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Cancer Informatics

Health Information Technology in Oncology Practice: A Literature Review

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ABSTRACT: The adoption and implementation of information technology are dramatically remodeling healthcare services all over the world, resulting in an unstoppable and sometimes overwhelming process. After the introduction of the main elements of electronic health records and a description of what every cancer-care professional should be familiar with, we present a narrative review focusing on the current use of computerized clinical information and decision systems in oncology practice. Following a detailed analysis of the many coveted goals that oncologists have reached while embracing informatics progress, the authors suggest how to overcome the main obstacles for a complete physicians' engagement and for a full information technology adoption, and try to forecast what the future holds.

KEYWORDS: HIT, CDSS, CPOE, cancer care, patient safety, quality of care

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Current Role of Health Information Technology in the Healthcare System

Two decades ago, it was commonly acknowledged that health information technology (HIT) would affect healthcare as much as it did other critical sectors. Nevertheless, implementation of HIT in healthcare services proved to be much more complex, and it is still less widespread than it is in other areas. However, the medical science available today is unprecedented and remarkable: understanding and applying this rapidly expanding amount of information without the fundamental contribution of HIT would be simply unfeasible. In fact, HIT is increasingly integrated into medical care to the point that 57% of office-based physicians in the U.S. now use electronic health records (EHRs),[1] while a 2013 European report showed that 92.6% of general practitioners use EHRs, although paper has not been abandoned yet.[2]

The EHR is the core of any HIT application, and it is the system that stores patients' data. Although it might vary in structure, content, applications, and impact,[3] according to International Organization for Standardization (ISO),[4] the EHR is "a repository of patient data in digital form, stored and exchanged securely, and accessible by multiple authorized users. It contains retrospective, concurrent, and prospective information and its primary purpose is to support continuing, efficient and quality integrated health care."

Despite being originally conceived for collecting and processing administrative data (namely, patient and payer-related data, reporting, claims, etc), the EHRs soon started to include clinically relevant information in order to support clinical workflow. At present, EHRs usually incorporate computerized physician order entry (CPOE) and clinical decision support systems (CDSSs).

CPOE systems enable medical order management in clinical setting, and it has been established as an important tool for minimizing errors, hence improving patient safety.

CDSSs are defined as "any software designed to directly aid in clinical decision-making in which characteristics of

individual patients are matched to a computerized knowledge base for the purpose of generating patient-specific assessments or recommendations that are then presented to clinicians for consideration."[5] The goal is to "help health professionals make clinical decisions, deal with medical data about patients or with the knowledge of medicine necessary to interpret such data."[6] In principle, this means that CDSSs provide support for any decision that has to be taken in the major areas of medical activity, including prevention, diagnosis, treatment, and prognosis. However, for the purpose of this paper, the most interesting applications are related to the different aspects of antitumor treatment, ie, prescriptions, dosing, etc. CPOE and CDSS being autonomous subsystems, a careful integration should be pursued to avoid conflicting suggestions in the decision-making process.

Health information systems have reached widespread use over the past years with their complexity proportionally increasing. As a matter of fact, small departmental systems have been subsequently replaced with fully implemented hospital information systems or with even larger networks also involving outpatients.[7] Notably, this gradual process required interactions among different types of systems with EHRs from different clinical departments or EHR and other informatics systems (eg, pathology) communicating between each other.

For this to occur, standards are needed to ensure interoperability among systems, ie, to exchange data in a meaningful way, limiting and possibly eliminating any need for manual input. Health informatics standards exist and provide operating solutions to many interoperability needs, although they are still not always adopted by software providers. Furthermore, the accumulation of interconnected data from different sources leads to the availability of large data sets – the so-called *big data* – from which unforeseen discoveries at the time of data collection are possible.[8]

According to the analysis carried out by Schuemie et al.[9], there are three main clusters of research in HIT: the first one deals with health information systems and their application, evaluation, and organization; the second one is focused on how to collect and use medical knowledge such as clinical guidelines, ontologies, databases, and natural language; the third one deals with imaging, signal, and data analysis, including classification techniques, statistical modeling, and microarrays.

All these clusters are relevant in oncology, although the clinical oncologist might be more directly involved as user of information systems and data mining.

The aim of this paper is to offer the readers a nonsystematic review on this key topic providing also an expert's perspective that focuses on the future development of HIT in oncology practice.

Anatomy and Physiology of HIT in Oncology

EHRs are not simply the digital version of the patient's paper chart. They are indeed a sophisticated tool containing important information such as past medical history, diagnosis, medications, treatment plans as well as algorithms that help clinicians to provide appropriate medical care with improved quality of care and safety.

From a clinical point of view, the main components of an EHR are[10] (Figure 1):

- Results reporting information system (RRIS)
- CPOE system
- CDSS: rules, alerts, and workflow tools

The RRIS integrates important patient information such as clinical, laboratory, and radiological test results, aiming to achieve a continuity of care regardless of the disease and patient setting (inpatient, outpatient, acute or chronic disease).

The CPOE system is a tool that allows the creation and transmission of orders throughout a health system.

CDSS consists of alerts and workflow tools that help clinicians to develop a more efficient decision-making process thus improving patient safety.

A thorough analysis supervised by American Society of Clinical Oncology (ASCO) has been carried out to identify the basic requirements of the EHRs for their specific use in oncology (Table 1).[11] The results of this study showed that the main functional requirements expected for an EHR to be efficient include the ability to generate and transmit cancer treatment plans and clinical summaries (Table 2). It should be noted that while ASCO lists all of the above components as functional parts of the EHR, some functions are provided by separate subsystems, able to interact with the main EHR module through specific programming interfaces or up-to-date health informatics standards (Table 3). Besides collecting data, the EHRs automate and streamline the clinician's workflow and may help in the decision-making process. Decision support can be user initiated or system initiated, sometimes referred to also as passive and active CDSS, respectively.[12] In the former case, the user explicitly asks for support and manually provides to the system all the data needed for decision. In the latter, there is a host system integrated with the CDSS (typically, the EHR or the CPOE system) that is able to directly provide the data needed without user intervention. While clinical

Table 1. Functional elements established by ASCO 2008 for oncology-specific EHR.

FUNCTIONAL ELEMENTS IN ONCOLOGY-SPECIFIC EHR
Tumor staging
Multidisciplinary and data-intensive workflow
Chemotherapy dosing and administration
Toxicity assessment and management
Clinical trial and protocol management
Drug inventory management
Survivorship care

Table 2. ASCO's list of clinical data elements that can be part of the EHR in a mandatory or optional way.

CLINICAL DATA
Demographics Name Date of birth Race Ethnicity Contact information
Diagnosis Site Histology/pathology Staging (TNM) Biomarkers (ER, HER2, c-Kit etc)
Prior Treatment
Current plan Performance status Intent/goals of therapy Sites of disease being monitored List of lesions/sites being monitored
Follow-up care

guidelines are usually written in a narrative format for human users, their conversion to computer-interpretable guidelines (CIGs) allows us to develop CDSSs, which in our opinion are more likely to positively affect the clinician behavior. So far, many attempts have been made in order to formalize both structure and content of guidelines making them executable by computers, for any health information system that might benefit of decision support (eg, Arden Syntax, Guide, Asbru, ProForma, and others). Outside the academic environment, however, those approaches have not yet reached a large audience, but research is still very active.[13] In oncology, a valid example is given by the Oncocure project, which translated the protocol for breast cancer treatment into the Asbru language and connected it to the EHR used in an oncologic unit.[14]

In order to achieve a complete implementation of the EHRs, a "semantic interoperability," ie, a commonly agreed language for data exchange, is compulsory. Opposed to syntactic interoperability that deals with the format of data, semantic interoperability is based on the availability of shared representations of knowledge. These representations traditionally assume shape – with limitations – of terminologies and classifications (eg, International classification of diseases [ICD] for describing diseases), but more recently attempts have been made to represent them through the so-called ontologies.

Table 3. ASCO-identified specific functionalities for oncology EHR.

ONCOLOGY SPECIFIC EHR FUNCTIONALITIES
Chemotherapy/Drug Management
Oncology-specific Billing Charge
Calendar/Scheduler
Clinical Trials and Research
Compliance Safeguards

"Ontology" is a term that comes from the philosophical branch and deals with the nature of being. Although there are different definitions for its use in computer science, for our purposes, an ontology can be considered as an explicit representation of a conceptualization; in other words, it logically defines the concepts and relationships that are relevant for modeling a biomedical domain,[15] which are based on logics. Semantic interoperability is also needed for exploiting big data, such as large collections of health-related data created by different systems, which need to be linked together in order to generate new information.[16] Among the key players in health informatics, we can mention HL7 and DICOM, which work in collaboration with companies, academic experts, doctors, and other stakeholders. The two most important standards provided by HL7 are a set for messaging between systems and a complex set of formats and templates for clinical documents known as Clinical Data Architecture (CDA).[17] CDA templates are developed by working groups devoted to specific topics, and they may provide semantic interoperability by linking structure and content to terms coming from terminologies, classifications, and ontologies. Since the last decade, ASCO has been actively participating in the development of CDA templates, including the Breast Cancer Adjuvant Treatment Plan and Summary (http://www.asco.org/quality-guidelines/chemotherapy-treatment-plan-and-summaries). Moreover, Integrating the Healthcare Enterprise (IHE) is a non-profit organization that sponsors an initiative by the healthcare industry to improve the way computer systems share information by defining several standards, such as HL7 and DICOM. The most used classifications are those managed by the World Health Organization (WHO) and in particular ICD, while the reference terminology for an entire EHR is SNOMED-CT.[18] In oncology, a subset of ICD has been expanded in order to provide more details on cancers (ICD-Oncology, www.who.int/classifications/icd/adaptations/oncology). Ontologies have recently flourished for novel areas like genomics, where the Gene Ontology Project [GO][19] logically describes gene products, cellular components, and molecular functions. However, there is a trend toward adaptation of knowledge currently represented with classifications and terminologies in more formal ontological terms.[16] Finally, a worldwide ambitious project originally developed in Europe[20] is currently ongoing and trying to define an overall view on the various components of EHR, including decision support, inside a common framework based on the so-called archetypes.[21] The OpenEHR project aims to identify tools that will help defining standards, interoperable and reusable document templates, data quality controls, and executable guidelines.

The Impact of HIT on the Daily Practice of a Medical Oncologist

Nowadays, the two major issues faced by cancer care are the growing amount of knowledge increasingly oriented toward precision oncology[22] and the challenge of sustainability.[23]

In this scenario, technologic innovations such as database containing information about patients and their disease or real-time decision support systems could improve cancer care (Table 4).

First and foremost, information technology allows us to store, process, and transmit patient's data, ensuring that such data are shared and managed among all providers. Therefore, human errors can be minimized and patient safety improved by implementing adherence to evidence-based medicine. This applies mainly to chemotherapy prescriptions and their appropriateness, as they are often prone to errors because of their complexity.[24] Among the various interventions that could be performed to improve the safety of patients receiving chemotherapy, the CPOE system is supported by a fairly high evidence,[25] although a margin of error related to the training of the physician or incomplete implementation of the system is still possible.[26] In order to ensure appropriateness of chemotherapy prescriptions, some accessible decision-making tools are available online such as Adjuvant! Online (www.adjuvantonline.com) and the Cancer Profiler Tool provided by LiveSTRONG and NexCURA (www.nexprofiler.nexcura.com): based on clinical and biological characteristics of the disease, they can actually suggest tailored treatment options. In addition, the adoption of EHRs allows us to adequately register and store medical records as well as chemotherapy order documentation, improving user satisfaction.[27] CPOE and CDSS not only play a crucial role in the uploading, prescription, and management of standardized cancer treatment regimens, but they are also useful in performing management tasks such as appointment booking, patients' data sharing, and toxicity monitoring.[28] Modern software systems are able to tailor treatments and to provide support for staging. CDSS can also be exploited by multidisciplinary teams for data collection and in the evidence-based decision-making process.[29] CDSS also supports physicians in monitoring and managing drug-related adverse events, and it may reduce avoidable costs.[30] Although the CDSS improves drug prescription's quality, alerts for drug interaction or drug/dose-related toxicities may be sometimes redundant or even inappropriate. However, the refinement and implementation of the system might increase its specificity and appropriateness.[31]

In order to ensure an adequate adherence of chemotherapy regimens to the latest guidelines, HIT should be continuously updated and a careful supervision is mandatory.[32] While waiting for an informatics system quality validation (such as CancerLinQ – see below), some interesting solutions were applied in oncology practice. One of these solutions was the creation of a group committed to the systematic revision of chemotherapy dictionaries to ensure their adherence to the guidelines.[33–35]

Another important use of HIT is data extraction from electronic resources, which provides input to clinical and epidemiological research. Modern information technology not only supports randomized controlled trials, but it also demonstrates that the long-promised benefits of the EHRs for research are becoming a reality through different platforms and projects.[36] A wide variety of examples explains this potential role of HIT.[37–40]

Another important task of HIT is the management of cancer care. If validated tools allow reducing human errors and help physicians to monitor patient safety, HIT can guarantee a better management of oncology services, saving time and costs. For example, a centralized unit of drug processing, combined with a CPOE system, allows us to minimize drugs waste, with substantial savings.[41] Moreover, CPOE implementation leads to better allocation of pharmacists' time with an increased number of order actions processed per hour, thus improving workflow productivity.[42] Data extraction, even in this case, is very useful to analyze resource allocation and to assess the efficiency of cancer units and physicians. Human resources requirements can be estimated from the integration and the analysis of extracted data, allowing an accurate prediction of staff costs.[43] Furthermore, analysis of the collected data enables us to monitor unplanned visits and to identify inappropriate hospital admissions or avoidable interferences with work plan.[44]

Compared to a paper-based system, both the CPOE system and CDSS clearly involve some extra costs, which, however, should be considered acceptable whenever they help prevent a medical error or a serious adverse event.[45]

Along with a more widespread and appropriate use of HIT, an advanced implementation of its single components such as CPOE and CDSS is also expected in the near future. However, the efficacy of EHR in terms of clinical impact has not been fully demonstrated yet.[46–48] Future research is needed to identify new effective solutions for CDSS and CPOE implementation.

Finally, web-enabled mobile devices or free internet access would facilitate communication between physicians and improve patient–physician relationships. Based on these premises, laptops, tablets, or online platforms available for downloading patient-reported outcomes (PROs) will play an important role in the near future. Such devices will ensure continuity of care and possibly a home-based, real-time management of symptoms.[49–51] Internet can be useful to patients for sharing common experiences, improving communication with the physician, and retrieving helpful information about novel cancer treatments.[52] Ultimately, this means that patients need access to trustworthy and accurate internet-based information.[53]

Table 4. Main HIT components and benefit of its adoption.

KEY POINTS
Clinical Decision Support
Clinical Physician Order Entry
Clinical risk management
Documentation management

Websites available for patients' consultation, supervised or sponsored by reliable associations or organizations, may ensure a direct medical information source (www.acor.org; www.ecpc-online.org; www.aimac.it, and many others).

Therefore, HIT plays a relevant role in modern cancer care enhancing clinical practice and quality of care, improving resource allocation, and empowering cancer patients to become more active. The ability of data mining opens a new compelling world for data representation and management in clinical trials through information technology platforms for translational and comparative effectiveness research and implementation of privacy control.[54]

Which are the Main Obstacles to HIT Adoption?

HIT adoption may help oncologists to tailor treatments and to ensure the most effective care, including screening, active therapies, surveillance, or follow-up, with the fewest risks and costs.[55,56] Trusting in these practice-changing advancements is of paramount importance to patients, clinicians, researchers, and policy makers, particularly nowadays when we are on the threshold of a global medical informatics transformation. The goal of this progress is to make the healthcare system more comprehensive, accessible, and affordable. However, an impartial and fair benefit-to-risk evaluation of HIT adoption is mandatory, even when translating evidence of efficacy into estimates of effectiveness may be potentially inconvenient.

Noticeably, the diffusion of HIT has substantially increased over the last decade,[57] leading to improved patient safety and healthcare efficiency, reduced healthcare costs, and significant savings.[58] Nevertheless, HIT has been often presented as a simple replacement of paper records instead of being proposed, embraced, and adopted as a ground-breaking novelty. Moreover, the overall HIT value has not been completely confirmed because of its relatively recent introduction in cancer clinical practice.

The level of adoption and diffusion of HIT in the healthcare system is still insufficient. As a matter of fact, an inadequate engagement of oncologists with HIT has already been reported, and concerns regarding safety, security, and privacy[59] or quality of delivered care have been described.[60] Similarly, different reasons may account for the low rate of HIT implementation, including the complexity of the systems, the high costs, the massive time commitment, and its limits A non-systematic review including 27 relevant papers has recently analyzed the major key barriers perceived by physicians to the adoption of EHR.[61]

Moreover, it has not been established yet whether HIT is time-saving: initial teaching as well as repeated training sessions are necessary to become confident with the system, and acquiring specific skills requires an even greater time commitment. During these sessions, medical productivity may decrease significantly.[62] In a recent study conducted in 215 hospitals in Japan after the introduction of complex informatics systems, no difference was observed in the time required to produce medical records and the overall time for each medical care.[63] The time needed to set and implement the computerized healthcare system depends on the size and complexity of the department/hospital, and periods as long as 7 years have been reported to reach a complete installation of an EHR.[64] Interoperability may also be very complicated. Although a knowledge-based taxonomy is crucial to create exchangeable files,[65] it is not unusual to find that data stored in different departments of the same hospital do not share a common lexicon and eventually may not work together properly.[66]

Patients' data or test results collected in different hospitals are often electronically stored in different and incommunicable formats, creating the so-called "information silos," large amount of data collected but not exploited.[66]

Not surprisingly, however, physicians are completely blinded to external data, and the patient is forced to repeat laboratory tests or exams locally. Moreover, many oncologists may not have adequate computer skills or complain about a lack of informal help from colleagues or formal technical support. Because many medical schools do not engage HIT or train their students for its use, the integrated system may be later too complex for them to use. This may lead to an increasing workload and stress despite the Association of American Medical Colleges (AAMC) has released guidelines for medical informatics education since the mid-1990s[67] and the International Medical Informatics Association (IMIA)[68] maintains updated education guidelines. Not surprisingly, however, the same system may be slow and unrewarding for other experienced users, who are very familiar with speedy, multifaceted computerized networks, with broadband wireless connections.

Although the introduction of CPOE systems generally reduces chemotherapy medication errors, specific types of errors may also arise or increase,[69] and unexpected safety risks have emerged with the use of electronic medical records. Some HIT technologies may even introduce new types of errors.[70] The repeated use of template notes, for instance, may generate copy-and-paste errors.[71,72] This acknowledgment has spurred a three-step plan to mitigate preventable risks that may hamper endeavors to create a safer EHR-enabled healthcare system.

Money investment is also a big issue, and systems have been developed to evaluate and verify the cost effectiveness of HIT adoption.[73] The continuous need for standardization, implementation, and interoperability is costly, and it may also limit HIT clinical application, especially in those countries with limited economic resources.

In summary, despite the positive effects of adopting HIT in oncology practice, the diffusion of such systems is still low, and this is mainly because of the fact that they can affect clinical practice both positively and negatively with respect to time, workload, and productivity.[69] To overcome these limits, physicians should first recognize and categorize the hurdles to analyze them accurately and then collaborate with medical informatics to find the most adequate solutions.[74]

Perspective: What does the Future Hold?

The 2013 Institute of Medicine (IOM) report pointed out the U.S. cancer care crisis and made bold recommendations to ensure high-quality care. Several of these recommendations strongly emphasize the importance of HIT, and we can easily guess the role expected from information technology tools in the near future. Accordingly, in order to benefit from the increasing computerization of health systems, health care policies should promote initiatives toward new perspectives, concerning quality of care improvement, research into healthcare outcomes of cancer patients and molecular biology, and enhancing patient-centered care[55] (Table 5).

Quality of cancer care. Two of the 2013 IOM recommendations for cancer care discuss the role of HIT in supporting quality improvement programs: "Develop a healthcare information technology system for cancer that enables real-time analysis of data from cancer patients in a variety of care settings" and "Develop a national quality reporting program for cancer care as a part of a learning health care system."[75] So far, few studies have assessed the optimal methods for capturing and reporting clinical information from medical records necessary to support quality improvement projects. Moreover, many quality measurement systems are still evolving from paper-based charts to electronic platform. National Cancer Institute (NCI) Community Cancer Centers Program suggests that the lack of a functioning EHR may limit the participation in quality improvement projects, as it is the Quality Oncology Practice Initiative by ASCO (QOPI). Moreover, several ongoing quality of care initiatives are characterized by passive quality measurement systems, where performance data are collected once treatment has already been delivered. Feedback lags range from several months for QOPI to almost 2 years for measurement systems that rely on cancer registries as a source of data collection and reporting.[21] Nevertheless, in order to improve clinical efficacy, evidence-based medicine needs to be associated with evidence-based management. The Commission on Cancer recently launched a pilot program to test a real-time reporting and tracking system of breast and colorectal cancer patients as part of a Rapid Quality Reporting System (RQRS) project.[76]

Data mining and research. Another 2013 IOM recommendation ("Expand the depth of data collected in cancer research through a common set of data elements that capture patient reported outcome, relevant patient characteristic, and health behaviors") is focused on how a better collection of clinical data could generate accurate insights.[77] Big data hugely affected many scientific sectors; likewise, it is expected that they will rapidly transform health care too.[78] Big data sets can be created using patient information, and may be exploited to inform us on the reality of cancer patients. This model, called Rapid Learning Healthcare System (RLS),[79] has been adopted by ASCO Board of Directors, which approved and supported the creation of ASCO's CancerLinQ, the first RLS in medicine.

CancerLinQ (Fig. 2) is an information system that allows a real-time interaction with the EHRs of oncologists, drawing in data and providing clinical decision support, analytic reports, and a new generation of knowledge products.[80] According to ASCO President Clifford A. Hudis, CancerLinQ "can be a powerful complement that may save time and money for society as we develop new and better treatment."[81]

Data warehouse is indeed a huge source of information, which enables us to increase medical knowledge, to facilitate the interpretation of complex data, and to optimize oncology costs. In such a scenario, data mining becomes fundamental in order to identify compelling and actionable patterns hidden within large amounts of data.[82] At the Memorial Sloan Kettering Cancer Center, IBM Watson™ is currently tested as a diagnosis and treatment advisory system, which allows us to compare patient's medical information with published research, journal articles, and National Comprehensive Cancer Network (NCCN) guidelines. The goal is to help oncologists, providing them with tailored and appropriate recommendations (Memorial Sloan Kettering Cancer Center New York, NY, www.mskcc.org). This could be a revolutionary system that would process information similarly to a human being, understand natural language, generate evidence-based hypotheses, and provide knowledge.[83]

Another development area for data mining is molecular biology. Molecular data represent in fact a new critical class of cancer data, which is expected to play an increasingly important role in tailoring cancer treatment. Panomic (genomics, transcriptomics, proteomics, and metabolomics) data are far more complex than previous type of laboratory data and lack well-established standards for reporting. This raises new major challenges for digital representation of cancer data in HIT systems.[84] In view of the importance of cancer genomic

Table 5. Future developments of HIT.

FUTURE POINTS
Rapid Learning Healthcare system
Rapid Quality Reporting System
Data mining for big data
Patient Reported Outcomes

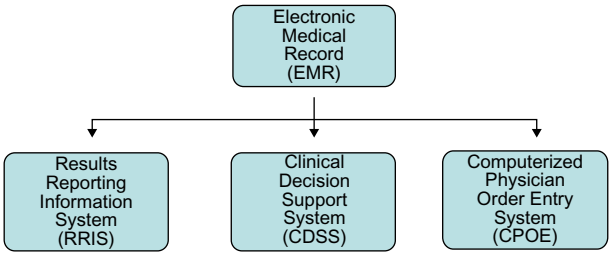

Figure 1. Medical record anatomy.

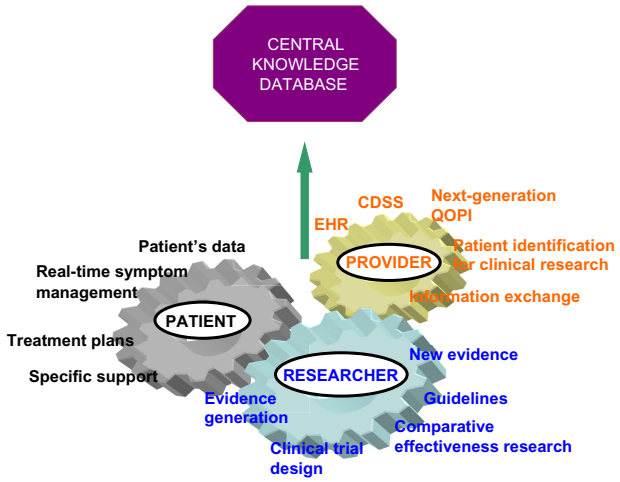

Figure 2. CancerLinQ system: all patient data were collected, analyzed, and assembled in a central knowledge database. We can use a large organized folder to upload clinical data stored in EHRs; to aggregate information from EHRs, new clinical trials, and guidelines; to identify trends and associations between variables and parameters, in order to generate new hypotheses; to translate and verify those hypotheses in patients' real-world setting; to exploit the subsequent conclusions and form a continuous cycle of learning.

profiling, database interaction and accessibility to large sets of real-time updated genomic information may refine clinical decisions, treatment options, and personalized care. Interactive Supercomputing (ISC) software is an exhaustive platform that uses popular tools like Python or MATLAB but is simultaneously and interactively launched on parallel high performance computers (HPCs). The system enables us to create algorithms and models that can dramatically accelerate cancer genomic profiling, spurring new hypotheses about genetic risk factors for cancer, promoting new tests to detect tumors, identifying genetic changes caused by novel therapies (www.interactivesupercomputing.com). NCI uses ISC software (Star-P) and associates a genomic array with a database of 100,000 probe pieces of a gene searching specific DNA components. Analysis results can confirm and improve knowledge about cancer and its genetic features. Similar software (Magnus Opus) may help physicians to discriminate cancers of unknown primary origin or equivocal pathological samples.[85]

Enhancing patient-centered care. Patient-centered care focuses on the preferences, needs, and overall experience of cancer patients. Interest has grown in incorporating patient perspective into evaluation of the clinical benefit of therapies and the patient care experience.[23] PROs include information reflecting the health-related quality of life that the patients experience during the disease course. Patient-reported data may provide valuable information for oncology quality measurements, and this is another aspect of HIT waiting to be developed and exploited.[86] In particular, a cancer monitoring and reporting system for outpatients is an attractive field, and telemedicine may allow oncologists to receive real-time information about toxicities or symptoms that could be managed at home. Mobile technology may help physicians to constantly monitor patients between two visits, to give advice or recommendations, and to reduce the anxiety of both patients and their families. With a simple web application, eg, PaTOS,[87] patients can fill in a daily toxicity report, using an interface to grade the severity of symptoms, and can send a short message to the physician. On the other side, physicians can assess toxicities and insert or update database information. A recent study has tested a tablet-based health management aid (My Journey Compass) for breast cancer patients, which resulted useful in supporting patients and their families (PDF resources, several applications, entertainments, bookmarks, and cancer navigation resources).[88] Other researchers have assessed mobile devices to help cancer patients and to allow them getting the latest clinical information.[89–91] In a recent review of Electronic Patient-Reported Outcomes Systems in Cancer Clinical Care, 33 unique systems were identified, which lack uniformity in their focus and features.[92] In order to be useful in cancer care, HIT is required to continuously capture patients' needs throughout the whole clinical pathway. Although research on these applications in clinical practice is a recent development, we believe that there is a strong demand for new evidence on this issue.

Conclusions

At present, HIT is a useful tool for oncologists in everyday practice though its potential is not fully exploited yet. Despite improving the quality of clinical documentation, enhancing doctor–patient relationship, and supporting health services management, the impact of HIT on patient care and outcome is still debated. In line with this, a systematic review by Garg et al demonstrated that CDSS improves practitioner performance, but the effect on patient outcomes remains understudied.[93] Moreover, HIT has not been able so far to completely fulfill a number of other needs, because of the many difficulties encountered once it has been applied within the healthcare systems, including cancer care.

This conundrum represents an opportunity for both clinicians and researchers in terms of quality of care improvement, CDSSs, data mining, and patient-centered care. Major scientific societies strongly support the need to narrow the gap between current clinical practice and the international guidelines recommendations. In order to empower the implementation of HIT in oncology practice, a full involvement of medical oncologists and their commitment are mandatory. Finally, we hope that research on clinical and managerial applications of HIT in oncology will soon have increasing relevance. For this to occur, we reckon that a stronger level of evidence of the benefits provided by HIT is needed.

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Author Contributions

Conceived and designed the experiments: GF. Analyzed the data: GF, MM, AF, KR, GA, VDM. Wrote the first draft of the manuscript: GF, MM, AF, KR, GA, VDM. Contributed to the writing of the manuscript: GF, MM, AF, KR, GA, VDM. Agree with manuscript results and conclusions: GF, MM, AF, KR, GA, VDM. Jointly developed the structure and arguments for the paper: GF, MM, AF, KR, GA, VDM. Made critical revisions and approved final version: GF, MM, AF, KR, GA, VDM. All authors reviewed and approved of the final manuscript.

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