Introduction to Health Information Technologies

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Abstract. Health information technologies have the potential to advance healthcare delivery and assist patients and providers in achieving better outcomes. While development and adoption of electronic health records (EHR) already have reached high levels, health information exchange is still a challenge. This paper presents some of the basic terms and concepts in the domain. The lack of standards and security concerns are discussed as the main technical barriers for reaching integration and interoperability. Mobile technologies are described as a new source of data and promising tool for providing personalized care. Latest trends and solutions are presented, as well as the need of advancement.

1. Health Information Technology (HIT)

1.1. Introduction and definitions

The term "health information technology" refers to the electronic systems that create, transmit, store and manage individuals' health data [1]. Adoption of electronic records and digital systems in the area of health care delivery occurred later compared to other industries. The current use of health information technologies is widespread among providers, patients and other stakeholders. That makes possible aggregation of data of millions patients, their analysis in order to gain new knowledge, and using it to make care delivery better quality and more efficient at a lower cost. According to another definition [2], health information technology is defined as any clinical information technology system that captures patient data in an electronic record.

Electronic records can be divided into two groups: The first group includes those records created and utilized by licensed professionals (health providers, physicians, etc). They are considered institution-centered records, this kind of records are Electronic Medical Records (EMR) and Electronic Health Records (EHR). The second group includes Personal Health Records (PHR), which are created and managed by patients. The records in this group are considered patient-centered [3].

1.2. Electronic medical records

An electronic record of health-related information on an individual, that can be created, gathered, managed, and consulted by authorized clinicians and staff within one health care organization [4]. Garets and Davis in [3] define EMR as an application environment composed of clinical data repository, clinical decision support, controlled medical vocabulary, order entry, computerized provider order entry, pharmacy, and clinical documentation applications. That environment is used by healthcare practitioners to document, monitor, and manage health care delivery within a care delivery organization (CDO). EMR contains medical and treatment history of the patients in one CDO. This is the reason it is considered an internal, organizational system.

1.3. Electronic health records

An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be created, managed, and consulted by authorized...
clinicians and staff across more than one health care organization [4]. EHR is a subset of each care delivery organization’s EMR. It is owned by the patient and has patient input and access that includes episodes of care across multiple CDOs within a community, region, country or several countries [3]. EHR summaries patient’s health data from multiple sources into one record (e.g., electronic prescription, emergency information, medical tests orders, decision-support systems, digital images, and telemedicine) and this makes it inter-organizational system. Making providers accessible to patient health data, EHR improves clinical decision support and achieves care coordination between different providers, which leads to fewer medical errors and duplicated lab tests. The effect of reducing errors is prominent in using electronic prescriptions. A study from 2010 shows that medication errors decreased nearly sevenfold, from 42.5 per 100 prescriptions (95% confidence interval (CI), 36.7-49.3) to 6.6 per 100 (95% CI, 5.1-8.3) prescriptions within a year of adopting e-prescribing [5].

1.4. Personal health record
PHR is an individual’s electronic record of health-related information, that can be obtained from multiple sources. It is managed, shared and controlled by the individual [4]. PHR can include clinical health records shared by EHR/EMR systems or personal’s daily activity data gathered from sensors, mobile or wearable devices. The main benefit of PHR is to leverage patient’s engagement, involvement and interest, that has the potential to increase the effectiveness of care delivery and therapeutic processes.

2. Health Information Exchange (HIE)
Health information exchange (HIE) includes a variety of technologies to improve the provider’s access to patient information collected and maintained by other organizations [4]. By providing access to timely and comprehensive patient information, HIE is a solution intended to address the threats to quality, safety, and efficiency caused by inaccessible, incomplete or missing information at the point of care. A patient survey from 2016 shows that 19% of patients in U.S. and 24% in France say that their medical records or test results had not been available at the time of an appointment or that duplicate tests had been ordered in the past two years [6].

HIE is essential for care coordination especially in chronic diseases management. According to the World Health Organization, 60% of all deaths in our days are due to chronic diseases [7]. Chronic diseases that are not well controlled cause other chronic diseases and complications. They cause 70% of all deaths and account for 78% of the healthcare expenses in the United States [8]. As a result, those patients yearly encounter multiple specialists, which need to coordinate the care among them. Using paper records is not efficient, it is error prone and often providers need to make decisions without the needed medical information as the survey shows. HIE has the potential to improve care coordination and reduce costs through avoidance of unnecessary testing, duplicate medications and procedures.

Sharing data with patients improves patient engagement in their own care. Aggregated health and behavioral data are suitable for big data analysis and medical research.

2.1. Privacy and security
Health information exchange requires core technologies to assure privacy, security and trust. Privacy means that only individuals or entities authorized by the patient may access their data. Security is preventing access to data by unauthorized entities. Trust ensures the identity of entities with which the data is being shared.

Since health data protection has been a serious concern for users for a long time, governments put in place laws and regulations to protect personal data. In USA this is Health Insurance Portability and Accountability Act of 1996 (HIPAA) [9]. HIPAA defines administrative, organizational and technical requirements for storing and transmitting personal health information. The General Data Protection Regulation (GDPR) [10] was enacted by the European Union in 2018 to establish personal data protection regulations. It is a comprehensive set of guidelines that acknowledges that sensitive data such health, biometrics or genetics require highest level of protection.

Technical safeguards for achieving HIPAA and GDPR compliant architecture include: setting up private cloud infrastructure, data encryption at rest (AES-256), data encryption at transit (HTTPS, SSL/TLS), data de-identification, data backups, implementation of auditing tools and other.

2.2. Interoperability
The major technical issue for HIE is interoperability. Interoperability is the ability of different information systems, devices or applications to connect in a coordinated manner, within and across organizational boundaries to access, exchange and cooperatively use data amongst stakeholders, with the goal of optimizing the health of individuals and populations [11].

**Structural interoperability** defines the structure or format of data exchange. It ensures that the clinical or operational purpose and meaning of the data is preserved and unaltered. Structural interoperability defines the syntax of data exchange. It ensures that data exchanges between information technology systems can be interpreted at the data field level.

**Semantic interoperability** is the ability of two or more systems to exchange information and to interpret and use that information. Semantic interoperability requires both structuring of the data exchange and codification of the data, including standard, publicly available vocabulary, so that the receiving information management systems can interpret the data [12][11]. Achieving semantic interoperability is still an ongoing challenge.

In the current situation there are multitude of EHR systems, mobile health applications, clinical decision support systems, etc., that were not designed to record data in a standard format or to share data with other systems or systemizing common protocols. Different vendors distribute EHR systems with different data models (e.g., HL7 v2, RIM v3, FHIR, CDA, OpenEHR, ISO/IEEE 11073, CEN EN13606, and DICOM). They use different encoding terminologies (e.g., SNOMED CT, LOINC, UMLS, RxNorm, ICD, MeSH), different datatypes, different schemas, different vendors, different formats, etc.

An example illustrating the lack of semantic interoperability is the need to integrate data from mobile health applications with EHRs and clinical decision support systems (CDSS). An EHR contains comprehensive patient medical and administrative data. Mobile health applications provide real-time patient generated data, captured from wearables, sensors, devices (such as blood glucose meters, blood pressure meters, etc.) or manually entered by the patient. The collected data can be supervised and studied by physicians. CDSS assists physicians with personalized decision support based on patient data. Integrating all provides end-to-end comprehensive care that supports patients and providers in achieving better outcomes. In addition, these data can be integrated with other patient data and used by big data and machine learning tools to discover model patterns. Linking all of these heterogeneous systems requires solving the problem of semantic interoperability, because currently there is no universal standard or terminology to ensure this [15].

Different data and interoperability standards have been developed for achieving health information exchange. Some of the most popular currently in use are:

2.3. Data standards

*International Classification of Diseases (ICD)* is a coding system of diseases and signs, symptoms, abnormal findings, complaints, social circumstances and external causes of injury or diseases, as classified by the World Health Organization (WHO). It is used to classify diseases and other health problems recorded on many types of health and vital records including death certificates and health records. Current revision of ICD is 11.

*Logical Observation Identifiers Names and Codes (LOINC)* is a universal code system for identifying laboratory and clinical observations. LOINC has standardized terms for all kinds of observations and measurements that enable exchange and aggregation of electronic health data from many independent systems.

*Systematized Nomenclature for Medicine (SNOMED)* is a universal standard for identifying laboratory observations and clinical results. It includes not just medical and laboratory code names, but also nursing diagnosis, nursing interventions, outcomes classification, and patient care data set.

*RxNorm* provides normalized names for clinical drugs and links its names to many of the drug vocabularies commonly used in pharmacy management and drug interaction software.

**Digital Imaging and Communications in Medicine (DICOM)** is the international standard to transmit, store, retrieve, print, process, and display medical imaging information.

2.4. Interoperability standards

Interoperability standards define the way health data is packaged, transported and shared.

*Health Level Seven (HL7)* is a not-for-profit, ANSI-accredited standards developing organization dedicated to providing a comprehensive framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services [16]. *HL7's Version 2.x (V2)* messaging standard is one of the most widely implemented standard, released in 1987. The standard is
based on EDI/X12 technology. However, V2 requires significant site customization, which leads to semantic inconsistencies across implementations [17]. The HL7 Reference Implementation Model (RIM) defines the semantics of a common set of administrative, financial and clinical concepts in order to foster interoperability. It consists of five abstract concepts: act, relationship, participation, roles and entities. RIM offers a model for expressing clinical statements in a semantically consistent way, but implementation complexity leads to incompatible documents [18]. The Clinical Document Architecture (CDA) defines HL7 Version3 RIM-based documents that are assembled from elements, including administrative and clinical data, for particular purposes [19]. The current version of CDA is called Consolidated CDA(CCDA). CCDA documents are assembled from templates of XML components. The unsuccessful of HL7 v2 and v3 standards to ensure semantically consistent approach for sharing granular clinical data forces the development of Fast Healthcare Interoperability Resources (FHIR). FHIR represents clinical data as resources that are subset of RIM. Each resource is an expression of meaning stated in terms of well-defined fields and data types. Data are queried through RESTful API and serialized in XML or JSON formats. FHIR’s clinical resource definitions are concepts such as Patient, MedicationPrescription, Observation, and Device. These resources constitute a graph of clinical data by explicit inter-resource references. For example, a MedicationPrescription resource explicitly references its prescriber (a FHIR Practitioner), its patient (a FHIR Patient), and the drug prescribed (a FHIR Medication). FHIR does not include detailed models for every aspect of a clinical record, but provides a built-in extensibility mechanism to enrich existing resource definitions. FHIR resource definitions do not directly promise semantically consistent data out-of-the-box. Instead, to serve distinct contexts (e.g., EHRs, public health reporting workflows, wearable devices), FHIR resources might use specific data payloads with distinct terminologies. Semantic consistency relies on an abstraction layer called FHIR profiles that constrain and extend resource definitions in particular contexts [20][18].

**SMART on FHIR** is a set of open specifications aimed to integrate third party apps with EHRs and other health information systems. SMART acronym stands for “Substitutable Medical Apps, Reusable Technology” [21]. It is based on FHIR models and API, including authorization (OAuth2), authentication (OpenID Connect) and UI integration. A SMART on a FHIR app (application, service) runs against a SMART on a FHIR system, extending its functionality through the use of clinical and contextual data [18].

The openEHR approach for achieving interoperability is based on multi-level, single source modeling within a service-oriented software architecture. The openEHR design specification is based on reference model (RM), archetypes and templates. The RM defines the logical structures of EHR and demographic data. All EHR data in any openEHR system obey this RM. Archetypes are data points or data groups, independent of particular use. These data-points and data-groups are assembled into context-specific data sets called templates. The international library of openEHR archetypes (CKM) currently contains about 500 archetypes, or 6,500 data points. The benefits of this approach according to [22] are systems and tools built around the same data model which solve the problem with semantic interoperability.

Another approach for HIE is Direct Project created in 2010 to specify a simple and secure way to send authenticated, encrypted health information directly to known and trusted recipients using secure email. DirectTrust is a non-profit association of health care providers that authenticate the identity of the participants and issues email addresses. To assure secure transport via email Direct uses Simple Mail Transfer Protocol (SMTP) with special Direct email addresses, associated with X.509 certificates. It uses Secure/Multipurpose Internet Mail Extensions (S/MIME), a public key standard for encrypting email attachments that can be in any format (image, ODF, HL7 CCDA document, etc.). The system supports both provider-to-provider and bi-directional patient-provider exchange[23][12].

**Blockchain** is the newest technology addressing health information exchange issues. In [24], John D. Halamka discusses the potential of blockchain to transform electronic health records. Azaria et al. [25][26] provides a proof-of-concept that uses blockchain as a mediator to health information, called MedRec. For MedRec, the block content represents data ownership and viewership permissions shared by members of a private peer-to-peer network. The prototype uses smart contracts on an Ethereum blockchain to log patient-provider relationships that associate a medical record with viewing permissions and data retrieval instructions (essentially data pointers) for execution on external databases. Health insurance companies are running pilot project to use blockchain as a way to manage provider’s data inputs [27]. In [12] Mark Braunstein mentioned a possible use of blockchain to create a uniform patient ID and storing patients’ specific permissions for data sharing.

3. Mobile health technologies
I already mentioned the growing prevalence of chronic diseases nowadays and how they are the greatest cause of raising healthcare costs. Poor lifestyle choices as smoking, overuse of alcohol, poor diet, lack of physical activity are the main reasons for development of chronic diseases, including obesity, type 2 diabetes mellitus, hypertension, cardiovascular disease and other. Behavior change and continuous monitoring are the key drivers for positive outcome. The daily routines made by patients with chronic diseases (e.g. tracking vital signs as blood glucose, blood pressure, weight, pulse; tracking physical activity; medications adherence; keeping a healthy diet) are very important for disease management.

Mobile health technologies (mHealth) are capable to assist patients and providers to perform chronic disease management in a dynamic and more effective manner. The World Health Organization (WHO) says that “The use of mobile and wireless technologies to support the achievement of health objectives (mHealth) has the potential to transform the face of health service delivery across the globe. A powerful combination of factors is driving this change. These include rapid advances in mobile technologies and applications, a rise in new opportunities for the integration of mobile health into existing eHealth services, and the continued growth in coverage of mobile cellular networks.”[28].

mHealth facilitates patient-provider connection, creating a smart environment and engaging the patients into their own care. Data from mobile applications, wearable devices and sensors are used by health care teams to make accurate decisions and provide the most adequate treatment according to the patient’s state.

A good example of application of mHealth technologies are the AliveCor’s devices used to screen for Atrial fibrillation (AF) [29]. AF is the most common cardiac arrhythmia affecting millions of peoples and an important risk factor for stroke. Early diagnosing of AF for patients in risk can prevent the occurrence of stroke. AliveCor’s Kardia Mobile device detects electrocardiogram (ECG) heart trace and sends it to a mobile smartphone app using inaudible ultrasonic signals and phone’s microphone.

AliveCor’s KardiaBand is a special band for Apple watch. The SmartRythm software takes data from the watch’s heart rate sensor and accelerometer and uses neural network to recognize rates that may indicate atrial fibrillation. Then the system notifies the user to take an ECG using the band. The user sees the ECG on the watch and may send it to their physician. There are studies that reports the positive results of AF screening using the devices [30].

Another area where mobile technologies already have taken significant place is diabetes management. Regarding diabetes guidelines physical activity, healthy eating, medication adherence (e.g., insulin dosing), monitoring (e.g., blood glucose and weight tracking), education, and problem solving are the six essential behaviors for improving diabetes self-management [15]. There are multitude of applications, helping patients in these routines. Usually they come integrated with wireless or Bluetooth-compatible devices, such as blood glucose meters, continuous glucose monitoring devices, insulin dosing devices, etc.

A new approach for diabetes management emerged in 2015 as a research collaboration between Emory University/Healthcare, the Atlanta VA Medical Center, Georgia Tech and Grady Memorial Hospital and later released as a remote patient monitoring system called Diasyst [31]. Diasyst is dealing with the problem of clinical inertia, defined as a failure of health care providers to initiate or intensify therapy when indicated [32]. The cloud-based system incorporates 4 strategies for improving glycemic control: personalized management based on individual patients’ clinical markers and medications; facilitated transmission of patient data to clinicians; patient education and engagement; implementation of diabetes management guidelines and algorithms. Patient A1C levels are managed by personalized plan change recommendations based on patient real time data. The early results published in [33] show improving of A1C levels within a month of use with little hypoglycemia occurrence.

An article from 2018 reviewed the current state of the art in mobile health in general, and concentrated on the diabetes domain in particular. The study reviews mobile health from various points of view, including relationships between mobile health and EHRs, semantic interoperability, the clinical decision support systems, the wireless body area networks, the IoT, cloud computing, and big data analytics. At the end authors say “According to the results, mobile health applications still have plenty of room for improvement in order to take full advantage of unique mobile platform features and to truly fulfill their potential.”[15]

4. Conclusion
This paper presented the basic concepts and challenges in the area of health information technologies in general. The current situation in the domain is the presence of multiple EMR/EHR systems and
tools, adopted by providers and patients, that cannot communicate and share data among them. The key challenges now are health information exchange and receiving useful information of storing and analyzing vast quantities of digital health data. Interoperability is the major issue in order to achieve HIE. That need is especially important in the present state of increasing number of chronic diseases worldwide. The lack of standards and security concerns are determined as the main technical barriers to HIE. Organizations as HL7 have facilitated development of standards but widespread interoperability has not been achieved yet. Except data from traditional medical records, new sources of health data have appeared with the spread of mobile and wearable devices. Access to medical and behavioral data facilitates personalized care but still greater level of enhancement is needed.

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