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Using implementation science to develop and deploy an oncology electronic health record

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Abstract

The management of oncology clinical processes involves the efficient management of data using electronic clinical records to effectively monitor and treat oncology patients. As the process of treating and monitoring cancer patients involves multiple stakeholders with differing perspectives, the implementation and deployment of oncology clinical registries represent a significant challenge. In this study, we address this complexity by employing a technique that helps translate implementation strategies into requirement identification methods, which are subsequently disseminated throughout the implementation and deployment phases of health information systems. We applied this technique to develop an electronic health record for the national cancer plan in Chile. The findings indicate that six implementation strategies are essential to addressing stakeholder needs, as well as three requirement identification techniques to describe the underlying problem. Furthermore, a study conducted with 27 stakeholders revealed that the perception of the oncology electronic clinical record has considerable acceptance in three critical functionalities related to the clinical process of oncology patient management. The use of implementation science strategies provides an alternative approach to understanding the underlying problem that stakeholders face when they require healthcare technologies.

Previous Next

Keywords

Electronic health record; Cancer; Implementation sciences

1. Introduction

Oncology electronic health record (oncology EHR) systems are designed to address the specific and complex needs of oncology care. These systems support the comprehensive documentation, storage, and retrieval of patient health information, focusing on the entire range of cancer care. The development and evolution of oncology EHRs have been significantly advanced by integrating complex patient data, treatment protocols, and clinical trial information. Additionally, these systems facilitate precision medicine by incorporating genomic data, which helps personalize treatment plans [1]. However, the adoption of oncology EHRs in Latin America varies significantly from country to country. Public healthcare systems often face budgetary constraints, which impact the widespread adoption and maintenance of oncological EHRs. Private clinical institutions may have more advanced systems and more resources, but interoperability between the public and private sectors is limited [2]. In Chile, advances aimed at improving the detection, care, and monitoring of people with cancer have gradually reached certain milestones. One of the most recent milestones is the National Cancer Plan in 2018, which aims to strengthen registration, information, and surveillance systems to provide timely information that enables better management of the network, more cancer research,

monitoring the development of the National Cancer Plan, and making decisions at the population level in cancer.

The development of oncological electronic health records presents a range of multifaceted challenges. Fulfilling all stakeholder requirements related to the oncology clinical process necessitates a comprehensive understanding of often complex issues. In this regard, several challenges identified in developing countries involve governance, financial resources, and service provision [3]. From a clinical standpoint, inefficiencies in the healthcare system, coupled with poor resource allocation, can adversely impact the quality of medical care. In this context, oncology EHRs offer a viable solution to address some of the aforementioned challenges. However, developing and implementing a system that meets stakeholder expectations is a challenging task. If the identified requirements are inaccurate or incomplete, the oncology EHR may fail to meet stakeholder expectations. Moreover, improper elicitation of requirements can result in the creation of a system that does not align with users' and stakeholders' needs and expectations. If the requirements are not accurately captured or understood, developers may create functionality that does not fit users' workflows, omit critical functionality, or include unnecessary elements, leading to inefficiencies and user dissatisfaction. In healthcare, misalignment can result in increased costs due to rework, delays in project timelines, and potential failures in healthcare compliance, rendering the system unfit for its intended purpose and potentially causing operational disruptions and clinical team and patient mistrust [4].

This article discusses the implementation and deployment of oncology in EHR oncology, utilizing implementation science as the primary methodology to address the intricacy of stakeholder needs identification and system development. Implementation science in healthcare address the study of methods and strategies aimed at promoting the systematic integration of research findings and evidence-based practices into routine healthcare practices and policies. Its objective is to understand and address obstacles to effective implementation, ensuring that scientific discoveries prove effective in improving patient outcomes and the quality of clinical care. Our study examines how end-user-based requirements identification, supported by the D&I Framework, can positively influence the functionality of a health information system. The perspectives provided by stakeholders and end users enable us to elucidate key requirements for the success of a health information system which, through the sciences of health implementation and dissemination, significantly impact the context in which the health information system operates. Using the D&I framework technique [5], we successfully delineated the problems identified by stakeholders in the oncology process and facilitated the implementation of EHR oncology. We conducted this study within the context of the design and implementation of a national cancer registry platform in Chile, whose mission is to store superior quality clinical information and generate knowledge through the systematic recording of variables related to the diagnosis, treatment, monitoring, and control of cancer patients.

The main contribution of this study is the development of the EHR oncology based on stakeholder requirements identified through a framework that utilizes implementation and dissemination sciences in healthcare. This framework facilitates the analysis of barriers and facilitators to

information system adoption. Consequently, the EHR oncology requirements incorporate strategies to address barriers and leverage facilitators. Furthermore, it helps in the design of a system that is both efficacious and adaptable to the specific needs of users, including patients and clinicians.

The rest of the article is structured as follows: Section 2 describes the related work; Section 3 details the research context; Section 4 describes the results; Section 5 describes the oncologic EHR; Section 6 discusses the discussion; and Section 7 describes the conclusion of our study.

2. Related work

Dubovitskaya et al. [6] created a system that streamlines the management, exchange, and consolidation of electronic health record (EHR) data securely and dependably. This system facilitates the management of medical records across various hospitals. Furthermore, the system ensures the defense of patient privacy and guarantees security in accordance with the criteria of healthcare data management, including the access control policy specified by the patient. The system was designed using a blockchain with permissions for sharing and integrating EHR data. The authors explained that each hospital will supply a blockchain node that is integrated with its own EHR system to form a blockchain network. Conversely, the actual data in the system are encrypted and saved off-chain in Health Insurance Portability and Accountability Act (HIPAA)- compliant cloud storage. The system employs asymmetric encryption based on public key infrastructure and digital signatures to safeguard the shared EHR data.

Asan et al. [1] conducted an empirical investigation via semi-structured interviews with oncologists at an urban academic medical center, with the aim of understanding their perceptions of EHR use before, during, and after clinical visits to patients. The interview guide was developed based on a working system model. The transcripts were analyzed using inductive content analysis. The study's results reveal four main themes related to oncologists' EHR use practices and their perceptions of EHRs: (i) EHR use for care coordination, (ii) EHR use during clinic visits, (iii) safety risks associated with care coordination and EHRs, and (iv) recommendations for improvement.

According to Osterman et al. [7], the method of obtaining common minimum oncology data elements has enhanced the exchange of cancer patient data between electronic health records and facilitated superior cancer care delivery. This proposal primarily emphasizes the interoperability of cancer patient data. The six high-level domains that organize the common minimum oncology data elements are patient, laboratory/vital, disease, genomic, treatment, and outcome. Additionally, within these domains, 23 mCODE profiles were organized, comprising a total of 90 data elements. The authors of the study indicated that the approach described has the potential to improve cancer care delivery and research. Currently, several pilot applications are being implemented.

Palis et al. [3] evaluated the adherence to four components (completeness, comparability, timeliness, and validity) regarding the capacity of electronic registries to access information in the U.S. hospital National Cancer Database (NCDB). This study utilizes data from the U.S. Cancer Statistics, which are the official federal cancer statistics, and joint endeavors between the Centers for Disease Control and

Prevention (CDC) and the National Cancer Institute (NCI), including data from the National Program of Cancer Registries (NPCR) and Surveillance, Epidemiology, and End Results (SEER) to assess the completeness of the NCDB between 2016 and 2020. The results obtained indicate that the NCDB is characterized by a high level of completeness and comparability of cases with uniform standards for data collection and by hospitals with a high degree of compliance, timely submission of data, and high rates of compliance with registry validity and data quality assessment standards.

Giusti et al. [8] provided an overview of the quality check software utilized by the Center-European Network of Cancer Registries Quality Check Software (JRC-ENCR QCS), which processes data files submitted by population-based cancer registries contributing to the European Cancer Information System (ECIS). The authors detailed the software's role and its various functionalities. They also explained that the JRC- ENCR QCS is an evolving process, with periodic updates implemented to include new and revised European and international recommendations and classifications.

3. Research context

3.1. Motivation

Electronic health record systems for oncology are essential in any healthcare system, as they provide a solid foundation for diverse applications ranging from direct clinical care to public policy formulation and scientific research [9]. Particularly in developing countries, oncology EHRs enable clinicians to access a detailed and up-to-date medical history of patients, thereby improving the accuracy of diagnosis and treatment. In addition, they allow for more accurate patient monitoring and continuity of long-term follow-up, which are crucial for the management of chronic diseases [10]. From a scientific perspective, oncology EHRs provide essential data for clinical and epidemiological research, allowing studies on cancer prevalence, incidence, and risk factors as well as the evaluation of the effectiveness and safety of new cancer treatments and drugs.

Nevertheless, the development and implementation of EHR oncology systems are challenging due to the diverse views involved [11]. Balancing factors associated with interests and needs with technical and organizational constraints is necessary. Stakeholders in oncology health have different levels of obligation and authority when contributing to oncology EHR. They can range from occasional contributions to full involvement of the system. Additionally, given that Chile has centralized demographics, access to information differs in certain territorial regions. This implies that diverse organizational cultures are adopted for patient care and data collection. Considerable effort is required to train users and ensure the effective adoption of the new system and, above all, consolidate information.

With respect to Chile, the development of digital health policies has progressed significantly alongside the substantial growth of digital health in the country [12]. Legislation addressing cybersecurity and interoperability has been implemented to improve the quality and privacy of

patient care in Chile. Nevertheless, the creation of oncological EHRs presents a multifaceted and intricate process with several obstacles. The primary challenges are listed below:

- Diversity of existing systems: Health institutions in Chile, both public and private, use different information systems that are not always compatible, making data integration difficult.
- Data standards: The lack of uniform standards for data collection and exchange complicates the creation of a cohesive and efficient system.
- Territorial inequalities: Rural and less-developed areas may lack the necessary technological infrastructure, such as high-speed Internet connectivity and modern hardware, which limits the implementation and use of advanced information systems. Some institutions may not have the technical staff trained to maintain and operate complex information systems.
- High concentration in primary health: According to data provided by the Department of Health Statistics and Information (DEIS), the general overview of health facilities in Chile indicates that, out of a total of 3,905 institutions, the institutions that lead the primary clinical care of patients are rural health posts (1,114 institutions, 29% of the total), family health centers (600 institutions, 15% of the total), community health centers (288 institutions, 7% of the total), and low-complexity hospitals (108 institutions, 3%). From the point of view of complexity, 3,173 (81% of the total) institutions belong to the low level, 605 (16% of the total) to the medium level, and 127 (3% of the total) to the high level, which implies that the most significant and relevant groups of patients and clinical data are concentrated in primary health care and low complexity (primary level) institutions.

The challenges described above have a direct impact on oncology patients in Chile, as health institutions use different data management systems, which makes it difficult to integrate and exchange information consistently.

3.2. Implementation sciences

The field of implementation science aims to bridge the gap between the production of knowledge based on scientific evidence and its practical application in real-world scenarios. Specifically, it examines the factors that influence the effective and complete utilization of scientific innovations in practical settings [13]. This is achieved by studying methods that promote the systematic integration of research findings into clinical practice, with the ultimate goal of enhancing the quality and effectiveness of healthcare services. In this way, implementation science aims to maximize the beneficial effects of health interventions [14].

The field of implementation science has gained increasing attention and momentum in recent years, with a growing focus on the factors that impact the success of implementing new practices and care. According to Proctor et al. [15], there is often a disconnect between what is known to be effective (e.g., a specific treatment) and the care that is actually delivered (e.g., in a hospital setting). While much research has focused on the effectiveness of different treatments in hospital settings, there is a need for more studies that explore how treatments are implemented in practical settings and how they are experienced by patients.

3.3. Problem

The development of oncology EHRs includes both development and deployment phases that must satisfy the various stakeholders' expectations of the system. The most crucial task in developing a system is the identification of requirements and design. The process of identifying requirements in software development involves the description, analysis, documentation, and validation of stakeholders' needs and expectations, which establishes the basis for the system's construction [16]. It ensures that the final product meets both business objectives and user expectations. Software design, which is a critical stage in the software development lifecycle, entails creating an architecture and a detailed plan for the system's implementation. This phase focuses on how the software will be constructed by breaking down the requirements into smaller, definable components, establishing the structure of the code, and specifying the interfaces between these components.

Despite the fact that Software Engineering has several techniques for identifying requirements, several studies have highlighted the complexity of identifying the needs of health information systems [17]. This complexity is associated with several factors intrinsic to the healthcare environment, such as the complexity of clinical workflows and the nature of healthcare data. Healthcare encompasses a wide range of specialties, each with its own specific needs and workflow. Clinicians, including physicians, nurses, laboratory technicians, pharmacists, and others, all have different needs and ways of working [18]. Additionally, healthcare delivery often requires close collaboration among specialists, creating the need for a health information system to support interdisciplinary workflows, which can be complex and difficult to standardize.

In the context of oncology clinical processes, the clinical environment is dynamic, and patient conditions and emergency situations are constantly changing. Consequently, any requirements for an oncology EHR system must be able to adapt quickly to these changes [2,19]. Oncology treatment often involves a team of specialists, including oncologists, surgeons, radiologists, pathologists, and supportive care providers, which can make coordinating care among these disciplines complex. Strong communication and collaboration are essential to ensure effective care. Furthermore, cancer treatment is highly individualized, requiring customized treatment plans based on the type, stage, and molecular profile of the cancer, as well as the patient's overall health and preferences. This personalization adds complexity to the treatment-planning process.

To develop and deploy an oncology EHR system that meets the needs of stakeholders, it is necessary to consider orthogonal perspectives that can help characterize the underlying problem of tracking and monitoring oncology patients in an information system. By using other domains to characterize the needs of stakeholders, it is possible to design an oncology EHR that can largely satisfy all expectations [20].

3.4. Research objective and questions

The primary objective of our research is to evaluate the application of scientific approaches that affect the planning, construction, and deployment of oncology EHR systems. Therefore, we use an expansion of our prior studies [5,21] that focuses on the comprehensive integration of clinical priorities, implementation strategies, and requirements gathering methods. The D&I framework [21] provides guidance on acquiring information about the clinical problem that the software should address (see Fig. 1). The framework incorporates requirement elicitation techniques and clinical intervention-based implementation and dissemination strategies [22] to facilitate software development teams in creating clinical software. The framework is divided into three phases: identifying project stakeholders and clinical priorities, collaboratively selecting implementation strategies, and disseminating decisions in the software development process.

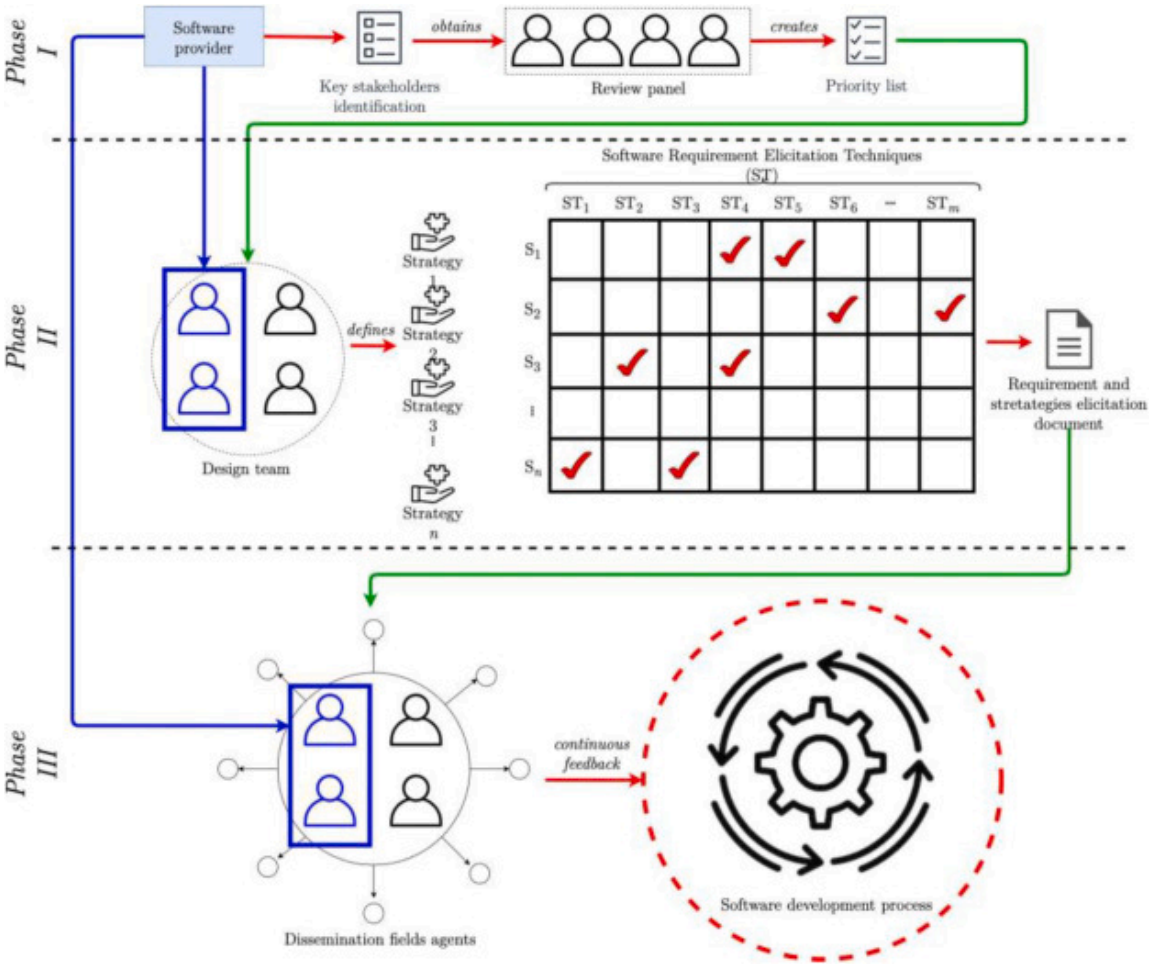

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Fig. 1. The D&I framework.

The D&I framework addresses the disconnect between the generation of scientifically-backed knowledge and its practical application in actual clinical settings. It identifies factors that contribute to the comprehensive and efficient utilization of scientific advancements in practice. The formal definition of dissemination and implementation science encompasses the examination of strategies that facilitate the systematic integration of research outcomes into everyday clinical practices. This integration aims to enhance the quality and efficacy of healthcare services, thereby maximizing the positive impacts of medical interventions.

Prioritization stands as the initial crucial element of the framework. During this phase, the software provider must accurately determine the key stakeholders involved in the project. After identifying the stakeholders, the subsequent step involves establishing a review panel. This panel's primary purpose is to narrow down the comprehensive set of requirements to a more focused group that effectively addresses genuine user needs in a way that strongly appeals to potential users. The framework also employs a knowledge base that links implementation strategies with requirements gathering techniques in Software Engineering. The software supplier must generate a requirements specification document using identified software requirement elicitation techniques or methods for executing the strategies. At this stage, the D&I framework allows the supplier to select the most appropriate requirement description techniques (such as use cases, user stories, or scenarios).

The D&I framework then recommends establishing a specialized team to communicate all information about strategies and priorities to the software vendor throughout the development process, regardless of the vendor's chosen software development methodology. This communication team consists of clinical experts (who have previously been involved in the framework) and the same technology specialists who took part in strategy selection. The D&I framework's primary objective is to establish a shared vocabulary between software developers and healthcare organizations for creating high-quality software and systems. By leveraging implementation and dissemination science, the framework offers guidelines that can be adapted to the software engineering context, specifically for defining requirements. As a result, the D&I framework minimizes the likelihood of developing software and systems that might prove ineffective within the healthcare environment.

The research questions (RQ) of our study are as follows:

- RQ1: Which are the implementation strategies that address the clinical priorities related to the treatment and monitoring processes of oncology patients in Chile? This research question aims to identify the strategies that are most effective in addressing the top clinical priorities in oncology patient treatment and monitoring.
- RQ2: Which requirement elicitation techniques are most representative of the identified implementation strategies in oncology EHR development? This research question aims to describe the techniques that are most effective in eliciting the main inputs for each phase of oncology EHR development.

- RQ3: Which are stakeholders' perceptions of oncology EHR with respect to health information systems currently used in oncology patient management? This research question aims to compare the key issues in the clinical management of oncology patients using current health information systems versus EHR oncology, as perceived by stakeholders in the oncology network in Chile.

3.5. Methodology

The research methodology used in our study is shown in Fig. 2.

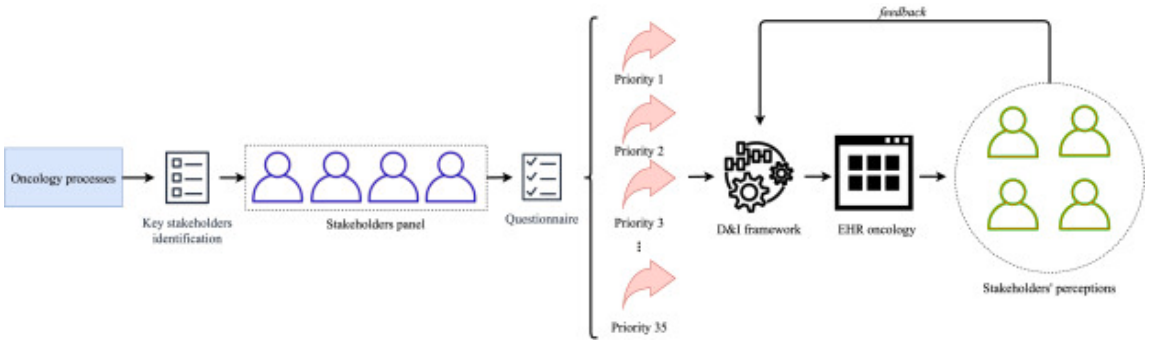

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Fig. 2. Research methodology process.

To address the first research question, we assembled a group of 27 stakeholders to determine the principal clinical priorities for oncological processes in Chile. Stakeholders were selected on the basis of their experience in oncology. Each stakeholder must have at least five years of experience in patient care as well as oncology care management.

Following the stakeholders selection, we conducted a questionnaire modeled using the Individually Prioritized Problem Assessment [23], which is designed to identify problems associated with decision-making resulting from a lack of information, the significance of these problems, the current difficulties posed by existing resources, and the potential difficulties of resolving these problems with EHR oncology. All the answers to the questionnaire were tabulated in a template to analyze the results obtained by each stakeholder in detail. This template is intended to be used to identify clinical priorities based on stakeholder responses. After completion of the questionnaire and categorization of responses, we identified 35 critical clinical priorities.

Regarding the second research question, we employed the D&I Framework. The framework encompasses various implementation strategies and requirements elicitation techniques to generate a set of techniques that enable a more precise understanding and characterization of the underlying problem. These implementation strategies translate broad stakeholder needs into precise, actionable objectives that guide the development of specific intervention plans reflected in key EHR oncology functionalities. This approach facilitates the organization of stakeholder requirements within a

systematic framework, enabling the identification of specific domains in which EHR oncology should engage. Furthermore, the strategies ensure that the intervention plans align with stakeholder expectations through the iterative process of testing and refining strategies based on feedback.

About the third research question, we intend to analyze whether stakeholders perceive a substantial change in oncology EHR in comparison to the current systems utilized in the management of oncology patients. Specifically, we aim to assess whether a system developed, implemented, and deployed using the strategies applied during the software development phases leads to the creation of more practical information systems that meet stakeholders' needs.

4. Results

4.1. RQ1: implementation strategies

The 35 identified clinical priorities resulted in the development of six implementation strategies [24] that facilitated the characterization of treatment and monitoring processes. These strategies are described as follows:

Identify Barriers and Facilitators. This strategy assess various aspects of an organization to determine its readiness for implementation, identify potential barriers that may impede implementation, and leverage strengths that can be utilized in the implementation process of the system to be introduced. Furthermore, it proposes a systematic approach to evaluate and comprehend the numerous factors that may impact the adoption and success of a new practice or intervention within an organization. The aforementioned is pertinent in the procedures of monitoring and treatment of cancer patients, as it allows for the evaluation of whether there is adequate technology in place to manage cancer patient data. Additionally, it enables the determination of resistance among medical staff to transition from a conventional system to a more streamlined and digital system.

Coalition building. The process of recruiting and nurturing relationships with partners who are involved in the monitoring and treatment of cancer patients is crucial. It entails the establishment of a network of key players who work together to attain a shared objective, which in this case is the monitoring and treatment of cancer patients. This strategy is built on the foundation that teamwork and cooperation among various stakeholders can markedly enhance the efficiency and durability of healthcare interventions. By bringing together diverse stakeholders in a collaborative network, coordination can be improved, resources can be increased, innovation can be fostered, and policies and practices can be aligned with the requirements and realities of a specific context.

Conduct local consensus discussions. Incorporating local providers and other stakeholders in discussions about the significance of a specific health problem and the appropriateness of clinical innovation to address it is a vital strategy. This approach aims to reach a consensus on the relevance of a health issue and the suitability of clinical innovation in addressing it. This strategy ensures that decisions are based on a mutual understanding and knowledge of the local challenges and needs. It is

crucial to ensure that cancer patient monitoring and treatment interventions are appropriate and effective in a particular context. By engaging local stakeholders in a collaborative and reflective process, implementation becomes more aligned with community requirements and capabilities, leading to greater acceptance and sustainability of clinical innovation.

Conduct a local needs assessment. The following strategy involves the systematic collection and analysis of data to determine the necessity for innovation. This approach incorporates a comprehensive process of gathering and evaluating pertinent information to discern and comprehend the specific requirements of a community or population with regard to a particular innovation. Conducting this assessment guarantees that interventions are relevant and efficient, based on a clear comprehension of local contexts and challenges. By making decisions based on solid data and a thorough understanding of local needs, strategies can be created and executed to enhance the quality of care, promote fairness, and optimize health results for cancer patients.

Engage patients/consumers and family members. The following strategy entails the participation of patients and their families in the implementation process. This strategy ensures that patients and their families are integrated actively in all stages of the design, planning, implementation, and evaluation of interventions and clinical practices. This strategy acknowledges the worth of the unique experiences, knowledge, and perspectives of patients and their families, fostering a patient-centered approach that can enhance the quality and efficacy of healthcare. With the active integration of patients and their families, more effective, relevant, and sustainable interventions can be developed and implemented to improve the quality of care and health outcomes.

Promote networking. The method of recognizing and employing established connections and networks, both internal and external to the organization, such as teams and departments, for the purpose of promoting collaboration, problem-solving, and a unified objective for the application of innovative ideas. This strategy aims to encourage collaboration, problem-solving, and the setting of a shared vision and objective for the implementation of innovative ideas. Networking can involve a variety of stakeholders, including medical professionals, managers, researchers, patients, and community organizations. By identifying and utilizing existing connections and networks, the coordination, communication, collaboration, and effectiveness of interventions can be enhanced, resulting in improved patient care and better health outcomes.

4.2. RQ2: elicitation techniques

According to the strategies obtained, the D&I framework has identified the following elicitation techniques: business process modeling, requirement identification by consensus, and requirement identification through brainstorming sessions.

Business process modeling. This technique entails evaluating and describing the operations and requirements of an organization to create software that enhances and streamlines its procedures. This procedure entails comprehending the workflows, organizational structure, and business objectives of the organization. The main advantage of this approach is that it enables the

identification of all stakeholders, including physicians, nurses, patients, researchers, administrators, and regulators, and their respective roles, impacts, and needs. This facilitates early detection of functional and non-functional requirements. This technique guarantees that oncology software is aligned with both clinical and administrative requirements, ultimately enhancing the efficiency and quality of patient care [25].

Identification of requirements by consensus. The purpose of this method is to bring together all relevant parties to collaboratively discuss and agree upon software requirements. This approach is centered on collaboration and consensus, with the goal of considering and addressing all perspectives and needs. This section provides a detailed explanation of this technique's application and its specific application in defining the requirements of the healthcare oncology process. This technique complements the business process modeling technique by analyzing the current oncology process and identifying problem areas, such as delays in treatment, errors in the management of medical records, and a lack of communication between departments. Consensus is achieved through voting to determine the most critical requirements and prioritize the development of functionalities in the oncology EHR [26].

Brainstorming. This method entails a collaborative exercise that encourages the open and unrestricted generation of concepts and proposals to comprehensively address the diverse requirements and aspirations of stakeholders. This technique is particularly valuable in fostering innovation and in gathering an extensive array of suggestions that can subsequently be honed and ranked according to priority [27].

Utilizing the methods discussed previously, we were able to actively involve stakeholders in the process of identifying and documenting detailed and complex requirements for the EHR oncology, ensuring that the system meets the expectations and needs defined by these stakeholders.

4.3. RQ3: stakeholders perception

The 27 key stakeholders addressed three critical issues identified in the clinical priorities: data management, data integration, and oncology clinical reporting. Each stakeholder was asked to evaluate the complexity of performing the activities associated with these issues using their current EHR and the oncology EHR that we developed in our study. Using a 5-point Likert scale, where 5 represents very difficult and 1 represents very easy, the stakeholders evaluated the complexity of executing the activities. The results of this evaluation are presented in Fig. 3, Fig. 4, Fig. 5. The blueline describes the evaluation of the current EHR utilized by the stakeholder, while the red line represents the oncology EHR implemented in our study.

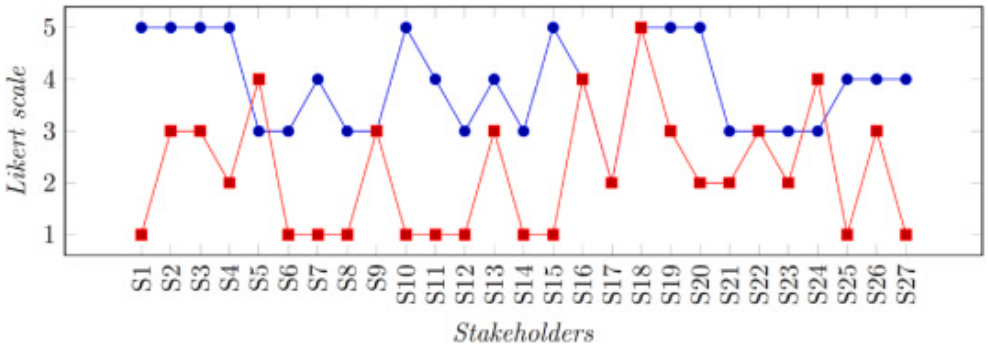

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Fig. 3. Data management complexity evaluation results.

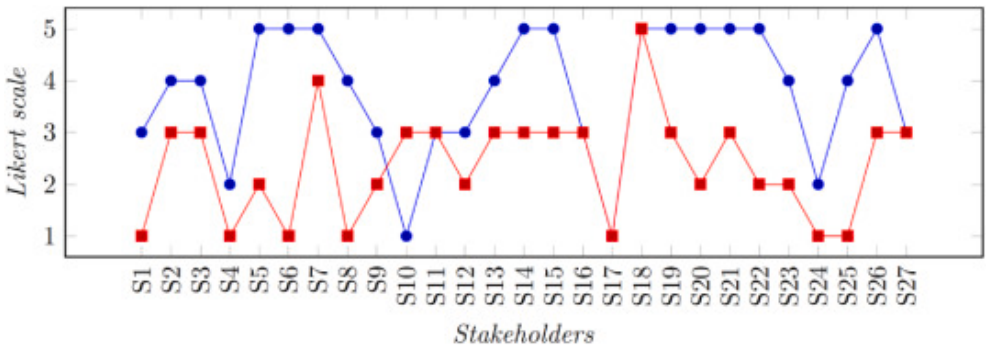

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Fig. 4. Data integration complexity evaluation results.

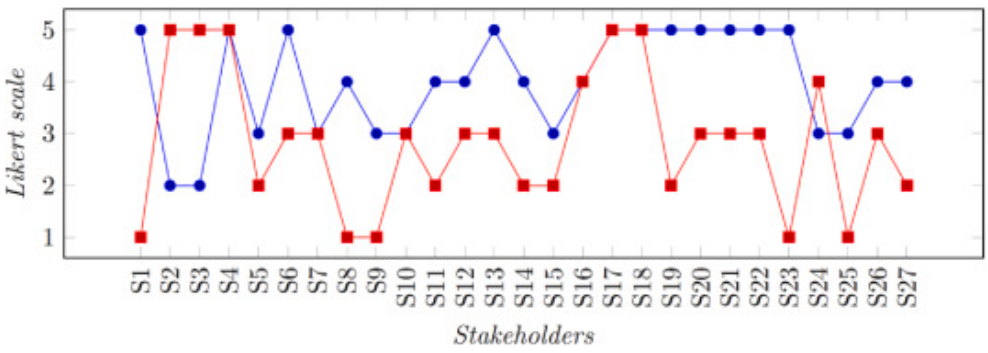

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Fig. 5. Oncology clinical reporting evaluation results.

The average complexity of performing data management-related activities was 3.9 for the current EHR and 2.2 for the oncology EHR. For data integration-related activities, the average complexity was 3.8 for the current EHR and 2.3 for the oncology EHR. Lastly, for oncology clinical reporting activities,

the average complexity was 4.0 for the current EHR and 2.9 for the oncology EHR. Our findings indicate that, from the stakeholders' perspective, the complexity of performing key tasks is lower when using the oncology EHR as compared to their current EHRs in their respective healthcare institutions. However, we cannot generalize that our oncology EHR system is easier to use for all key tasks in the oncology process. Nevertheless, the D&I Framework proved to be a useful tool in identifying stakeholders' needs for data management, data integration, and oncology clinical reporting, which can be translated into the various stages of implementation and deployment of the oncology EHR.

5. The EHR oncology

5.1. Actors

We identified eight key stakeholders (stakeholder panel, see Fig. 2) as essential for the EHR to be effective and positively impact the quality of oncology patient care. These stakeholders begin with the D&I framework. These stakeholders consist of both natural persons and institutions, given that oncology patient management is multifaceted and involves clinical professionals as well as specialized teams of healthcare providers. The stakeholders are presented in Table 1.

Table 1. Oncology EHR stakeholders.

Stakeholder	Description
Chilean Ministry of Health	It has the authority to manage the creation and approval of profiles and view cases at the national level.
Director of the health institution	This actor has the ability to view the records made by the hospital and download the anonymized records taxed by the hospital.
Regional Health Secretariat	It is responsible for visualizing and downloading cases registered in its circumscribed regional secretariat. For this user level, there are 16 health secretariats.
Health Service	Agency responsible for executing integrated actions to promote, protect, and recover the health and rehabilitation of the sick.
Treating Physician	Professional responsible for patient care and generating the epicrisis document.
Pathologist	Medical specialist in anatomical pathology, in charge of analyzing the cellular structure or tissues with a microscope. One of his or her responsibilities is to generate a histological confirmation corresponding to the patient's diagnosis.
Oncology Committee	The aim of this committee is to define a therapeutic plan for people diagnosed with cancer, comprising different specialists, subspecialists, and professionals from different areas.
Validator	Professional in charge of validating cancer cases, either through morphological confirmation records or clinical resolution for notification. This professional has the power to download

Stakeholder	Description
	associated records and validated cases depending on the facilities assigned to the user.

Based on our evaluation, the actors listed in Table 1 are well-suited for the EHR oncology to capture and analyze data related to diagnosis, treatment, and patient monitoring. The different perspectives described by these actors allow the identification of clinical priorities. Additionally, these identified actors provide real-world data that are crucial for precision medicine and can complement the findings of clinical studies.

5.2. Requirements

Once the 35 priorities have been identified, the D&I framework is used to identify the main functional requirements of the EHR oncology. Given the complexity of EHR oncology, we obtained a significant list of functional requirements. Each functionality is described into more concrete descriptions called use cases representing more specific tasks (see Table 2).

Table 2. Main use cases of the oncological EHR.

ID	Use case	Description
UC1	Record morphological confirmation form	This use case provides access to the associated actors to make records associated with biopsies and sampling performed in the respective establishments, taking as first action the notification of cancer cases.
UC2	Record clinical resolution form	This use case provides access to the associated actors to make records associated with treating physicians and oncology committees in the respective establishments, taking the notification of cancer cases as an action.
UC3	Validate cases	This use case validates cancer cases given a patient, where there is a compilation of associated records for both morphological confirmation and/or clinical resolution, and the user validates field-by-field through the crossing of information associated with cancer records.
UC4	User management	The objective is user management, whose purpose is to approve and delete users, along with the assignment of roles and usage profiles for the system.
UC5	See cases	Allows the consultation through the assigned profile of a patient's cases by ID.
UC6	Download data sheet	Allows consultation through the assigned profile of a patient's cases by ID.

The primary function of UC1 is to create records using the form for the registration and notification of biopsies conducted on confirmed cancer cases. Furthermore, this use case is designed to facilitate the completion of missing information for cancer cases through the validation process, including the creation of new records or the correction of data entered by other registrars. Additionally, UC1 allows

for the attachment of a digital file in PDF format, which can be the histological report. Moreover, UC1 enables non-provider users to access and correct the date of birth.

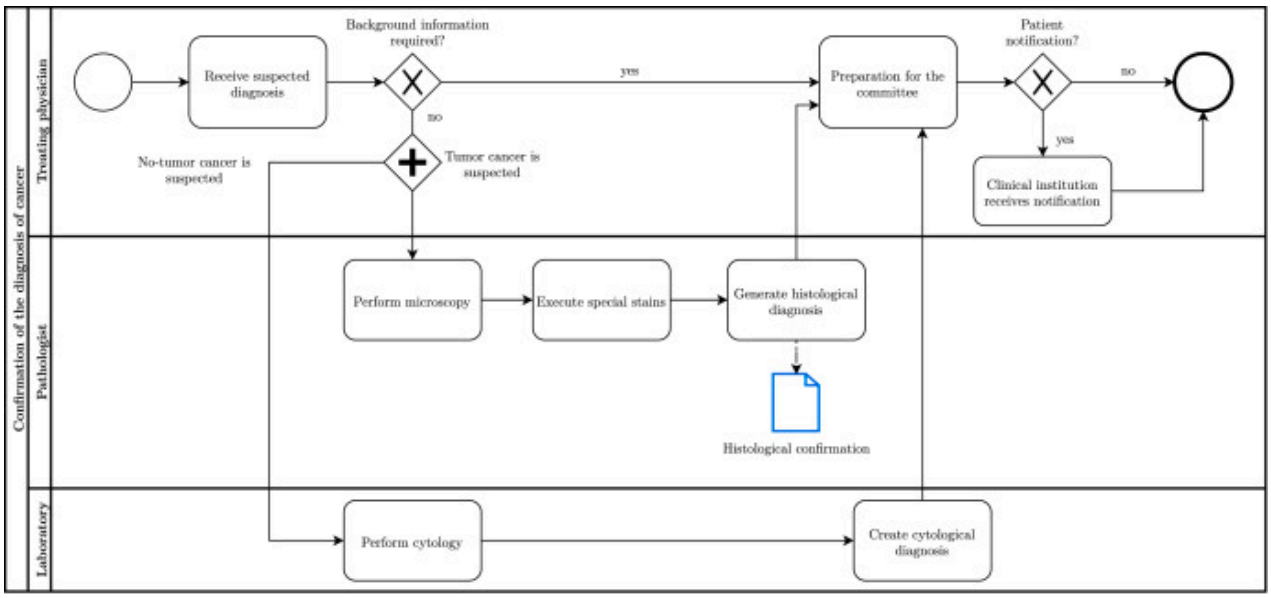
UC2 prioritizes the submission of cancer case records through an online form for notification purposes. Additionally, the UC2 is responsible for completing missing information on cancer cases, creating new cancer case records, or correcting records made by other registrars. The use case also includes filling in data on treatments performed on the patient, updating the patient's staging and diagnosis information, and recording the patient's usual residence, considering the region and commune.

UC3 aims to acquire morphological confirmation records in order to include new cancer information and fill in gaps in existing information. Furthermore, it involves creating clinical resolution records that incorporate both new and missing cancer data. This use case facilitates selecting fields to verify a cancer case, subsequently altering its status for the ultimate cancer report. It is crucial that search engines are vigilant when cases cannot be located.

The primary objective of patient management as it pertains to UC4 is to facilitate the querying of user information through the use of their name or ID, thereby enabling the editing of previously entered users and the approval or deletion of requests submitted to the system registry. In a similar vein, UC5 enables the searching of patients based on their ID, within the limits of each individual profile. Lastly, UC6 oversees the management of user profiles, allowing for the downloading of data sheets that correspond with the data entered within the scope of the respective profile.

5.3. Processes

Two essential processes in cancer care have been recognized: the confirmation of a cancer diagnosis (see Fig. 6) and the subsequent identification of an appropriate treatment (see Fig. 7).



Download: Download high-res image (344KB)

Download: Download full-size image

Fig. 6. Confirmation of the diagnosis of cancer process.

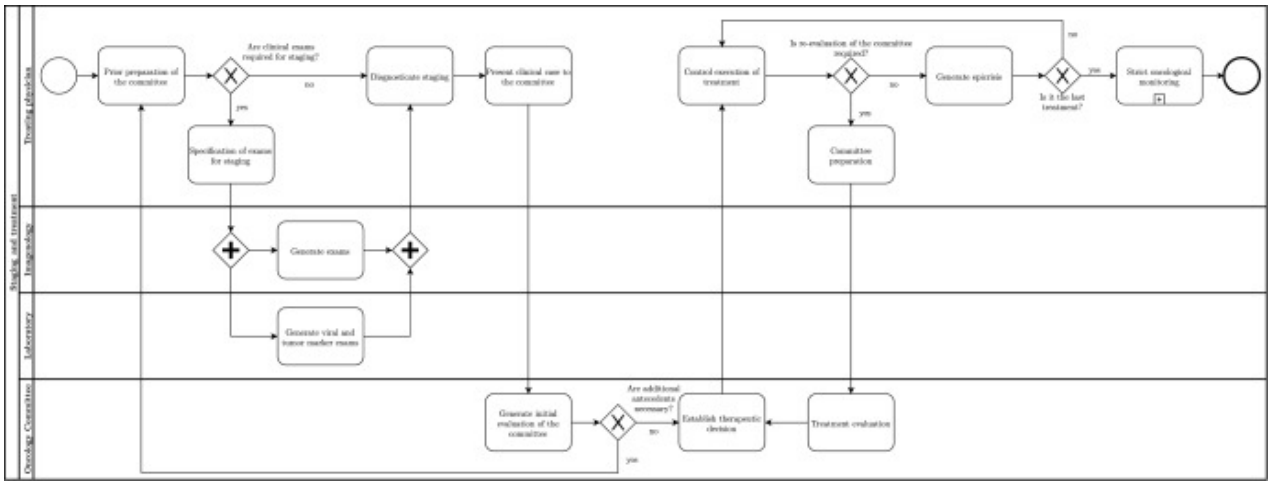


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Fig. 7. Staging and treatment process.

The process of confirming a cancer diagnosis encompasses receipt of a suspected diagnosis from a non-cancer center, histological confirmation, and clinical notification to the patient. If the patient's history or biopsy is insufficient for diagnosis or further analysis is required, the process continues with Anatomic Pathology for suspected tumor cancer or the laboratory for other types of cancer. If the patient's history or biopsy is sufficient for diagnosis, the case proceeds to committee preparation. The pathologist then diagnoses and codes the cancer based on the histological diagnosis from the biopsy. The laboratory manager generates a cytological diagnosis of the sample and refers it to the treating physician. However, if diagnostic confirmation by the Oncology Committee is required, no event is generated for the EHR. At this point, the treating physician prepares the patient's presentation to the Oncology Committee, organizing the available background for diagnostic confirmation, staging, and treatment resolution. This includes notifying the patient of the cancer diagnosis during a medical consultation, whether it is suspected, histological, or cytological, and informing them of their future presentation to the committee.

With regards to the staging process and corresponding treatment, it is essential to emphasize that this procedure depends on the patient's data, histological diagnosis, mythological diagnosis, and suspicion of diagnosis. The imaging specialist conducts tests according to the indication of the treating physician and produces a report of the tests. Similarly, the laboratory carries out tests based on the indications of the treating physician and generates test reports. Following this, the oncology committee evaluates the background and determines whether a therapeutic decision can be made. If necessary, the histological diagnosis is updated. If the patient's history is insufficient, the treating physician is requested to order additional tests before a therapeutic decision is made. These preceding steps lead to the generation of a therapeutic decision, which signifies that the treatment plan that must be followed for the patient has been determined. After the therapeutic decision, the

patient undergoes one or more treatments. This process involves controls performed by the treating physician during this activity. The control can occur (i) during a treatment, (ii) upon completion of one of the numerous treatments assigned to the patient, or (iii) upon completion of the final treatment. If the attending physician recognizes the need for the patient to appear before the committee again, they will proceed with the necessary preparations. Otherwise, if the patient has additional controls and treatments, they will return to a new control. In the event that there are no further treatments available, and the patient does not require evaluation by the committee, they will be placed on strict oncology monitoring. The attending physician assessed the patient during treatment and determined that it is essential for the committee to evaluate the patient. This may occur, for instance, following surgery. Ultimately, the oncology committee evaluates the patient based on the outcome of their treatments and the information gathered by the attending physician during the controls. A new committee resolution is formulated, which corresponds to the same document generated in the therapeutic decision, updating the available data.

5.4. Software architecture and quality attributes

In our analysis of the requirements specification, we identified fourteen non-functional requirements (NFRs) that are critical to the main stakeholders for the performance of the EHR oncology. These NFRs represent the main desired qualities for the EHR oncology to be successful [28]. However, as NFRs are not always expressed in a structured manner, we utilized the sub-characteristics of ISO 25010 to characterize them. We then classified the NFRs according to the main characteristics described by ISO 25010, resulting in seven key attributes: compatibility, reliability, security, performance, maintainability, usability, and portability. Table 3 provides a detailed overview of the NFRs, including their description in the EHR oncology, the quality attributes associated with each NFR, and their relevance to the project.

Table 3. Description of the non-functional requirements, quality attributes and relevance.

NFR	Description	Quality attribute	Relevance
Interoperability	The system must be able to interoperate with other external systems	Compatibility	High
Coexistence	The system must be able to coexist with other independent software in a common environment sharing common resources	Compatibility	Medium
Fault Toleance	The system must be able to maintain a specific level of performance in the event of a failure of any system component or external to the system	Reliability	High
Availability	The system must be able to have the data available when required for use.	Reliability	High

NFR	Description	Quality attribute	Relevance
Integrity	The system must be capable of preventing unauthorized access or unauthorized modification of data	Security	High
Confidentiality	The system must be able to ensure that the data is accessible only to those authorized to have access	Security	High
Non-repudiation	The system must be able to prove that actions or events have been performed, so that they cannot be repudiated later	Security	High
Responsibility	The system must be able to uniquely track a user's actions	Security	High
Authenticity	The system must be able to prove that the identity of a user or resource is the one claimed	Security	High
Temporary Behavior	The system must be able to have response times of less than 5s for 95% of data extraction queries, measured based on the generation time recorded on the server	Performance	Medium
Modularity	The system should be structured by software components, so that a change to one component has minimal impact on other components	Maintainability	Medium
Protection Against User Error	The system must be able to protect users against errors	Usability	Low
User Interface Aesthetics	The system must have a user interface that allows a pleasant and satisfactory interaction for the user.	Usability	Low
Portability	The system must be useable in modern browsers such as Chrome, Firefox, Safari and Internet Explorer	Portability	Low

Although the quality attributes listed in Table 3 represent the characteristics that the EHR oncology system should possess, from an operational perspective, it is not feasible to address all of these attributes entirely. This implies that trade-offs exist between the quality attributes. Some studies, such as [29,30], argue that in practical application, it is not possible to achieve all of the desired quality attributes, as some attributes may compromise others. For instance, enhancing the performance of a system may require additional resources, which could affect its scalability and portability. This suggests that two or more quality attributes are incompatible or mutually exclusive. As a result, trade-offs and conflicts between quality attributes are unavoidable, as they reflect the diverse and sometimes conflicting needs and expectations of stakeholders. Table 4 illustrates the trade-offs between the quality attributes for EHR oncology.

Table 4. Trade-offs between quality attributes.

Quality attribute	Trade-off	Value
Compatibility	Reliability	N/A
Compatibility	Security	Negative
Compatibility	Maintainability	Positive
Compatibility	Portability	Positive
Compatibility	Performance	N/A
Compatibility	Usability	N/A
Reliability	Security	Positive
Reliability	Maintainability	Positive
Reliability	Portability	N/A
Reliability	Performance	Negative
Reliability	Usability	N/A
Security	Maintainability	Positive
Security	Portability	N/A
Security	Performance	Negative
Security	Usability	Negative
Maintainability	Portability	Positive
Maintainability	Performance	Positive
Maintainability	Usability	N/A
Portability	Performance	N/A
Performance	Usability	Positive

Table 4 summarizes the trade-offs that should be considered in the development of the EHR oncology. One example of a trade-off is the compatibility of different infrastructures, which may negatively impact the security of the system. However, a more system with acceptable performance may result in greater maintainability of the EHR oncological. This type of trade-off analysis is crucial for making decisions regarding the software architecture of the EHR oncology. After analyzing and establishing the design decisions based on the trade-offs, architecture decisions can be made (as shown in Table 5).

Table 5. Description of architectural decisions in the oncology EHR.

Quality attribute	Decision	Rationale
Reliability	Using the Retry design pattern	The Retry pattern is used to detect failures and retry the operation in case of a temporary system failure or unexpected system difficulties
Security	Use the national authentication mechanism called Single Key and invoke Spring Security libraries	The use of Single Key allows authenticating the system users and Spring Security allows performing the authorization of the users to the system
Portability	Use Angular 7	The use of Angular 7 allows to support multiple browsers (Chrome, Firefox, Safari, and Internet Explorer 11)
Performance	Perform database query tuning	By applying indexes to queries, adjustments can be made to databases
Usability	Use Angular 7 and Angular Material	The use of these technologies allows users to achieve their goals with effectiveness, efficient and satisfaction in a specific con- text of use

The design of the EHR oncology architecture addresses reliability, security portabiliity, performance, and usability as quality attributes. These characteristics define the main requirements that the EHR oncology must meet, as well as the systemic properties that stakeholders expect. Furthermore, Table 5 establishes the development plan for the EHR oncology and outlines the appropriate methodology for deploying the system. The technological infrastructure of the EHR oncology is characterized by compatibility, maintainability, and potability as quality attributes. These attributes refer to the necessary ecosystem of services, tools, and servers that are required for the EHR oncology to meet stakeholder expectations.

5.5. Interoperability

The HL7 Clinical Document Architecture (CDA) standard [31] is an XML markup standard with the objective of establishing specifications for the encoding, structure, and semantics of electronic clinical documents. The purpose of complying with this standard is to enable the exchange and interoperability of information between different actors or health-information systems.

A CDA document has the following characteristics that make it valuable for the implementation of health information systems implementation of health information systems:

- Persistence: A clinical document continues to exist without any alteration or modification, for a period of time, defined according to local regulations and laws.

- Management: A clinical document is maintained by an organization in charge of its care.
- Authentication: A clinical document has the capacity to be registered or signed by a legal representative, ensuring its integrity and accuracy of the clinical information contained in the document.
- Context: Clinical records tell a story about the care provided to a patient. It contained information about the participants in the care where it was provided and when it was performed.
- Integrity: Authentication is applied to the entire document and not to portions of the document, without context.
- Legible: It must be a human-readable document.

Regarding the EHR oncology that we developed, we identified objects or elements within the clinical document using an ID. In the case of the structure of a CDA, there are two possible ways to carry out this process: by means of universal identifiers or local identifiers. The identification of universal elements such as a coding system, a catalog, etc., is carried out by means of a system called OID (Object Identifier), which, based on a composite number, builds the object identifier by assigning its id from a root value. On the conformation of the OIDs used in the Shared Health Record project, refer to the document “OID for HCC.” When what is required is a local identifier for an object, such as an internal document, a process document id, etc., what can be generated is an identifier by means of a Universal Unique Identifier (UUID). This identifier is generated by software and corresponds to a 16-byte number and is expressed by 32 hexadecimal digits divided into five groups separated by hyphens, for example, 550e8400-e29b-41d4-a716-446655440000.

For EHR oncology, based on the data elements defined in the work tables with the community and stakeholders, we obtained a set of relevant proprietary data that are necessary to interoperate (see Table 6).

Table 6. Sample of EHR oncology interoperable elements.

XPath	Cardinality	Value
Section		
templateId	1..1	
@root	1..1	
@extension	1..1	
Code	1..1	

XPath	Cardinality	Value
@code	1..1	31205–8
@codeSystem	1..1	2.16.840.1.113883.6.1
@displayName	1..1	Cancer Type (Histological Diagnosis)
@codeSystemName	1..1	LOINC
entry	1..1	
observation	1..1	Diagnostic Observation
entry	0..*n*	
observation	1..1	Observation Complementary Examination

Based on this work with the community and stakeholders, we were not only able to define the dataset for defining the type of cancer and diagnostic observations. We also defined the data for observation of complementary oncological examination and tumor-nodule or lymph node-distant metastasis examination.

5.6. Testing

The testing strategy for EHR oncology was designed with a comprehensive and wellstructured approach to evaluating its performance. All necessary components were thoroughly examined and subjected to a standardized analysis and testing process that encompassed a wide range of scenarios, including errors, successful outcomes, and edge cases. This rigorous testing methodology guarantees the validation of the system's functionality, which is crucial for the certification process. Furthermore, the testing process involved multiple modules that covered a variety of key aspects, such as case management, morphological confirmation, clinical resolution, user profiles and registration requests, and contact details.

In the context of test planning, the scope of the solution and the complexity of its processes were considered to determine the levels of tests to be applied. The time required for the execution of each test was assessed, considering the resources involved and the expertise and training of the team responsible for conducting the tests. Clear acceptance criteria were established to guide the evaluation of the results obtained from the tests, ensuring that the solution met the required quality standards. Testing was integrated into the entire product development lifecycle, and the test plan was updated to reflect changes in the requirements and/or the development process. This approach ensures thorough and effective planning, optimizing the efficiency and effectiveness of the testing process.

The verification and validation tests were carried out as well. The scope of the tests was defined by the KACTUS-HR framework, which comprises the business logic layer, data access layer, and

functional requirements. Actual data were employed to confirm the proper functioning of the application, while in exceptional circumstances, fictitious data were utilized to simulate specific tasks.

Static tests were conducted with the goal of identifying potential errors that could lead to system failures and generate bugs. These tests included a comprehensive review of documentation generated during the certification process and requirements analysis, as well as an evaluation of requirement documents, test case designs, and test plans. Additionally, a detailed analysis of the maintenance design was conducted, with a particular focus on the user experience (UI-UX), and a thorough inspection of the code was performed without the need for execution.

The dynamic testing process involves the application of various techniques and approaches to ensure the quality of the software. These techniques include:

- Integration tests, which assess the interaction between different components of the system
- Mutation tests, which evaluate the robustness of the code by introducing small changes called mutations
- Interaction tests, which focus on validating communication between the system and its users
- Regression tests, both local and remote, which detect possible side effects of code changes
- Swept regression tests, which comprehensively review all system functions for potential bugs
- Triggered regression tests, which are automatically triggered in response to code changes
- Alpha and beta acceptance tests, which involve evaluating the software by real users in different environments
- Acceptance tests, which ensure that the software meets the defined acceptance criteria.

Furthermore, user interface (UI) testing is conducted to guarantee an optimal user experience. These dynamic testing techniques enable us to effectively identify and rectify potential problems in the software before its final implementation.

All required functions were documented during the quality monitoring procedure to guarantee the proper operation of the system. This included the identification of the requirement and its specifics, along with the allocation of a defect ID if a failure was detected. Each test case was thoroughly

described to specify the particular functionality assessed. The date of each test's execution, as well as the system module it belonged to, were recorded. The input actions needed to conduct the test and the expected outcome of the test were both documented. Any disparities or findings between the anticipated results and those obtained were detailed, along with the current status of the defect. A record was kept of the most recent date the defect status was updated, as well as the test execution and any final observations made by the QA team. This comprehensive tracking approach allows for effective defect management and ongoing enhancement of the system.

5.7. Deployment

The implementation of EHR oncology involves several critical steps and factors to ensure the security and proper functioning of the system. First, it is essential to update the database to ensure that it contains the most recent changes and enhancements. Subsequently, the upgrade of both the frontend and backend components should be conducted, implementing the latest versions to improve system stability and security. In addition, extensive verification of the configurations was conducted to ensure that they were correctly configured and optimized for the production environment. To protect access to the system, a unique password and secure production credentials are used. Moreover, recommendations are provided to the client to enhance security, including the installation of FileZilla for secure file transfer and the creation of directories using this tool to ensure the secure management of project files. Collectively, these steps and practices contribute to the secure and effective deployment of RCE in the project.

The development of a comprehensive training program was essential to ensure that users could master the various functions and processes of the system. This program was designed to cover different modules, including system login, registration form for morphology confirmation and clinical resolution, as well as validation of cancer patient cases and user administration. Each module was broken down into its specific components, and training sessions were designed to focus on each of these components, thereby ensuring that users acquired complete and practical knowledge of the system and could perform their roles effectively.

In addition to the training program, a detailed user manual has been created that provides clear and concise instructions on how to use each function and process of the system effectively. The manual includes all the aforementioned content, making it an invaluable resource for users to refer to when they need guidance on using the system. With the help of this comprehensive training program and user manual, users can be confident that they have the necessary knowledge and skills to use the system effectively and efficiently.

6. Discussion

The implementation of EHR oncology in Chile has greatly enhanced the comprehensive management of cancer in the country. In this study, we considered only two processes (Fig. 6, Fig. 7) owing to cost constraints, as the cancer process is very complex. However, these processes allow us to identify

existing cases in Chile by addressing the confirmation of diagnoses (which could not be done directly with existing EHRs and required centralization processes) and to evaluate the effectiveness of treatments at the national level to support public policy formulation and research. By creating a centralized registry system, detailed and updated data on cancer patients can be collected and continuously monitored at the population level. This advanced system is a significant milestone in the country's healthcare infrastructure, providing a vital tool for improving clinical care and developing evidence-based health policies.

Implementation science is of relevance importance in the advancement of EHR oncology. By employing implementation science strategies, we are able to systematically integrate research findings and evidence into clinical practice. One of the key benefits of implementation science is the identification of essential requirements for the development of EHR oncology. Implementation science provides a multidimensional perspective that ensures that stakeholders' needs are successfully designed, implemented, and met. It is crucial to identify barriers and enablers within the healthcare environment, as this helps to tailor the system to specific needs and conditions. Coalition building is also essential, as it encourages collaboration among stakeholders, which enhances the acceptance and utilization of EHR oncology. Additionally, generating consensual local discussions ensures that a wide range of viewpoints are considered, leading to a more comprehensive and inclusive set of requirements. A local needs assessment is critical, as it provides insight into the unique demands and challenges of the target population, which guides the customization of EHR oncology to effectively meet local needs. Patient, consumer, and family engagement is crucial to ensure that the system is user-friendly and patient-centered, resulting in better health outcomes and increased satisfaction. Finally, networking promotes the sharing of knowledge and experience, fostering continuous improvement and innovation in the development of EHR oncology.

The platform offers a structured framework for storing and managing clinical and epidemiological data, integrating information from diverse sources, including hospitals, clinics, and research centers, and is based on a robust ethical consideration that considers the perspective of the law. This consolidation enables longitudinal tracking of patients, providing a complete view of the disease trajectory from diagnosis to treatment and beyond. The real-time access and update of clinical information significantly optimize medical decision-making, favoring a more effective personalization of oncological treatments by considering the person beyond their biomedical diagnosis and considering their biopsychosocial context.

One of the key advantages is the enhancement of medical care coordination. The platform facilitates communication between healthcare providers, ensuring that all professionals involved in patient care have access to the same current information. This increases the efficiency of care by preventing the repetition of tests and treatments. The centralization of data enables the early identification of patterns and trends in cancer epidemiology, providing valuable information for disease prevention and control at the national level. In terms of its public health impact, the platform will be instrumental in generating data for research and the development of public health policies. The collected data will enable more precise epidemiological studies, identify risk factors, and better

evaluate the effectiveness of available treatments through cost-effectiveness and cost-benefit analyses, even in the medium term, allowing for the assessment of interventions in real-time.

Based on the evidence derived from the application of the D&I framework, direct engagement with users facilitates the acquisition and analysis of implementation data, thereby enabling the refinement of health information system requirements to accommodate temporal changes or enhancements. Through the systematic examination of workflows and user interactions, the utilization of the D&I framework ensures that information systems are intuitive, user-friendly, and congruent with the operational routines of healthcare professionals. This approach contributes to the development of information systems that are both efficacious and tailored to the specific requirements of users, including patients and clinicians.

6.1. Implication for researchers

EHR oncology plays a significant scientific role, encompassing various areas of research, epidemiology, and public health management. In terms of research, the platform offers access to extensive longitudinal clinical and epidemiological data essential for conducting cohort studies and clinical trials to evaluate the efficacy of new treatments and intervention methods. Moreover, it facilitates the integration of data from multiple sources, enabling the identification of population-level patterns and risk factors, improving cancer epidemiology by detecting trends, and assessing the impact of prevention programs. This data integration also supports the development of predictive models that can guide resource allocation and clinical decision-making. From a public health standpoint, the platform provides a robust evidence base for health policy formulation, allowing policymakers to design more accurate and effective measures to decrease cancer incidence and mortality in Chile. Additionally, it establishes a robust ethical framework that upholds patient rights, safeguards personal information, and promotes scientific advancement and optimal cancer treatment in a legally compliant manner.

Our findings indicate that the application and dissemination sciences in healthcare systematically facilitate the identification of stakeholder and patient needs. These sciences emphasize stakeholder engagement and promote collaboration to capture diverse perspectives, including those of patients, physicians, and families. The identified perspectives enable a more pragmatic translation of the problem into the solution. The models that support EHR oncology tend to be more realistic, suggesting that system functionalities are more comprehensive.

6.2. Implication for practitioners

EHRs in oncology have broad clinical applications that span multiple aspects of cancer care, including screening, diagnosis, staging, treatment, rehabilitation, palliative care, patient and family support, and management of specific health guarantees. The ability to analyze clinical and epidemiological data enables early detection of cancer cases and accurate staging, which is essential for determining prognosis and developing treatment strategies. Additionally, the EHR oncology offers a comprehensive view of available treatment options and their effectiveness, allowing for

individualized interventions based on each patient's unique characteristics and enabling the tracking of clinical outcomes.

Conversely, the gathered information enables the creation of more personalized and effective programs for physical and emotional recuperation, enhancing the quality of life after treatment. The project also strengthens assistance for patients and their families by offering precise and current details about the disease's status and accessible resources, enabling well-informed choices and active involvement in care. Moreover, the system enhances the administration of explicit health guarantees and shortens waiting lists by supplying real-time information on service availability and prioritizing urgent cases. This improves resource allocation efficiency and reduces wait times for critical treatments. Consequently, the system promotes cost-effectiveness and a favorable cost-benefit ratio in the comprehensive care and support of cancer patients in Chile.

6.3. Limitations

Although EHR oncology achieves good results in diagnostic processes as well as staging and treatment processes, there are several limitations that should be analyzed. Considering that other institutions related to oncology processes can contribute additional data, this is a limitation of EHR oncology. The extraction and exchange of a subset of records, to which they may add new variables to be observed, proves to be a considerable challenge owing to the exchange of information. Although EHR oncology has a flexible architecture, in our research, we did not consider the extension of the system to other systems because the standards and interoperability architecture for this purpose require specific features that were not addressed in this research. Interoperability requirements are architecturally significant; therefore, the D&I framework does not consider them.

Another limitation is incomplete or missing data. Although efforts have been made in EHR oncology usability, the implementation and use of EHR oncology have shown that users often make manual entry errors or inconsistent data collection practices, which eventually limits the reliability of the datasets. This scenario also produces side effects, such as duplicate records derived from redundant entries. These duplicate records eventually produce data integrity problems such as typographical errors, outdated information, and invalid formats.

7. Conclusions

This paper presents a study that explores the implementation and deployment of EHR system for oncology patients in Chile. We used implementation science strategies through a method called D&I framework, which connects implementation techniques to requirements identification. Our aim is to characterize the root problem of the system in a practical manner by examining the context using implementation strategies.

Our research uncovered six crucial implementation strategies that are vital for identifying the background problem that must be addressed by EHR oncology. Among these, the D&I framework technique yielded three requirement identification techniques that work in synergy to help us

comprehend the underlying problem and the needs of the stakeholders. Eventually, we evaluated EHR oncology on three critical issues identified in the clinical priorities: data management, data integration, and oncology clinical reporting, involving 27 key stakeholders. The findings show that the stakeholders perceive EHR oncology as easier and more beneficial in handling the functions related to these three issues. This conclusion allows us to establish that the implementation and deployment of EHR oncology contribute to the effective clinical management of oncology patients.

Our future work is focused on incorporating additional elements into EHR research in the field of oncology. These components will specifically address the needs identified by stakeholders and enumerated in their feedback. Furthermore, our objective is to enhance the D&I framework by integrating recommender systems to achieve improved outcomes in the identification of requirements.

CRediT authorship contribution statement

Carla Taramasco: Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Rene Noel:** Methodology, Investigation, Conceptualization. **Gastón Márquez:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Diego Robles:** Writing – review & editing, Writing – original draft, Methodology.

Ethical statement

Through this letter, I would like to clarify that the manuscript titled "Using Implementation Science to Develop and Deploy an Oncology Electronic Health Record" did not require approval from an ethics committee, as no experimentation with human subjects was conducted, nor were any sensitive patient data collected.

This study focused on the application of implementation science principles for the development and deployment of an oncology electronic health record system without involving direct patient intervention, clinical trials, or the collection of identifiable personal information.

Therefore, in accordance with the ethical regulations of the universities that participated in the study, this work does not require evaluation by an ethics committee.

We remain available for further inquiries on this matter.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Carla Taramasco reports administrative support was provided by ANID FONDAP. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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