Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 210 (2022) 236–241

Procedia Computer Science

www.elsevier.com/locate/procedia

The 3rd International Workshop on Healthcare Open Data, Intelligence and Interoperability (HODII)
October 26-28, 2022, Leuven, Belgium

Towards an Effective Clinical Decision Support System in Intensive Medicine

Francini Hak[a], Júlio Duarte[a], Tiago Guimarães[a]*, Manuel Santos[a]

[a]*ALGORITMI/LASI Research Center, University of Minho, Braga, Portugal*

Abstract

In Intensive Medicine there is a constant need to support daily activities and the decision-making process. However, some Clinical Decision Support Systems (CDSS) are not fulfilling their purpose and are not being considered effective. The present narrative literature review aims to identify the state of knowledge of a CDSS, regarding its strengths and weaknesses. Three different perspectives that can influence the performance of a CDSS in a Intensive Medicine were identified, making a crossing with the challenges faced and their possible mitigating actions.

Keywords: Clinical Decision Support Systems; Intensive Medicine; Knowledge-based systems; Electronic Health Records.

1. Introduction

Intensive Medicine (IM) is a medical specialty that deals with critical and complex health problems of patients [1]. The focus of the health professionals' work is on the direct application of their clinical knowledge to the patient. Thus, professionals in this field have access to a large amount of data for IM monitoring, which is constantly updated from heterogeneous systems [2]. As this exponential growth of data produced daily the process of knowledge extraction becomes essential [3].

* Corresponding author.
E-mail address: tiago.guimaraes@algoritmi.uminho.pt

10.1016/j.procs.2022.10.143

Therefore, there is a growing need to acquire knowledge through technological resources to improve the quality of service in Intensive Medicine, focusing on the improvement of Electronic Health Record (EHR) systems [1].

The activities of collecting and transforming data into information guarantee the production of knowledge, in order to support the decision-making process. Clinical Decision Support Systems (CDSS) are essential for this role being one of the main factors that guarantee the correct functioning in knowledge management from EHR systems [3]. The premise of CDSS is to support healthcare professionals in obtaining insights and making decisions without uncertainty. Health professionals in IM, as they are in constant rush and pressure, need to have their work simplified and facilitated, to avoid wasting time with unnecessary tasks and to focus entirely on improving the patient's health.

However, some CDSS when applied in real context, do not have the expected return. A literature review study [4] that we recently developed showed that the analyzed CDSS do not reach maturity and often demonstrate more flaws than benefits. Like all information technology, a CDSS has numerous benefits but also concerns and challenges that sometimes lead to cases of failure and compromises its efficacy. In this sense, this narrative literature review aims to identify the benefits and challenges highlighted in the use of CDSS, based on the literature. In addition, the identified challenges are crossed based on three perspectives (organizational, technological and social) that can directly influence the performance of the system.

This article is structured in four sections. First, an introduction about the topic of the study is presented. In the second section is described the background of Clinical Decision Support Systems, as well as its benefits and concerns. Thirdly, a cross-checking with the three perspectives is made. At last, in section four, conclusions are drawn leaving open doors for future work.

2. Clinical Decision Support Systems Background

As far as is known, the decision support activity started to be represented by a computerized system in the mid-60s, giving rise to Decision Support Systems (DSS) [5]. In the Intensive Medicine domain, many needs arise with the exponentially growth of data, encouraging the adoption of information systems capable to transform unstructured records into knowledge. The responsible for this role are, fundamentally, Clinical Decision Support Systems (CDSS). HIMSS [6] defines CDSS as a “process for enhancing health-related decisions and actions with pertinent, organized clinical knowledge and patient information to improve health and healthcare delivery”.

There are many ways to represent clinical decision support activities. Moreover, the computerized CDSS are normally distinguished into two types: knowledge-based and non-knowledge-based. The first one requires a knowledge base that can produce rule statements, interconnecting with inference and communication mechanisms. On the other hand, a non-knowledge based CDSS uses the clinical data focusing on learning algorithms through Machine Learning and Artificial Intelligence techniques [7], [8]. Both approaches have pros and cons, but within the scope of this article the focus will be on knowledge-based systems.

2.1. The gains

With the technological advancement in the healthcare field, there is an evident growing demand for information systems capable of storing and processing Electronic Health Records [3]. Several studies portray the CDSS as essential, substantial, and unique. However, it is important to identify its specific benefits, to justify its adoption. According to literature, CDSS aims to present the evidence-based clinical practice, to support healthcare practitioners in the decision-making process [9]. Overall, improve the quality in healthcare delivery is one of the most promising expected outcomes that encourage the CDSS adoption. As well providing a better management in the workflow tasks, lightening the workload of healthcare professionals. This is directly related with the reduction of errors and malpractices in services, which increases safety and the quality of the service provided to patients [10].

The cost reduction also motivates the adoption of CDSS, using analytical tools or other mechanisms that help in the data collection process in a safe and effective way [11]. Shahsavarani [10] states that all systems should be cost-effectiveness, and cost-quality ratio is also highlighted by [12]. Moreover, computerized-based systems also allow time reduction and streamlining process due to the replacement of paper files. This saved time can be used to improve the interaction between the health professional and the patient, as well as relieve the professional from other tasks

[10]. The ability to adapt to specific workflows is also seen as a benefit by some authors [7], [10], meaning that a CDSS can be applied in several areas of care if it is well implemented.

After describing the benefits most found in literature review, it is important to link these factors with the effectiveness of a CDSS. Shahsavarani [10] establishes three domains as being the biggest benefits of a CDSS and states that if these benefits are accomplished, the CDSS reaches its efficacy: (i) improvement of quality of healthcare and patient safety; (ii) increase of effectiveness/cost ration; (iii) improvement of medical and professional knowledge.

On the other hand, Jao [12] states that reducing medical errors and improving patient safety are key points to bring effectiveness. At the operational level, Jao [12] defends three key elements for a successful CDSS: (i) access to accurate clinical data; (ii) access to relevant medical knowledge; (iii) ability to use appropriate problem-solving skills. Overall, an effective CDSS can involve different levels in the decision-making process, ranging from alerting, interpreting, criticizing, assisting, diagnosing and managing [10], [11], [13], being the alerts highlighted as the best strategy to achieve the effectiveness of a CDSS.

2.2. What is missing?

Greenes [8] affirms the importance of a DSS in the health area but highlights some non-conformities and existing failures that are not yet solved. The key obstacle of the slow process in CDSS adoption regards to knowledge representation for decision support, that should be in a standard form so that records can be read semantically for any system [8]. This issue is also highlighted by [14] where the author states that the lack of clinical terminologies and standardized approaches are a limitation identified from the last decades, and, despite its evolution, it is still needs to be addressed. Besides, Purcell [15] counters that the key point for the effectiveness of a CDSS lies in its knowledge base, which must be reliable and robust.

Standardization techniques are recognized as an asset in structuring clinical data, in order to overcome barriers of data transfer and interpretation [11], [12]. The standardization of data generates attention to other problems that may be directly or indirectly linked to it, being a barrier to the clinical practice evidence, highlighting interoperability, legacy systems, data structuring, and open data [13], [16]. The authors of [14] is an advocate of the open data movement, defending that make the knowledge available inside and outside the organization provides the ability to examine community, environmental, and other public health data, as well as to accelerate diagnostic and treatment processes. To complement, the use of open data standards allows professionals in the field to share a vast knowledge base, in order to translate clinical evidence into decision support artifacts, improving the quality and variability of clinical data [13], [14], [16].

Some concerns and requirements were referred by [11], [13], [15], which must be considered for the design of an effective CDSS, highlighting: (i) creation of a configurable, intuitive and appealing interface; (ii) provide decision support in real time and with speed; (iii) use technological interventions in a balanced and simplified way; (iv) qualified and semantically interoperable decision engine; (v) representation of clinical knowledge through an agile and effective inference mechanism.

3. Cross-checking

3.1. Perspectives

According to Tcheng et al. [17], the availability and sharing of knowledge among the stakeholders of an organization encourages collaboration between both parties, helping them to overcome challenging moments and to improve work practices. Thereby, when studying the possibility of adopting a new system for an organization, it is essential not to carry out a general analysis of organizational management. This involves different perspectives and stakeholders of an organization's structure [16]. In this study it was considered three potential views related to the Intensive Medicine specialty, as shown in Fig. 1.

Fig. 1. Different perspectives within Intensive Medicine.

The organizational component has a sight focused on the interests of the organization. Political and legal restrictions (such as data protection), economic aspects, and ethical and moral issues, are some examples of concerns that health organizations deal daily [18]. Issues related to the financial department and the human resources department also have a direct impact on the decision-making process and in the healthcare delivery.

The technological perspective has as focus issues related to the processes that involve the technical and technological infrastructure of a hospital. Following the example of the software installation process, some aspects are essential to be questioned, such as: interoperability between systems, resource management (whether technological, human or financial), reliability in data management, continuous updating, and privacy and security [18].

The social view involves all aspects directly or indirectly related to the individuals of an organization, both providers and consumers [3]. Here, is highlighted the satisfaction of both entities regarding to the services provided, as well as physical and psychological well-being, rights and duties, cultural aspects, among others.

3.2. Cross-checking

Clinical Decision Support practices can be represented in several ways. A system designed to execute these practices, requires a continuous evaluation of its functioning. Berner [18] describes that a system should be evaluated in practice based on the impact caused to users and stakeholders in the organization, in addition to issues related to the performance of the system.

A systematic literature review previously developed [4], allowed us to identify common features contained in CDSS. Based on the benefits and concerns previously identified through literature review, we gathered the information and cross-checked with the different perspectives involved in Intensive Medicine, in order to understand and prepare an organization of the possible risks related to the construction of a CDSS. Table 1 shows an overview of the features and challenges related in the CDSS adoption, related to the associated perspectives and possible mitigating actions.

Table 1. Cross-checking of CDSS

Features	Challenges	Perspectives	Mitigation action
Recommendation	Infrastructure failures and misinterpretation of data	Technological and social	It is important that users are comfortable with the system, i.e., be capable to learn its correct operation. Performance tests and system roll-out also need to be done, to prevent possible problems.
Computerized alerts and reminders	Excessive and incorrect issuing of alerts	Technological	Here it is considered the way that a user accesses the system and check the time stamp of the alerts. It is also a good idea to provide an error reporting platform to strengthen and streamline communication between users and IT team.
Rule engine	Dependency on the computer environment and data encoding issues	Technological	Construction of a robust and adaptable engine to changes. For the construction of the rule engine, preconditions, clinical guideline, and if-then statements (if applicable) should be considered.

Process automation	Data processing issues	Technological	A CDSS must ensure that operational processes are communicating effectively. Communication and configuration tests are relevant in this context.
Document and forms editor and generator	System failure and user misuse	Technological and social	As it is a feature that is very required in a system, it is important thar users are able and motivated to use the system without any problem.
Clinical terminologies	Data encoding problems	Technological and organizational	First, it is necessary for the organization to choose a clinical nomenclature that seems most appropriate to it. Thereafter, to avoid coding errors, is necessary a continuous maintenance of the coding system for clinical terms in a standardized way.
Interoperability	Lack of resources and interoperability solutions	Technological and organizational	At this point, in addition to certifying the correct communication between systems at a technological level, the organization may also consider standards or models that provide the necessary interoperability, both semantically and syntactically.
Knowledge management	Incomplete knowledge extraction and lack of resources	Technological and organizational	It is important to ensure the maintenance of the knowledge base repository and select the relevant knowledge. Here, it is also important for the organization to verify all necessary resources before committing to integrate the decision system.

According to Berner [18], the culture of clinical practice has always emphasized the autonomy of healthcare providers, as the activity of Clinical Decision Support was always present, even in an indirect way. Computerized Clinical Decision Support Systems have come to provide the most complete and direct use in the decision-making process. To this end, an organization must be prepared when deciding to adopt a new technological system. Ensuring all the necessary resources is the first step, be they human, functional or technological. Variables such as time and costs are also directly related to the preparation and must also be factors that influence the adoption of a new system. Motivating users has become an essential task that the organization has before its professionals, to ensure that the desired benefits are achieved [18]. For this situation, workshops and talk sessions may be relevant to introduce the new system to the users, to demonstrate its correct functioning and avoid its misuse.

After the organization has prepared for the implementation of the new system, technological aspects prevail at this stage. Performance tests, infrastructure verification, and interoperability between operational processes, must be valued, in order to avoid communication failures and data loss. The accomplishment of clinical terminologies, classification systems and clinical guidelines, has demonstrated a history of errors in the coding system. This requires a large investment in version control, so that the system is kept up to date, without any flaws or errors in data representation [19].

As previously seen, technological aspects such as interoperability, are fundamental in clinical decision support systems, highlighting the use of components such as the knowledge base and inference engines, enabling to construct an effective communication between operational systems [19]. Clinical information from different data sources must be processed and validated, resulting in the desired knowledge to perform clinical practices, administrative processes and other functions. The application of data management methods aims to acquire clinical knowledge to ensure data quality and reliability and to promote the desired clinical decision support.

Through the exponential increase in the relationship of clinical knowledge with the advancement of computational systems capable of dealing with complexity, storage and maintenance of information, a growing demand for clinical terminology and classification systems has become evident. That said, the representation of clinical terminologies and classification systems has been increasingly impacting, such as SNOMED, ICD and LOINC, already being considered as a requirement for an effective Electronic Health Record system.

4. Conclusion

Most Electronic Health Record systems are encouraged to or already include Clinical Decision Support practices that translates the decision support activity in a machine-readable computerized format. Clinical Decision Support Systems are responsible to support the decision-making process and to facilitate the tasks performed. However, some systems are not meeting expectations and are not achieving their effectiveness.

The present study allowed a comprehensive analysis of different perspectives, involving organizational, social and technological aspects, facing the challenges highlighted in literature review. In a nutshell, a healthcare organization must manage all internal processes in favor of technological perspective and combine the different interests and objectives involved. From a social point of view, it is necessary to highlight the importance of user satisfaction with the system, accepting suggestions for improvements so that professionals feel more comfortable over time. At a technological level, those responsible for the technical domain must guarantee the necessary resources for the implementation and maintenance of the system, emphasizing the importance of a versioning and updating component.

After surveying the state of the art of an effective CDSS, the future work focuses on the construction of a prototype that guarantees all the functionality identified here, as well as the integration of solutions to avoid the propagation of errors. The proposed mitigating actions, particularly the adoption of interoperability standards and open models, will be thoroughly studied to validate their benefits.

Acknowledgements

The work has been supported by FCT – Fundação para a Ciência e Tecnologia within the Project Scope DSAIPA/DS/0084/2018. Francini Hak thanks the Fundação para a Ciência e Tecnologia (FCT) for the Ph.D. Grant 2021.06230.BD.

References

[1] F. Portela, M. Santos, J. Machado, A. Abelha, Á. Silva, and F. Rua, "Real-Time Decision Support in Intensive Medicine An intelligent approach for monitoring Data Quality."
[2] A. S. Law, Y. Freer, J. Hunter, R. H. Logie, N. McIntosh, and J. Quinn, "A comparison of graphical and textual presentations of time series data to support medical decision making in the neonatal intensive care unit," *J Clin Monit Comput*, vol. 19, no. 3, pp. 183–194, Jun. 2005, doi: 10.1007/s10877-005-0879-3.
[3] D. F. Sittig *et al.*, "Grand challenges in clinical decision support," *J Biomed Inform*, vol. 41, no. 2, pp. 387–392, 2008, doi: 10.1016/j.jbi.2007.09.003.
[4] F. Hak, T. Guimarães, and M. Santos, "Towards effective clinical decision support systems: A systematic review," *PLoS One*, vol. 17, no. 8, p. e0272846, Aug. 2022, doi: 10.1371/journal.pone.0272846.
[5] D. J. Power, "A Brief History of Decision Support Systems," pp. 1–16, 2007.
[6] HIMSS, "What is Clinical Decision Support System?," 2016. https://www.himss.org/library/clinical-decision-support
[7] E. Turban, D. Delen, and R. Sharda, *Business intelligence and analytics*. 2014. doi: 10.4324/9781315206455-12.
[8] R. A. Greenes, "Clinical Decision Support: The Road Ahead," *J Chem Inf Model*, vol. 53, no. 9, pp. 1689–1699, 2007.
[9] M. Khalifa, "Clinical Decision Support : Strategies for Success," *Procedia - Procedia Computer Science*, vol. 37, pp. 422–427, 2014, doi: 10.1016/j.procs.2014.08.063.
[10] A. M. Shahsavarani, E. Azad, M. Abadi, and M. H. Kalkhoran, "Clinical Decision Support Systems (CDSSs): State of the art Review of Literature," vol. 2, no. 4, pp. 299–308, 2015.
[11] S. Sulley, "Impact of Clinical Decision Support Systems (CDSS) on Health Outcomes Improvement," *Int J Health Sci Res*, vol. 8, no. 5, 2018.
[12] C. S. Jao and D. B. Hier, "Clinical Decision Support Systems : An Effective Pathway to Reduce Medical Errors and Improve Patient Safety," no. January, 2010.
[13] Himss, "The HIMSS Analytics EMRAM," *Himss*, p. 2500, 2017, [Online]. Available: www.himssanalytics.org/emram
[14] B. Middleton, D. F. Sittig, and A. Wright, "Clinical Decision Support : a 25 Year Retrospective and a 25 Year Vision," pp. 103–116, 2016.
[15] G. P. Purcell, "What makes a good clinical decision support system," *BMJ: British Medical Journal*, vol. 330, no. 7494, p. 740, 2005.
[16] R. T. Sutton, D. Pincock, D. C. Baumgart, D. C. Sadowski, R. N. Fedorak, and K. I. Kroeker, "An overview of clinical decision support systems: benefits, risks, and strategies for success," *NPJ Digit Med*, vol. 3, no. 1, pp. 1–10, 2020, doi: 10.1038/s41746-020-0221-y.
[17] J. E. Tcheng *et al.*, *Optimizing strategies for clinical decision support: summary of a meeting series*. 2017.
[18] E. S. Berner, "Clinical decision support systems: state of the art," *Agency for Healthcare Research and Quality*, no. 09, pp. 4–20, 2009, [Online]. Available: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Clinical+Decision+Support+Systems+:+State+of+the+Art#0
[19] J. Neves, M. Santos, J. Machado, A. Abelha, S. Allegro, and M. Salazar, "Electronic Health Records and Decision Support Local and Global Perspectives," *WSEAS TRANSACTIONS on BIOLOGY and BIOMEDICINE*, vol. 5, no. 8, pp. 189–198, 2008.