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Towards a novel Data Mining System for Medication Error Management

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Abstract—Medication errors associated with the Medication Use Process present significant risks and require effective management. However, current practices do not address these risks. There is a lack of awareness that medication errors are unintended risks, and a lack of dedicated systems to manage them. To overcome these limitations, a digital system exploiting massive medical data (big data) is proposed. By integrating various data sources, this system aims to provide adaptable medication errors' management and continuous improvement. This article presents an overview of the system requirements and highlights the potential of Data Mining in healthcare. Implementing this system could revolutionize medication error management and improve patient safety.

Index Terms—Medication Use Process, Medication error, Requirement, Data Science, Reporting, Classification

I. INTRODUCTION

Managing risks associated with the Medication Use Process (MUP) is paramount due to their high frequency of occurrence and significant impact on all stakeholders involved in healthcare delivery. Medication error (ME) is one of such risks, but, which is not adequately managed and treated in current practices [1]. Studies found that there is a lack of awareness regarding the fact that MEs are non-intentional risks and that reporting their occurrence does not reflect negatively on the quality of the healthcare facility or the care provided [2] [3]. Also, there is a lack of implemented systems in healthcare facilities dedicated to ME to help improve the management process. Moreover, researchers such as [4] found that there exists a wealth of untapped contextual data surrounding ME that could have been leveraged for their correction or prevention [1].

As confronted with a considerable number of MEs occurring yearly [5] [6], MEs management becomes a challenging task for healthcare professionals. It is all about errors occurring during the MUP, which involves multiple steps, from prescription and dispensing to administration and monitoring. Multiple caregivers from doctors to pharmacists and nurses [7] are

participating in this process. In fact, throughout this complex process, there is potential for errors to occur, which can result in adverse drug events, patient harm, increased healthcare costs, and legal implications. Studies have shown that MEs are alarmingly common, affecting a significant number of patients across various healthcare settings [8].

Despite the gravity of the situation, current approaches used to manage those MEs often fall short [9]. Current methods rely on manual reporting on which the causes and consequences analysis is based. All this makes it difficult to grasp the full extent of MEs and their contributing factors. It is difficult to access all of the facility's reports and determine the frequency of occurrence of each type of error in each department. In addition, the unstructured nature of manual reporting makes analysis incomplete and subsequently influences the facility's approach to improvement.

To address these limitations, we aim to concept a digital system leveraging big data in the healthcare domain. By harnessing the vast amount of available medical data, that could be issued from various sources, it becomes possible to gain deeper insights into the occurrence and patterns of ME. These data can be sourced from electronic health records, patient report data, prescription records, clinical guidelines, and especially the reported errors (i.e., internal in the facility or external in the national or regional authorities). Such a system can help provide adaptable management of MEs shared with all the services of the facility and promise continuous improvement.

In this paper, we present the benefits of using data mining techniques in healthcare. How can healthcare professionals benefit from the evolution of data and computer science to improve the quality of care? To do so, Firstly, Section II presents an overview of the use of Data Mining (DM) in the healthcare area, pointing out its benefit on healthcare in general and in managing ME in hospitals especially. Secondly, Section III points to the requirements of our proposed system,

presenting the limits of the current management approach in hospitals and how to deal with ME-related data. And finally, we conclude in Section IV with our perspectives.

II. APPLICATION OF DATA MINING SYSTEMS IN THE HEALTHCARE AREA

A. Benefits of Data Mining in Healthcare

In an area, that is known for its abundance of big data, it is important to recognize the potential of using this data to achieve more positive outcomes within the system. The healthcare area as defined by the Oxford dictionary is “the service of providing medical care”. Furthermore, the Cambridge Dictionary defines it as “the services, provided by a country or an organization, that involve caring for people’s health and treating people who are ill”. In other words, healthcare is a multilayered system designed to prevent, diagnose, and treat various medical conditions. Involving several practitioners, different services, and a lot more stakeholders, made in the disposition of numerous patients, the healthcare area constitutes a huge source of patient-related data. In addition, the evolution in the digital era has led to the confluence of healthcare and technology resulting in the emergence of newer data-related applications [10]. All this contributes to the constitution of a huge amount of data related to the medical field “healthcare-related big data”. In contrast to big data in other domains, medical big data possesses several unique attributes. Acquiring medical big data is often challenging, and they are typically structured based on protocols, although they are not fully standardized. Given the complex medical context, professional knowledge plays a dominant role in data analysis and interpretation. Medical data are characterized by immense scale, rapid update rates, polymorphic nature, incompleteness, and time sensitivity. Establishing a big data platform will enable remote consultation, simplified operations, and reduced costs, fostering global cooperation to promote clinical practice, education, and scientific research. Additionally, this advancement has facilitated the global application of precision medicine and the emergence of innovative health management models. [11]. Exploring this data helps use data that was inaccessible or unusable data for better and faster decisions. It is usually used in disease surveillance, healthcare management and administration, privacy protection and fraud detection, mental health, public health, and pharmacovigilance [12] [13]. This means that involving analytics and DM systems in the healthcare area has an impact on:

- **Improving Clinical Decision Making:** These systems analyze huge amounts of patient data and help identify patterns. They can assist healthcare providers in making more accurate and evidence-based clinical decisions, leading to better patient outcomes.
- **Detecting and preventing early disease:** DM algorithms can recognize early warning signs and risk factors for various diseases. This could help healthcare professionals to intervene early, providing timely treatments and preventive measurements, which lead to potentially reducing the severity of diseases, and improving patient prognosis.

- **Providing personalized medicine:** These systems enable the creation of patient profiles based on genetic, demographic, and lifestyle data. This personalized approach enables healthcare providers to tailor treatment to each patient, ensuring more effective and targeted therapies.
- **Enriching research and development:** These systems support medical research by identifying potential areas of interest and helping to discover new patterns and relationships in large datasets. This support accelerates medical research and promotes advances in healthcare.
- **Continuous quality improvement:** These systems enable healthcare organizations to analyze performance metrics, patient outcomes, and process efficiency. This drives continuous efforts to improve quality, leading to better patient care and service delivery.
- **Preventing Adverse Events and Ensuring Medication Safety:** These systems could identify potential drug reactions and drug interactions, thereby enhancing medication safety. In addition, these systems can predict or help correct adverse events in general and ME in special, enabling proactive measures to prevent harm.

According to these observations, we can conclude that these systems offer numerous advantages in the healthcare area, but it is crucial to acknowledge the challenges of handling healthcare-related data. Dealing with medical information involves a complex concept due to the vastness of sources, high data modality, diversity in data type, imbalanced datasets, and intricate data structures. Despite the benefits, navigating these complexities requires careful consideration and robust methodologies to ensure the effective utilization of DM systems in healthcare.

B. Benefits of a Data Mining system for medication errors management

As previously mentioned, DM systems could be able to prevent adverse events, which aligns with our goal—correcting and preventing ME. Indeed, MEs and Adverse events are related but not the same. ME can lead or not to an Adverse Event. As defined by the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP), ME is “any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use”. And, Adverse events are defined as an injury that was caused by medical management (rather than the underlying disease) and that prolonged the hospitalization, produced a disability at the time of discharge, or both. In fact, using a DM system to manage ME in hospitals offers several benefits, as presented in Fig.1 including:

- **Early Detection and Prevention:** Analyzing large volumes of data with DM techniques can identify pat-



Fig. 1. DM system benefits for ME management

terns and trends associated with ME. By detecting these patterns early, healthcare professionals can intervene promptly to prevent errors from reaching patients, thus improving patient safety and reducing harm.

- **Improved Patient Outcomes:** By identifying ME and their associated risks, a DM system can help healthcare professionals make more informed decisions about patient care. This can lead to improved treatment plans, better medication selection, and reduced ME, ultimately enhancing patient outcomes.
- **Identification of systemic issues:** DM allows the identification of underlying systemic issues that contribute to ME. By analyzing data across different departments, units, or even hospitals, patterns and trends can be identified, highlighting areas where process improvements or policy changes are needed. This can result in targeted interventions to address root causes and enhance medication safety across the healthcare organization.
- **Enhanced Decision Support:** DM can be used to develop decision support tools that provide real-time guidance to healthcare professionals during medication-related processes. These tools can alert clinicians about potential drug interactions, contraindications, dosing errors, or other medication-related risks, aiding in making safer and more accurate decisions.
- **Continuous quality improvement:** A DM system can facilitate ongoing monitoring and evaluation of medication safety practices. By analyzing data on an ongoing basis, the system can provide feedback and insights to healthcare professionals, allowing for continuous quality improvement efforts. This iterative approach enables the

identification of areas for improvement, implementation of interventions, and measurement of the impact of those interventions.

- **Resource Optimization:** DM can assist in optimizing resource utilization in MUP. By analyzing data on medication utilization, prescribing patterns, and medication waste, healthcare organizations can identify areas of inefficiency and make informed decisions about resource allocation. This can help reduce costs, minimize medication-related waste, and improve overall operational efficiency.
- **Research and Knowledge Generation:** DM systems generate valuable knowledge and insights from the vast amount of healthcare data available. This information can contribute to research endeavors focused on medication safety, identifying risk factors, evaluating the effectiveness of interventions, and generating evidence-based guidelines for the MUP.

Overall, using a DM system to manage ME in hospitals empowers healthcare organizations to proactively identify, prevent, and address medication-related risks, leading to improved patient safety, enhanced decision-making, and continuous quality improvement efforts. However, the most relevant thing to our research is related to exploring existing issues from the internal ME reporting in the hospital. Solving this will help healthcare professionals to, first of all, structure their management process to correct those risks and secondly prevent their occurrence.

III. MANAGING ME USING DATA MINING TECHNIQUES

A. ME management process

The process of ME management in hospitals is based on three main steps, from reporting and analyzing to implementing preventive and corrective safety barriers. This process is presented in Fig.2. Each step contributes to the improvement of patient safety and the minimization of errors. The first step involves **reporting** and capturing instances of ME. This involves all healthcare professionals and requires precise documentation and communication of any identified errors promptly. The second step entails an in-depth **analysis** and investigation of the causes and effects of the reported errors. However, it is built on the results of the previous step. Hospital risk managers working with healthcare professionals will base their analysis on what has been reported. If the information is incomplete, so is the analysis, and so on. This analysis helps to understand the root causes, contributing factors, and patterns of ME occurrence. It helps also to understand the systemic issues that may be at the root of errors, enabling the development of targeted interventions to correct them and even prevent their occurrence. The final step is the **implementation of preventive and corrective barriers**. Based on the results of the analysis, risk managers in the hospital work on the follow-up of the implementation of those barriers. Those are designed to proactively identify potential risks, prevent errors from reaching patients, and quickly address errors that do

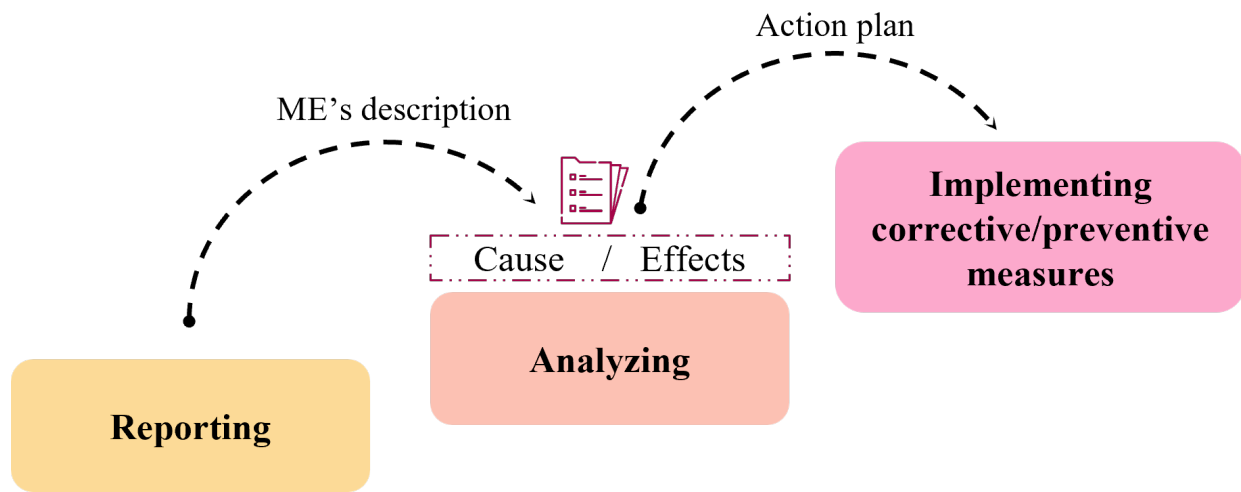


Fig. 2. ME management's process in hospital

occur to minimize their impact. The process described above is crucial for improving patient safety and minimizing errors. The problem with this process is that it is not well-organized. While the steps are indeed complementary, the transition from one step to another is almost arbitrary. The risk management committee of the healthcare facility chooses, based on the duration of their meeting and among the reports presented to them, one or two errors to be analyzed. Based on what has been described and through experience, there are no specific criteria for selection. This means that there may be an error among the reports that has had very serious consequences and occurs more frequently in different departments but has never been analyzed. Conversely, there might be an error that has no serious consequences, cannot develop into huge severity, is easy to correct, and is unlikely to recur, yet it is chosen for analysis instead of the more urgent one. This leads us to a very challenging issue, as it involves the patients' life prognosis, impacts the hospital's reputation, and leads to significant financial losses. Therefore, it is necessary to better organize this management and assist healthcare professionals in improving their management process to achieve a significant enhancement in patient safety. Hence the importance of reporting; it is crucial to report accurately and, above all, to analyze these reports thoroughly. Therefore, research efforts should focus on these reports, ensuring their categorization into very specific families to aid in selection and analysis. However, to ensure effective and targeted management, having high-quality and comprehensive data is essential. By extracting relevant data from the reporting step and applying data mining techniques, we can work towards achieving the main goal. This means that the first step to accomplish this is acquiring high-quality useful ME data.

B. Acquiring useful data reported ME

In our approach to managing ME in hospitals, we encounter several distinct data-related challenges. While the healthcare area is abundant in data, it is often unstructured. However,

the most significant hurdle lies in utilizing data from freely descriptive text provided by healthcare professionals to address ME. These texts contain abbreviations, and technical jargon, and are occasionally incomprehensible. This means that our first step is to try to extract important information from this unstructured written data. To achieve this, we have come up with two solutions:

- **Digitization of the reporting step:** As the reporting initiates the management process, it is important to consider the structure of this step. We propose to introduce a digital tool in all the hospital departments that enable the reporting of ME. It allows healthcare professionals to simply fill in a form with all the characteristics of the ME that will contribute to facilitating the understanding of the error. It has to help consider its causes and its consequences. This form, should, give information about the step on which the error occurs, the severity of its consequences, the immediate measures that were taken, the type of error, and eventual causes... However, all those information will be stored and archived in a database including all the errors occurring in all hospital departments. This database will be accessible by all the hospital staff, enabling the standardization of error management in the whole hospital and providing complete statistics per department and hospital. However, adopting this method means that we will drop all ME' reports made in previous years. We'll be then sacrificing a legacy of reporting rich in expertise and experience.
- **Extract information from existing reports:** For this, we will use all the existing reports of ME, and try to extract all their relevant information. For this, we propose to use the Natural Language Processing (NLP) information extraction techniques, which help to map the unstructured reporting text to structured ME information. This technique has proved its worth in various studies closer to our own. For example, the NLP has been

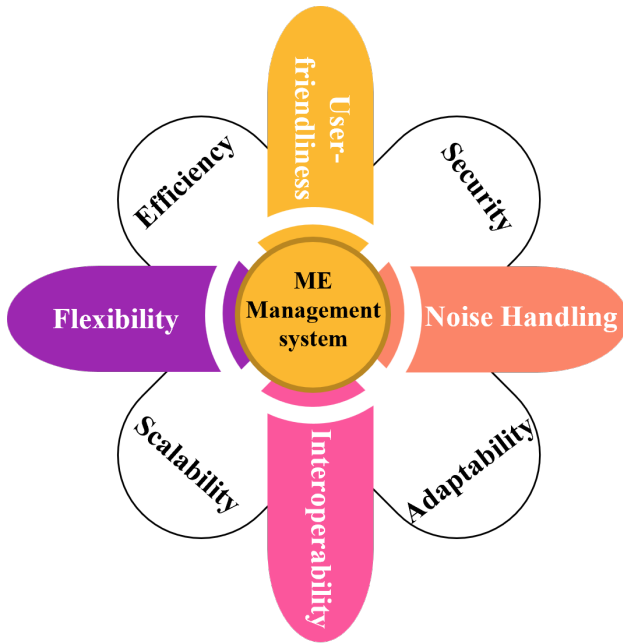


Fig. 3. Features requirements of a data mining system solution

used recently by [14], to identify Social determinants of health risk factors and social needs from electronic health records to improve patient care and outcomes. It has been used also for the detection of adverse drug events as presented by [15]. It promotes a good research field promising valuable results in the healthcare area [16] [17]. In comparison, with the first proposed solution, this one had the advantage of exploring a huge volume of existing data to rapidly help assist in automatically categorizing ME reports based on their types, severity, and contributing factors. By analyzing this text, NLP models can identify patterns and recurring themes, allowing healthcare practitioners to prioritize and address critical issues promptly. In addition, it can help pinpoint the root causes of MEs. The extracted information can be used to identify systemic issues, communication breakdowns, or faulty processes that lead to errors, enabling targeted interventions for prevention.

C. Solution Data Mining System requirements

While the data source problem is solved, we can explore the extracted information about ME. By using DM techniques, we can gain additional insights to enhance the quality of care and facilitate the correction and prevention of ME. This approach will simplify the management of risks associated with the MUP for healthcare professionals and offer them structured management solutions. To effectively address ME, we propose a solution system that involves data mining techniques and that must meet several critical requirements features [18] as summarized in Fig3. Firstly, the solution system should prioritize *user-friendliness*, ensuring that healthcare professionals can easily report errors. It has to operate with high *efficiency*

ensuring the capability to perform data mining on various data structures and delivering timely results considering the large volume of data involved. Additionally, it must be *scalable* to handle large datasets. Furthermore, *flexibility* and *adaptability* are also crucial, allowing the handling of data from various sources. Finally, it should properly *handle noise* and exceptional data efficiently to verify essential data validity. Also, the system should cater to different analytical needs by mining data at various abstraction levels. It is important to notice that the system's *interoperability* with existing healthcare systems enhances the overall efficiency. Data *security* is of utmost importance, and strong measures and role-based access control must be implemented to protect patient and stakeholders' privacy. The main goal of this solution is to deal with ME' data to improve patient care quality and reduce the risk of ME in the MUP. So, we are working on a classification problem that requires testing and training several techniques to find the most efficient one responding to our demand. This will help categorize Medication Errors (ME) occurring in the hospital and assist the Risk Management Committee in making informed choices regarding the categories for analysis. This, in turn, will save time and ensure effective management by correcting and preventing numerous errors. To do so, there are numerous data science techniques [19] available for addressing classification problems like this, as presented in previous research in [20], [21] or [22]. In our future work, we will test some of these techniques to evaluate their efficiency in responding to our research work.

IV. CONCLUSION

In conclusion, the benefits of using DM in the healthcare area are substantial, even for managing ME in hospitals. However, the current methods of hospital ME' management have limitations that can hinder patient safety and overall healthcare quality. By contrast, the introduction of a digital solution utilizing DM techniques in a comprehensive DM system can effectively address these challenges. However by leveraging the reported ME data, as we plan to do, hospitals can harness the power of large datasets to identify the patterns, trends, and potential risks associated with the MUP, such as ME. This enables healthcare professionals to make informed decisions, correct existing errors, implement proactive measures, and prevent errors before they occur, ultimately enhancing patient outcomes and reducing ME. The digital DM system solution we propose in this article sets forth essential requirements for its successful implementation, ensuring its potential to revolutionize medication errors management in healthcare facilities. Its integration into the hospital's management practice promises to bring about significant advancements, fostering a safer and more efficient patient MUP. Overall, the adoption of DM in the healthcare area holds great promise for improving patient care and safety. As technology continues to evolve, the potential of data to assist healthcare practices has become even more apparent. Embracing the digital age of data mining will undoubtedly lead to better patient outcomes and a brighter future for healthcare. In future work, we plan to place the

solution and evaluate its efficiency in response to our demand. Evaluating existing DM techniques in ME classification and NLP for extracting the ME required information.

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