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OpenEHR and Business Intelligence in healthcare: an overview

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Abstract

Healthcare systems are a constant concern in today's society. The healthcare sector, like any other, collects a large amount of information on a daily basis. This information has recently been stored in electronic health records, the EHR. These records are a way to store a patient's information electronically, consequently improving its availability for better management in the institution. On the other hand, it is important to realise that there is an interoperability in this data, since there is a large interaction of various systems, and it is important to ensure interaction between these systems. To combat this interoperability problem, OpenEHR modelling emerges. To improve the management of the existing information in these records, it is interesting to integrate with Business Intelligence. Therefore, the objective of this article is to present an overview of OpenEHR and Business Intelligence systems, as more specific to health sector.

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1. Introduction

Electronic Health Record (EHR) has provided instant benefits to medical organizations by reducing administrative activities, ensuring data availability, goal of creating EHR is to be able to analyse voluminous, varied and unstructured healthcare data and gain meaningful insights through analytical and decision-making tools. However, while these systems have numerous advantages, they still bring challenges and complications to the healthcare community. The existence of different and numerous big data tools in different environments makes it difficult to choose and adjust them for a given EHR [1].

To achieve these results, it is essential that the concepts of integration and interoperability are incorporated in these environments. Both are important for cooperation and information flow in healthcare organizations. However, they are based on different principles. While integration has as its priority to obtain information from various systems to improve capabilities, interoperability focuses on continuous communication and information exchange between systems. The main goal of interoperability in healthcare is to link applications so that data is shared across the environment and distributed by healthcare professionals more easily and efficiently [2].

The use of the OpenEHR approach enables the structuring, management, storage, and switching of patient data in a secure and reliable way between different healthcare organizations. The main idea of this approach is to standardize health-related concepts used in EHR databases or systems into a set of libraries, called archetypes [3].

The use of OpenEHR with Business Intelligence (BI) technology is an asset for these healthcare institutions. Although BI is more frequent in industrial organizations, when it is introduced in the healthcare context it helps them both at the clinical and administrative levels. It is able to manage the resources and capabilities available in the organization, helping to improve decision-making and institutional processes as a whole [4].

This article is divided into several sections, starting with a brief introduction. In chapter two, the definition of the OpenEHR methodology and its importance is presented. The next chapter discusses BI themes and their relationship with the health area are addressed. In chapter four, a review of BI systems and their relationship with OpenEHR is carried out. Finally, the main conclusions obtained are presented.

2. OpenEHR

EHR stores a large amount of medical data, data that must be available throughout a patient's life. In addition to the effort and cost, the solution must protect the information when data loss occurs, while being persistent and reliable over the years. The problem is often not the amount of data available, but the fact that most of the information is free text, serving only to record and query information [5].

OpenEHR is a non-profit organization that counts on the collaboration of a vast international community, with the goal of creating clinically comprehensive and interoperable EHRs. Its main goal is to ensure the interoperability semantic interoperability of clinical information between EHRs. It is based on a dual architecture in terms of information and knowledge, aligning technical knowledge with clinical knowledge. The clinical information is modelled by means of reference models, while knowledge is simplified through Archetype Object Model (AOM). This standard is based on its clinical knowledge artefacts, called archetypes, which clinically speaking, represent the basis for defining, discussing and present clinical content [6].

The objective of OpenEHR is related to the representation of a model of generalized information. The latter introduces the concept of archetypes related to a specific medical concept, as well as the reference model, which defines the EHR semantics, EHR extract and demographics. The particularity of the OpenEHR in compared to other existing EHRs, is that it not only provides the aspect of interoperability for the platform, but also an adaptability to the needs of the medical entity in question [1]. In terms of data security, it guarantees the resilience of the data by keeping it in the system in a historical and review approach. Each change in the patient's EHR is stored by means of the audit system, which provides high reliability to the framework [6].

The OpenEHR Foundation states that, OpenEHR has “multilevel modelling of single source within a service-oriented software architecture where models built by domain experts are at its layer”. In this sense, the OpenEHR architecture is based on two layers, separating information from knowledge as demonstrated in Figure 1 [7].



Figure 1- OpenEHR architecture, from [7]

One level contains the Reference Model (RM) that groups and defines the information processed in the system for each patient, followed by data items such as quantity or text. The other level contains the clinical knowledge applied in a structured and archetype-oriented way according to the Archetype Definition Language, promoting semantic interoperability [7], [8]. One of the main goals of the OpenEHR is the universal use of the same data structure in archetypes by heterogeneous systems. In this sense, the standard provides the OpenEHR Clinical Knowledge Management (CKM), an open knowledge repository that offers free access, management, and interaction of archetypes and templates, where they are selected and modelled according to a clinical purpose [7].

3. Business Intelligence Systems

Throughout this chapter, an exposition will be made on Business Intelligence systems and their connection with the healthcare context, as well as their specificities in the sector.

3.1. Business Intelligence

Business Intelligence (BI) is a concept that has existed since the beginning of organisational computing and was first used to describe concepts and methodologies aimed at improving business decisions through facts and information from information systems. Although not recent, it has only recently begun to gain emphasis. Currently, the implementation of these systems is seen as essential in face of the different obstacles and challenges present in the daily life of organizations [9].

According to Azvine (2006) [10], BI is the ability to collect, access, analyse, understand and convert an organization's data into active and useful information with Figure 1 - OpenEHR Architecture [7] the goal of improving organisational business. One of the main objectives of an organisation when implementing a system in BI is to increase organisational knowledge, allowing greater efficiency in the operations it performs, enabling it to achieve the desired objectives.

BI provides information and tools necessary for statistical analysis and trends in the organization. It uses key performance indicators to assess the state the organization is in. The focus of this system is on market analysis, its competition, customers and its position [9], [11].

3.2. Business Intelligence Systems in the Health Context

The healthcare sector recognizes the need to implement BI solutions, as it can guarantee new opportunities for improvement, gaining benefits and helping to overcome challenges. More and more this sector needs systems that not only help to manage data but also to obtain useful and precise information, capable of helping to improve the quality, safety, effectiveness, and efficiency of health care, in this sense the implementation of BI services becomes crucial for the improvement of this sector [12], [13].

The main objective for the health sector with the implementation of these systems is to bring benefits to patients and providers. In this way, they provide a better management of the population's health, improving the transparency of economic activities and the availability of information in real time. With the implementation of these solutions, healthcare professionals can identify patterns in the data, recognize risky patients, manage, and reduce risks and speed up the execution of tasks. To be able to coordinate the patient's needs, it is necessary to facilitate the integration of information about the patient, so that health professionals can access this data easily and anywhere, to be able to make the best decision for the patient [12].

BI systems offer the possibility of performing a clear and detailed analysis of operational and statistical data on a particular patient. In this way, it would become possible to identify risk situations in a quick and effective way. These systems are designed to provide greater security and quality of care, leading to an improvement in patient care [13]. According to, Coelho et al. (2016) [2] the main objective in the implementation of BI solutions is to improve the quality of care and patient satisfaction.

3.3. Specificities of the Health Sector

In general, the health sector, as in other sectors, faces many problems in relation to the implementation of these systems. However, in the health area some significant differences are present, as it is a sector that has some unique differences. Its structure is different when compared to other sectors as it has very visible differences in its regulations, high government investments and the low pressure associated with the efficiency and effectiveness of healthcare providers. Another very important difference is in relation to the medical team and with the quality of care, that is, although they are very important attributes for hospital performance, they are very difficult to measure, interpret and compare [4].

One of the challenges specific to healthcare is in the analysis of large amounts of information. These challenges range from lack of cooperation of the medical assistance system, long waiting periods for treatments or consultations, which leads to patient dissatisfaction [12].

This sector is subject to scrutiny, has the need to improve the care provided and reduce costs. Providers and their associates must understand and respond to privacy and security laws. There are a variety of factors that influence a non-redundant view of healthcare and quality, where among them are healthcare and practice regulations, patient registration and requirements, as well as the management of staff, facilities, and equipment. Data can bring a great advantage to the organization, but first it must be made useful for its use [14]. To have an improvement in institutional processes different types of data need to be extracted, cleaned, integrated, analysed and established by different actors and only then it can become useful for use [12].

4. BI systems based on OpenEHR

There are some Business Intelligence applications that contemplate the integration of electronic health record data from EHRs. Nevertheless, there are few applications that incorporate Business Intelligence with data following the OpenEHR modelling. Next, some articles that make this integration are highlighted:

- Oliveira et al., [6] used OpenEHR data, since they allowed to make a complete representation of the adopted patient workflow, allowing interoperability between different EHRs. With this data, they applied them to a business intelligence system. In this case, the applicability of this integration was to support healthcare professionals during the COVID-19 pandemic and thus support the needs that the organisation needs.

- Li et al., [15] made use of data that followed OpenEHR standards and rule to integrate with Business Intelligence. They divided the process into two phases, the first phase consists of using information from OpenEHR through CQL (Context Query Language). The second part consists in proposing a systematic approach to use and compute these clinical quality indicators and generate corresponding data reports and visual dashboards.

The adoption of OpenEHR modelling for data standardization of electronic health records is an asset for recording, querying, and classifying patient-focused information. However, for cross-cutting analyses involving information from multiple patients (for example, a particular disease, quality, and efficiency indicators) the OpenEHR model has limitations in integrating data into Business Intelligence Systems. Although there are advantages and opportunities, there are still difficulties that must be overcome. The following highlights the main difficulties faced by the healthcare sector when trying to implement a BI system with OpenEHR data [16], [17]:

- Scalability and storage and processing capacity.
- Application with real-time data update.
- Dynamics of OpenEHR structures and their versioning.
- Efficiency regarding processing time and resources.
- Relationship between OpenEHR structures and Multidimensional structures that support analytical processes considering analysis axes that cut across several patients or certain variables/characteristics of the same patient.

5. Conclusion

Recently, there has been a growing adoption of EHRs in different countries. Thanks to these systems, various healthcare organizations can store, manage, and process clinical data effectively. However, the existence of such powerful and meticulous entities raises new challenges and questions for healthcare professionals. In fact, although the main goal of EHRs is to derive actionable big data insights from healthcare workflow, very few healthcare professionals explore extensively analytical tools, this is mainly due to having to deal with multiple systems and stages, which completely discourages them from engaging [1]. For this reason, the level of interoperability of EHR systems is critical to the continuous improvement of the quality of patient care, global health research and the management of healthcare institutions. This level of interoperability ensures that the meaning and semantic understanding of information is exchanged between different systems [12]. To combat this need to ensure interoperability between systems it is strongly suggested to use the OpenEHR model, as it is a model that provides an interoperable structure, organizes clinical content with patient information, allowing integration with different health information systems [5].

The importance that BI solutions provide to the health sector is not only in simplifying the provision of communication and information, but it also contributes to new ways of working. Which allows the integration of information about organizations and the measurement of results, preferably in real time, which is considered an essential factor in health care [4].

In conclusion, the integration of these technologies and methodologies in the health area is important for an evolution both in terms of speed of patient care and quality of service, without forgetting the importance of interoperability that OpenEHR provides for better communication between services, and consequently, BI integration. According to my research, this integration between OpenEHR and BI has not yet been properly investigated, so there is a gap in this area that can be used for research. Future research work will be the realization of artefacts to adapt a BI system, in a generic way to the OpenEHR model. There may also be the possibility of conducting a study and/or artefacts that allow a BI system to work directly with OpenEHR.

References

- [1] F. Khennou, Y. I. Khamlichi, and N. E. H. Chaoui, “Improving the Use of Big Data Analytics within Electronic Health Records: A Case Study based OpenEHR,” *Procedia Computer Science*, vol. 127, pp. 60–68, Jan. 2018, doi: 10.1016/j.procs.2018.01.098.
- [2] D. Coelho, J. Miranda, F. Portela, J. Machado, M. F. Santos, and A. Abelha, “Towards of a Business Intelligence Platform to Portuguese Misericórdias,” *Procedia Computer Science*, vol. 100, pp. 762–767, 2016, doi: 10.1016/j.procs.2016.09.222.
- [3] T. Ribeiro, S. Oliveira, C. Portela, and M. Santos, “Clinical Workflows based on OpenEHR using BPM.,” in *ICT4AWE*, 2019, pp. 352–358.
- [4] T. Mettler and V. Vimarlund, “Understanding business intelligence in the context of healthcare,” *Health Informatics J*, vol. 15, no. 3, pp. 254–264, Sep. 2009, doi: 10.1177/1460458209337446.
- [5] D. Oliveira et al., “New Approach to an openEHR Introduction in a Portuguese Healthcare Facility,” in *Trends and Advances in Information Systems and Technologies*, Cham, 2018, pp. 205–211.
- [6] D. Oliveira et al., “Management of a Pandemic Based on an openEHR approach,” *Procedia Computer Science*, vol. 177, pp. 522–527, Jan. 2020, doi: 10.1016/j.procs.2020.10.072.
- [7] F. Hak, D. Oliveira, N. Abreu, P. Leuschner, A. Abelha, and M. Santos, “An OpenEHR Adoption in a Portuguese Healthcare Facility,” *Procedia Computer Science*, vol. 170, pp. 1047–1052, Jan. 2020, doi: 10.1016/j.procs.2020.03.075.
- [8] G. M. Bacelar-Silva, H. César, P. Braga, and R. Guimarães, “OpenEHR-based pervasive health information system for primary care: First Brazilian experience for public care,” in *Proceedings of the 26th IEEE International Symposium on Computer-Based Medical Systems*, Jun. 2013, pp. 572–873. doi: 10.1109/CBMS.2013.6627881.
- [9] N. McBride, “Business intelligence in magazine distribution,” *International Journal of Information Management*, vol. 34, no. 1, pp. 58–62, Feb. 2014, doi: 10.1016/j.ijinfomgt.2013.09.006.
- [10] B. Azvine, Z. Cui, D. D. Nauck, and B. Majeed, “Real Time Business Intelligence for the Adaptive Enterprise,” in *The 8th IEEE International Conference on E-Commerce Technology and The 3rd IEEE International Conference on Enterprise Computing, E-Commerce, and E-Services (CEC/EEE’06)*, San Francisco, CA, USA, 2006, pp. 29–29. doi: 10.1109/CEC-EEE.2006.73.
- [11] R. Duarte, T. Guimarães, and M. F. Santos, “A Business Intelligence Platform for Portuguese Misericórdias,” *Procedia Computer Science*, vol. 198, pp. 341–346, Jan. 2022, doi: 10.1016/j.procs.2021.12.251.
- [12] M. Isazad, A. Ojo, and F. Sullivan, *Analysis of Business Intelligence Applications in Healthcare Organizations*. 2019. doi: 10.24251/HICSS.2019.503.
- [13] N. Foshay and C. Kuziemyky, “Towards an implementation framework for business intelligence in healthcare,” *International Journal of Information Management*, vol. 34, no. 1, pp. 20–27, Feb. 2014, doi: 10.1016/j.ijinfomgt.2013.09.003.
- [14] N. Ashrafi, L. Kelleher, and J.-P. Kuhlboer, “The Impact of Business Intelligence on Healthcare Delivery in the USA,” *IJKM*, vol. 9, pp. 117–130, 2014, doi: 10.28945/1993.
- [15] M. Li, H. Cai, Y. Zhi, Z. Fu, H. Duan, and X. Lu, “A configurable method for clinical quality measurement through electronic health records based on openEHR and CQL,” *BMC Medical Informatics and Decision Making*, vol. 22, no. 1, p. 37, Feb. 2022, doi: 10.1186/s12911-022-01763-3.
- [16] W. Bonney, “Applicability of Business Intelligence in Electronic Health Record,” *Procedia - Social and Behavioral Sciences*, vol. 73, pp. 257–262, Feb. 2013, doi: 10.1016/j.sbspro.2013.02.050.
- [17] “Top 8 Business Intelligence Challenges and How to Handle Them,” *SearchBusinessAnalytics*. <https://www.techtarget.com/searchbusinessanalytics/tip/Top-11-business-intelligence-challenges-and-how-to-overcome-them> (accessed Jun. 18, 2022).