JMIR MHealth and UHealth*, *7*(10), 1–13. https://doi.org/10.2196/14926