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Applications of Automated Identification Technology in EHR/EMR

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ABSTRACT

Although both the electronic health record (EHR) and the electronic medical record (EMR) store an individual's computerized health information and the terminologies are often used interchangeably, there are some differences between them. Three primary approaches in Automated Identification Technology (AIT) are barcoding, radio frequency identification (RFID), and biometrics. In this paper, technology intelligence, progress, limitations, and challenges of EHR/EMR are introduced. The applications and challenges of barcoding, RFID, and biometrics in EHR/EMR are presented respectively.

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1. INTRODUCTION

1.1. Concepts of EHR/EMR

An electronic health record (EHR) is a patient record that exists in a computer system specifically designed to support care providers through accessibility to complete and accurate patient data, medical alerts, reminders, clinical decision support systems, links to medical knowledge and other aids [1]. The EHR includes information on patient identification information, history data, legal permissions, observations, temperature, blood pressure, X-rays, laboratory tests, treatments, therapies, allergies, diagnosis and diagnostic imaging reports, medicine scheme, patient notes (nursing notes, progress notes, therapist notes), and so on [2] [3]. Some countries have planned widespread implementation of EHRs and some healthcare systems have already developed and embedded EHRs in individual hospitals or in localized regions [4].

An electronic medical record (EMR) is the electronic record of health-related information on an individual that is created, gathered, managed, and consulted by licensed clinicians and staff from a single organization who are involved in the individual's health and care [5]. An EMR can contain a patient's personal medical history, lab results or other test results, physician diagnoses, allergy information, and other medical information and financial information [6].

The terms EHR and EMR are often used interchangeably although there are differences between them. The EMR can be, for example, the patient record created in clinics, hospitals, and ambulatory environments. On the other hand, the EMR is a data source for the EHR; however, the EHR includes a more comprehensive patient history. Unlike the EMR, some information of the EHR is allowed to move with a patient to other health care providers, specialists, hospitals, and nursing homes.

1.2. Functionalities, Criteria, and Advantages of EHR/EMR

Storing and sharing patient information electronically can improve legibility and enhanced access to medical records, advance the quality and safety of medical services, reduce healthcare costs, and expand population-level health [7]. Electronic records have numerous benefits for the clinician in patient consultation, accurate recording of data, and medical audit and statistical analysis. Through sharing patient data between medical staff, there is an increase in service delivery between different locations [8]. The transmission of measurement data through wireless technologies to the treating physician allows for the physicians to remotely monitor and follow-up on patients [9].

The EHR presents numerous advantages over traditional paper records, including a more complete and organized record, efficiency in navigating the record, communication ease between providers, and strong modules for scheduling and medical billing. In addition, the EHR offers benefits such as clarity in reading other clinicians' notes and labs; keep more informed and access information quicker [10]. The EHR also enables the efficient communication of medical information, eliminates redundant medication order transcription, eliminates medication administration records recopying, and thus reducing costs and administrative overheads. Furthermore, the EHR is geared to provide authorized healthcare professionals with legitimate access to a wealth of historical medical data at one access point [11] [12].

Based on the personal health data of the patient, reminders can be triggered or preventative action can be proposed to the patient if so recommended by the corresponding care guidelines. Physician-reported EHR data also holds great promise for the pharmaceutical industry. The EHR is helpful for better drug delivery. There is high potential for the use of EHR data in early stages of the pharmaceutical value chain, i.e. the discovery and research of new drugs and therapies [9].

Five criteria were identified which the end-users found relevant for an EHR. They were: availability, reliability, uniformity of working processes, less administrative work (letters, search activities and redundancy), and analyses (information for research and information for management) [13].

The EHR issues were discussed in the following aspects: workload, sharing information, access to information, record content, confidentiality, patient consent, and implementation. As for workload, an EHR could reduce duplication of work and reduce patient repetition of retelling their case histories. An EHR does however; create a range of recording and data collection tasks for clinicians and administrative staff. Sharing information was seen to be at the core of the EHR but patients perceive this as risky and as a potential for confidentiality compromise. Access to information implies that the practical access to records involves the issue of who, where, when as well as technical feasibility, legality, and ethical acceptability. The record content of an EHR needs an information balance between too much and too little. Confidentiality involves some legal issues regarding the transfer of patient information. Patient consent could be complicated due to contextual issues such as patients not wishing to be identified; unconscious or psychologically unfit patients who might be unidentifiable or unable to consent. Early on, there was some skepticism in the ability to implement a widespread EHR system. It was thought that an EHR could not replace the paper-based health records and that a paper-based backup was probably necessary [14].

Another aspect of today's healthcare industry that also drives the need for a well-equipped network is the migration from paper-based patient record keeping to EHRs [15].

An EMR system should have the following functionalities [16] [17]:

- Health Information, Data and Clinical Documentation: enable electronic visit notes; electronic lists of each patient's medications; electronic problem lists; patient clinical summaries for referral purposes; store and display test results; pertinent medical histories (including allergies, lists of other medications the patient is taking, medical and nursing diagnoses, patient demographics, and provider's notes).
- Results Management: organize and provide medical test results (such as lab test results and radiology test results) electronically to enhance provider access to information and promote efficiency with an emphasis on easier detection of abnormalities.
- Order Entry and Management: allow computerized medication orders and other care instructions (such as laboratory order and radiology orders) to reduce lost and duplicate orders; allow mistakes caused by illegible handwriting to be detected; and prevent delays in filling orders.
- Decision Support: allow for computer reminders (such as drug interaction warnings, letters or other reminders directed at patients regarding indicated or overdue care) and prompts to providers at the point of care that can improve preventive care, diagnosis, treatment, and disease management.

- Electronic Communication and Connectivity: enable electronic referrals and online communication among the medical staff, patients, and other providers (such as laboratories or pharmacies) through e-mail, web messaging, telemedicine, and home tele-monitoring.
- Reporting: enable to report clinical quality measures, patients out of compliance with clinical guidelines, patients with a condition, characteristic or risk factor.

An EMR can reduce the need for redundant data collection and allows a care provider to quickly review the history and update the medical records where necessary [18]. It can facilitate access to medical records across and within clinics and allows rapid and continuous assessments of patients' characteristics and service provision [19]. It can advance healthcare by enhancing patient care, preventative health, and provider convenience [6]. It offers information portability, greater patient safety (e.g. reduced medication errors), and promotion of standardized (protocol-based) patient care [20].

Ambulatory EMR systems hold tremendous promise for not only improving the quantity and quality of clinical data that can be recorded, but more importantly the ability to access health care data to improve quality of care. Over time patient charts contain considerable data regarding patient vitals (e.g., blood pressure, heart rate, and temperature), laboratory results (e.g., blood counts, blood sugars) and diagnostic tests (e.g., EKG). The EMR would allow physicians to easily generate and review graphical representations of one or more measures for a designated period of time. Graphical displays might alert caregivers of an emerging problem [18].

The EMR has been shown to provide significant health care savings, reduce medical errors, and improve patient health. Nursing leaders are at the forefront of their institutions to impact the reception, design, development, and implementation of EMR systems. This is because of their clinical workflow knowledge, decision-making capacity, and in their roles as nursing leaders they are able to achieve a higher-quality EMR [5].

The EMR is important in promoting safe, patient-centered, efficient, and effective healthcare. However, targeted training and education of healthcare workers in order to foster positive attitudes about technology, and build confidence in the benefits of these systems should precede the implementation of EMR [21].

1.3. Automated Identification Technology

Automated identification technology (AIT) is the methods of automatically collecting data and identifying objects using advanced devices. AIT mainly includes bar coding, radio frequency identification (RFID), and biometrics. Biometrics includes face, fingerprint, signature, voice, iris, retina, and DNA recognition. AIT can be used in production and manufacturing streamlining, supply chain management, criminal identification and homeland security, and medical and healthcare systems.

Barcodes have been widely used in hospitals. Drug safety in the national markets can be improved through advanced identification technology such as biometrics and RFID. The drug industry uses biometrics and RFID to police theft and counterfeiting. RFID applications in medical and healthcare services in hospitals can greatly improve patient safety by matching the right patient with the right procedures and medications.

This paper discusses the technology intelligence, progress, limitations and challenges of EHR/EMR, and AIT applications in EHR/EMR.

2. TECHNOLOGY INTELLIGENCE, PROGRESS, LIMITATIONS AND CHALLENGES OF EHR/EMR

2.1. Technology Intelligence and Progress

Three generations of the EHR could be found on the market and they were transformed into the following grades [22]:

- A first-grade EHR contains all the information that is gathered about a patient in back-office processes and makes this information available to the clinician;
- A second-grade EHR contains all the information of a first-grade EHR and adds to this the clinical documentation as entered by the individual clinicians for reference and accountability purposes;
- A third-grade EHR contains all the information of a second-grade EHR and adds to this the possibility to actively support the clinical work processes, in terms of care planning, workflow, and clinical decision support.

Within hospitals, information sharing has been common practice for many years. Interoperability requirements for information systems for medical support functions in hospitals, such as patient administration, laboratory, and radiology, are well understood. A number of interoperability standards have been developed to facilitate information exchange. However, information sharing between healthcare providers has not evolved as rapidly, mainly due to the poor response to electronic clinical documentation (the second-grade EHR). More advanced interoperability, in terms of seamless workflow integration across functional boundaries (the third-grade EHR), is even less well developed. The interest in the interoperability of EHRs has increased as a result of a number of reports on the role of information in relation to medical errors and patient safety [22].

Table 1 shows the logical building blocks of a potential EHR content. The second top level is a directory of possible nested folders for a patient, allowing for a high-level organization of the EHR, for example, per episode or per clinical specialty. Folders contain zero or more compositions by reference. A composition (which roughly corresponds to one clinical document) may contain sections with section headers and entries which consist of elements or clusters of elements. Each element has a single value of a single data type [2].

Table 1. Logical building blocks of EHR content

EHR	The electronic healthcare record for one person
Folders	High-level organization of the EHR, e.g. per episode, per clinical specialty
Compositions	A clinical care session, encounter or document, e.g. test result, letter
Sections	Clinical headings reflecting the workflow and consultation process
Entries	Clinical “statement” about Observations, Evaluations, and Instructions
Clusters	Nested multi-part data structures (tables and interval time series), e.g. audiogram
Elements	Leaf nodes with single data values, e.g. reason for encounter, body weight
Data Values	Data types for instance values, e.g. coded terms, measurements with units

Compared to claims data and many other administrative data sets, EHRs contain richer clinical information, although some of that information is buried in unstructured narrative text, rather than in structured coded data, and requires additional work to retrieve and analyze. The type of coded data that typically is directly extractable from the EHR includes pharmacotherapy, medical diagnoses, diagnostic laboratory and imaging tests ordered, referrals ordered, vital signs, and laboratory test results [23].

Data reliability is a crucial factor that may have a strong effect on how physicians and other medical providers use an EHR. The medical data in an EHR is composed from the EMR systems of different healthcare providers, paper-based medical reports, and referrals that patients received from those healthcare providers who do not have an EMR system or an electronic connection to the EHR system. Due to these factors, a Medical Data Reliability Assessment (MDRA) model was developed that can augment an EHR with metadata containing a reliability measure of medical data. The MDRA can communicate this reliability score to the EHR displayed on the medical practitioner’s computer to alert the provider to any reliability concerns [11].

Table 2 summarizes the factors that have been repeatedly found to be important for the successful implementation of EHRs across the world [4].

Table 2. Factors important for the successful implementation of the EHR

Technical Dimension	Usability, performance and integration, adaptability and flexibility
Social/Human Dimension	Attitudes, motivations, resistance and expectations, engagement and user input in design, training and support, champions, integration with existing work processes
Organizational Dimension	Getting the organization ready for change, planning, leadership and management, teamwork and communication, learning and evaluation, realistic expectations

On September 4, 2012, the United States Centers for Medicare and Medicaid (CMS) announced the final criteria for “Stage 2” for healthcare providers using EHR technology and, for doing so, receiving incentive payments from Medicare and Medicaid. CMS developed proposed rules in 2011 to govern the initiation of this incentive program to assist healthcare facilities with the implementation of an electronic record as mandated by the Health Information Technology for Economic and Clinical Health Act of 2009 (HITECH Act of 2009). As the mandated by the HITECH Act of 2009, the second stage, beginning in 2014, will be the last stage for organizations to get in on the incentives. The first stage, which began in 2011, included the transfer of data to EHR systems and the increased ability to share information among organizations, including electronic copies and visit summaries for patients. The second stage (proposed to be implemented in 2014) will include new standards such as online access to their personal health information for patients, as well as electronic health information exchange between providers. The third stage of EHR implementation (anticipated implementation in 2016) will be to demonstrate that the quality of health care has been improved. According to mandates in the HITECH Act of 2009, facilities not fully operational with an EHR by 2015 will be subject to financial penalties from CMS [15].

Centricity is an electronic health record (EHR) system that enables ambulatory care physicians and clinical staff to document patient encounters, streamline clinical workflow, and securely exchange clinical data with other providers, patients, and information systems. A subset of over 5000 physicians and other providers, including nurse practitioners and physician assistants, using Centricity contribute to the medical quality improvement consortium (MQIC) to create a research database. The database contains relevant clinical data extracted from the Centricity EHR. The database contains longitudinal clinical patient data including, but not limited to demographic information, vital signs, laboratory orders and results, medication list entries and prescriptions, and diagnoses or problems [24].

The text data in an EMR consist of paper notations about inspection reports, in-patient care plans, nutrition management plans, bedsore-prevention plans, fall checks, operation notes, summaries, and shift assessments. The doctor fills in the passage record and the nurses fill in the nursing records, which includes the life and inspection history of a patient. Since no guidelines exist about recording text, ambiguous feelings or impressions are sometimes included. Nurses sometimes remember or take notes about what the patients say while working and later input them into the EMR or input the data real time. There are four recording categories: subjective data (S), objective data (O), assessment (A), and plans (P) [25].

- S: information directly gleaned from patients
- O: objective facts and observations about the patient appearance or stated by colleagues
- A: evaluations and judgments derived from this information
- P: future plans and care actually taken

Although nursing records provide a complete account of a patient’s information, they are not being fully utilized. Such relevant information as laboratory results and remarks made by doctors and nurses is not always considered. A text data mining technique was used to extract useful information from nursing records within EMRs. Text data mining is often used to analyze information hidden in the text of a document and to extract key words, phrases, and even concepts from documents. It usually structures the input text (often by parsing, adding derived linguistic features, removing others and insertion into a database), deriving patterns within the structured data, and finally evaluating and interpreting the output [25].

Entering data into the EMR is complex. Typing with keyboards has its own limitations and repeated skimming of material for small checkboxes to appropriately find the right set of pre-set sentences or words are major sources of errors in the EMR. In order to overcome these problems, some EMR systems have used a more structured data entry system for the interim history, a risk assessment, and increased developmental screening and guidance sections of the record, which has resulted in better documentation in the EMR. However, the patient’s chief complaint and present illness were freely documented in the legacy paper-based medical record (PMR) and were recorded with narrative text rather than the structured data as seen in the EMR. The use of narrative text may cause loss of information in the EMR [26].

2.2. Limitations and Challenges

Currently, the EHR information is stored in all kinds of proprietary formats in a multitude of medical information systems available on the market. Typical formats include relational database tables, structured document-based storage in various formats, and unstructured document storage such as digitized hardcopies maintained in a classic document management system. This results in a severe interoperability problem in the healthcare informatics domain [2].

Although the strength of the EHR is the incorporated clinical information; prescriptions are only captured by physician order or if the patient mentions it in the medication list. This may under-represent treatment, because prescription refills are not recorded and numerous nonprescription obesity treatments are not documented or it may over-represent treatment because prescription fill information is not available [24].

The overall weaknesses of current EHRs include time consumption, a steep learning curve, poorly functioning chronic illness registries and flow sheets, and poor documentation for mental health clinician visits [10]. Physicians still have not found the EHR necessary or provider-friendly, but that the benefits from an administrative point of view, in the form of saving time and cost-savings, are clear. Therefore, physicians should be given more incentives for using the EHR [22].

It is vital that the confidentiality and integrity of health-care information is protected, whilst ensuring it is available to authorized health-care providers [8]. Nationally and globally linked EHR systems remain relatively rare, but are being developed around the world [7].

Although EMR systems have many advantages over paper records, its adoption in healthcare has been slow. The high cost of computerization is a major barrier to EMR adoption [21]. Physicians cite costs as both the most important barrier and financial incentives as the most important facilitator of EMR adoption. Studies have shown that financial incentives are key to EMR adoption. Federal incentive payments may play a crucial role in accelerating EMR adoption nationwide [16].

Physician resistance to EMR use has been attributed to a variety of factors including, but not limited to: 1) well-publicized EMR failures; 2) limited physician computer literacy on the part of physicians; 3) patient satisfaction; 4) unreliable technology; and 5) concerns over productivity (i.e., fear that an EMR would slow physicians down) [18]. According to a physician's perspective, it's faster to scribble a prescription on a piece of paper than it is to log onto an EMR system and electronically enter the data [27]. Many doctors are reluctant in the EMR system as they feel that it will reduce the clinical productivity. Some software uses strictly formatted or categorical fields to promote uniformity [19]. Physician acceptance is especially critical to widespread adoption of ambulatory EMRs [18].

Physicians and other healthcare providers may face additional liability exposure due to the introduction of EMRs. Additional liability for providers could come from a failure to perform all of the extra steps required by the consultation of EMRs, for example, a failure to follow confidentiality procedures, or a failure to spot something in a medical history that may be complex. To encourage widespread adoption of EMR systems, both the federal and state governments should take steps to protect healthcare providers such as the funding of a federal mandate for the nationwide adoption of EMRs or protections on a state-by-state basis to ensure that there is no unreasonable liability exposure; and there should be individual state restrictions limiting a physician's liability for EMR-related claims [17].

An important challenge in implementing EMR on a national basis is "customization." Each healthcare environment functions differently, often in significant ways. It is difficult to create a "one-size-fits-all" EMR system [19].

One of the main difficulties of adopting a widespread EMR system is the lack of protocols and standards. Many organizations across the country have developed their own EMR systems there are several electronic record providers. Each system operates independently and does not interface, although there are programs now available that some of the larger hospital systems have implemented that have permitted interface with other EMR systems. This is not, however, the standard across the country, and is limited to larger healthcare organizations. Standardization (which helps ensure interoperability and information sharing) and flexibility (which accommodates the various systems and architectures that different health-care providers need) must also be balanced. Too much standardization, and clinicians chafe under rules that don't match their own work habits. Too little, and workflow becomes less efficient. EMRs hold great potential for clinical-decision support, for example, by translating practice guidelines into automated reminders and actionable recommendations [27].

The privacy of the patients is also an important issue. Because the health record of each patient on EMR is widely available, it can be misused [19]. A more basic privacy-related challenge stems from the complexity of health-care delivery. It is important how it is determined which providers can access patient data. In general, only individuals with a direct medical need should be able to access files. Yet in an emergency room setting, dozens of people may need to examine a single patient's record, from physicians to nurses to interns—and speed is often necessary. Despite a number of challenges, patients' medical records are slowly making the transition to the digital age [27].

3. AUTOMATED IDENTIFICATION TECHNOLOGY IN EHR/EMR

3.1. Barcodes and EHR/EMR

The Food and Drug Administration (FDA) promulgated rules in 2004 that require all drug manufacturers to place a usable bar code on prescription medications, insulin, and over-the-counter products commonly used in hospitals. The products dispensed must be source-coded with a linear bar code that contains a National Drug Code (NDC) [28].

A wireless scanner with 2-D symbology capability (DS6878 Cordless 2D Imager) was used to scan products in the pharmacy inventory [28]. A personalized QR (Quick-Response) barcode generator was designed and implemented to meet the needs of a ubiquitous healthcare system's users, and provided comprehensive healthcare services to the users. Information such as patient name, patient identification number (ID), functions of the drugs, intake instructions, dosage amount and expired date are included in the barcode for the patient's reference. The QRCode library provides a function to encode the content into a QR code image which can be saved in JPEG, GIF, PNG or Bitmap formats, and also a function to decode a QR code image. The QR barcode generated can easily be printed and attached to the medicine packs [29].

All patients admitted to the hospital were given wristbands with a barcode and eye-readable identification wristband that included the surname, first name, gender, date of birth, patient identification number and blood group [30]. Nurses scan the bar code on the patient's wristband to display the personalized information. After scanning the wristband, the nurse scans the medication's internal entry number located on the barcoded package label [31]. Pharmacists checked and verified the order on the basis of patient information, which were obtained from the electronic medical record system by reading the barcoded label. Using a barcode reader, patient information and prescription orders were transmitted from an electronic medical record to the computer system. These data were stored on the server computer in the pharmacy division as well as in the EMR system [32]. Barcodes have been used in identifying patients, equipment or devices, drugs; patient charting; and scanning charges through scanning IV poles, beds, kangaroo pumps, suction setups, oxygen and setups.

Bar-code-assisted medication administration (BCMA), and an electronic medication administration record (eMAR) have been effectively implemented at healthcare organizations, contributing to a decrease in medication errors and a strengthened collaboration between pharmacy and nursing [33]. Barcodes have also been applied to verify and assist outpatients in medication administration, by capturing and decoding the barcode on medications using a mobile phone (with a built-in camera) [29].

A barcoded patient-blood unit identification system was implemented in all inpatient wards, operating rooms and an outpatient hematology unit in July 2002. The barcode identification system was based on the use of the linear barcode NW7. The barcode on allogeneic blood components identified the blood group, product type, unit of blood, and the product number depending on the donor and date of collection. In the case of autologous blood components, in-house barcodes identifying the product type and product number were attached [30].

In the world of transfusion medicine, two major barcode symbologies are Codabar and ISBT 128. Codabar is a soon to be obsolete linear barcode symbology. ISBT 128 is a newer internationally standardized bar coding system used for identification, labeling and processing of not only human blood, but also tissue and cellular therapy products. ISBT stands for the International Society of Blood Transfusion and 128 is the barcode symbology [20].

Bedside verification when collecting a blood sample or prior to giving a transfusion is a critical step. Most studies have demonstrated incremental improvements in patient safety with bedside verification of patient wristband and/or blood unit barcodes. Barcoded blood products can be used to track and trace units, and when used at the patient bedside they have been shown to also help prevent misidentification errors. Limitations of using a barcode-based technology include the soiling of barcodes and occasionally having the need for a nurse to put down the selected blood unit so as to line up the wristband with a barcode scanner [20].

All errors leading to failure of bedside barcode identification were categorized into four broad groups: human errors, handheld device errors, system errors and wristband errors. Wristband errors occurred when patients were not wearing wristbands at the time of transfusion because of cutting [30]. The most prevalent causes were that medications did not have accurate bar codes and that bar codes were missing or damaged in some fashion. One of primary reasons for failed scans was poor bar-code readability [28].

3.2. Biometrics and EHR/EMR

One of the major challenges in using medical history for authentication is the privacy issue. An example of good technology use is smart cards. The medical history data that is stored in a smart card could be used medical consultations in different clinics because it is easily transportable, easily accessible for the patient to carry to each provider, and easily updatable by each provider on a case-by-case basis [34].

Some of the authentication methods used in medical applications and healthcare are photo, password (personal identification number, PIN), birth date, name, insurance card, social security card or number, identification card, wrist bands, bar coding, and RFID. Personal data and the health information of patients in EHRs should be protected; however, data breaches, and medical identity theft and fraud have occurred. This has encouraged the development of biometric applications for authentication in the U.S. health care sector. The leading biometric applications in the United States are palm vein technology, fingerprint scanning, and iris scanning. Palm vein recognition scans the vein of the patient's hand, and a biometric template is used to correspond with the patient's EHR. A key advantage of the palm vein scan is its use in emergency rooms and trauma centers when patients arrive without identification. Many hospitals in the United States have implemented palm vein scanning for nonintrusive identification [35]. Biometrics can provide the best means of securing information while granting authorized people access to it.

Besides common biometric identification methods, a medical history can be used as ingredients for generating Q&A challenges upon user authentication [36]. Even the taking of a person's medical history data was advocated as biometrics as they may equally well in distinguishing a person and they are not easily counterfeited. Each medical record is handled supposedly by licensed medical professional and those who are trained in the use of electronic records. Two adults will hardly have exactly the same medical history in terms of conditions, prognosis, treatment procedures, times, and places over a certain length of time. The authenticator may be a machine device or a human officer that is able to generate some question-and-answer type of challenges to the testing the patient about his or her medical history. A model was proposed for preserving the privacy of the medical history by implicitly questioning the users using the features of the illness instead of the illness itself. When a set of features were used collectively together, they were sufficient to infer the identification of the illness. Taking the illness as the secrecy that is supposedly known only by the user, the questions that are derived from the selected features can be used to orally verify if the user knows of his past medical history [34]. In addition, a method was proposed for abstracting the medical data by using attribute value taxonomies, into a hierarchical data tree (h-Data). Questions can be abstracted to various levels of resolution for use in the authentication process. A biometric security card can store a number of h-Data, corresponding to each of the user's medical illness if he ever suffered from multiple major illnesses [36].

Biometric systems have their own limitations. Some of the challenges commonly encountered by biometric systems were: noisy sensor data, intra-class variations, and distinctiveness, non-universality, and spoof attacks. These limitations can be either overcome or reduced by using multiple biometric traits**.** A multimodal biometric fusion system was proposed to the highest level of security in the hierarchical architecture of the EMR. A multimodal biometric identification system was built combining information from both face and iris unimodal systems. After suitable normalization of scores, fusion was performed at the matching score level using weighted scores [37].

3.3. RFID and EHR/EMR

3.3.1. Advantages of RFID applications in EHR/EMR

RFID has advantages over barcodes since RFID does not depend on "line of sight" identification, eliminating the need to use both hands to line up identification tags [20]. RFID technology facilitates automating and streamlining patient identification processes in hospitals. It is also used for tracking inventory and managing personnel. RFID systems tend to reduce the data-entry workload of nurses. Additionally, hospitals often track high-value assets, including gurneys, wheelchairs, oxygen pumps and defibrillators. These systems reduce the time employees spend looking for assets, improving asset utilization [38].

RFID allows easy and quick patient identification and can act as an open access for the patient to load a health record by just approaching with their specially created personal health card. Technologies, such as ultra-high-frequency (UHF) passive RFID, have been proposed to complement the use of barcoding. RFID can also be used to automatically sense all of the medical devices and the patient, thereby reducing the manual barcoding steps required for the patient's care [39].

3.3.2. Technology characteristics and intelligence of RFID in EHR/EMR

Simson Garfinkel proposed an Electronic Bill of Rights in 2002 and suggested that people should have the following rights [40]:

- to know whether products contain RFID tags
- to have RFID tags removed or deactivated when they purchase products
- to use RFID-enabled services without RFID tags
- to access an RFID tag's stored data
- to know when, where, and why the tags are being read

One environmental concern centered on the number and location of the RFID readers. The RFID readers should be situated throughout the trauma facility to maximize potential "reads." Readers can be located above the doorways in the treatment and service areas, which proved to be the least disruptive and most accessible choice [41].

Wristband RFID tags have been used to uniquely identify a patient. These wristband RFID tags data are used to query the remote server for the patient information. In addition, information such as patient ID and other medical data can be written to the RFID tags using mobile PCs or mobile units. This is achieved by using read/write tags, which allow new/updated information to be written to the tag [42].

A sensor-enabled and RFID-integrated, Wireless Data Acquisition System (WDAS) for health-care applications has been developed, simulated and implemented. The system can accept various measurements via sensors placed on patients or elders and transmit information wirelessly to a base station at a remote location. The system can be used for healthcare applications including nursing homes in rural areas where access is difficult [43].

A mobile physiological patient monitoring system was proposed, which integrated current mobile smart phones and a wireless sensor network, Bluetooth, and RFID patient identification systems for patient monitoring. This system enables continuous monitoring and patient identification during intra-hospital or inter-hospital patient transport. A medical sensor node was used which was responsible for the acquisition of vital signs, such as electrocardiogram (ECG), blood pressure (BP) and pulse oximetry (SPO2). A medical sensor node contains a microprocessor, a memory storage unit, one or more sensors, and a Bluetooth interface. The microprocessor initiates measurements, gathers and stores sensor data and communicates with the control node. Data gathered by the control node can be accessed and forwarded over a wide- area mobile network. The control node is linked by Bluetooth wireless networking technology to the medical sensor system such as blood pressure (BP) monitors, electrocardiographs (ECG), and temperature sensor, etc. [42].

There are four major choices in implementing a scalable network for a mobile device: wireless local area network (WLAN, IEEE 802.11a/b/g), Bluetooth (IEEE 802.15.1), ultra-wideband (UWB, IEEE 802.15.3) and ZigBee (IEEE 802.15.4). WLAN has a great advantage because it is already installed in almost every building; the network is easy and relatively cheap to build. However, WLAN is quite bulky for this kind of mobile devices that transmit small amounts of data. The UWB network is used mostly for short-range wireless personal area networks (WPAN) with high-speed communication. However, the range of a UWB network is about 10 meters; thus it is more suitable for high data rate short-range applications. ZigBee and Bluetooth are low-power and rather low data-rate protocols. ZigBee has its mesh-network topology. ZigBee was selected to be the HF protocol of the RFID system. The difference between location accuracy of the RFID system and the WLAN and ZigBee systems might not be so significant [44].

3.3.3. General applications of RFID in EHR/EMR

RFID tags can be worn by patients around the patient's wrist, in gowns, or on ankle bracelets. A tag stores the identification number, which helps to identify the patient correctly [41] [42]. RFID bracelets can be used to track a patient's whereabouts in a facility or to confirm identification when medications, blood, or other therapies are administered. Patients with Alzheimer's or other similar disorders could have their tags implanted to verify their identity. An example of applications is an RFID tag on a laparotomy sponge to facilitate the sponge count [40].

For patients, information such as medical records, eMARs, medication dosage etc., can be stored and password protected so that the authorized healthcare providers can access the information, although quickly. Rapid treatment can be allowed, especially during transport, even before the patient arrives at the hospital, increasing the patient access to healthcare and improving patient care, essentially saving lives [42].

RFID applications in hospitals include medicine control, patient contact history, patient identification, equipment/apparatus tracking, injection management, physician order monitoring, medical malpractice prevention, blood bag quality control, and operation room workflow, etc. [45]. In transfusion medicine, RFID has been shown to have the potential to support rapid and easy access to process data generated in the blood supply chain, including collection, manufacturing, testing, release labeling, inventory, and distribution [20]. Hospitals own numerous pieces of expensive equipment. Both Wi-Fi and active REID systems allow hospitals to know where their equipment is, nearly in real time [46].

A system based on RFID was developed to improve patient management. It can be integrated into any local/national or international health information system and database. An RFID tag card stored clinical and personal data. The designed system allowed providers a very quick consulting of the clinical data of the patient. Any person can be equipped with an RFID smart card and any hospital can be equipped of an RFID wireless smart card reader for patient identification. The automatic access to all patients' clinical/medical history and information stored in a personal folder of files was implemented [47].

Direct observation has been widely used to assess interactions between healthcare workers (HCWs) and patients, but it is time consuming and feasible only over short periods. An RFID system was used to automatically measure HCW-patient interactions. RFID nodes included fixed devices in patient rooms and mobile devices carried by HCWs. During the period of RFID deployment, direct observation of patient-HCW interactions was performed. Interactions between HCWs and patients can be recorded accurately and continuously using RFID. RFID holds promise for better describing exposure and risk. RFID can be used for assessing the risk of transmissible infectious diseases [48].

In Figure 1, the Near-field imaging (NFI) system detects that a patient has fallen in a room and sends an alarm wirelessly to a central unit. All the nurses have their RFID tag. The central unit then decides where to send the alarm. Because of the location system, the alarm can be sent to the nurse who is nearest to the room from which the alarm was sent [44].

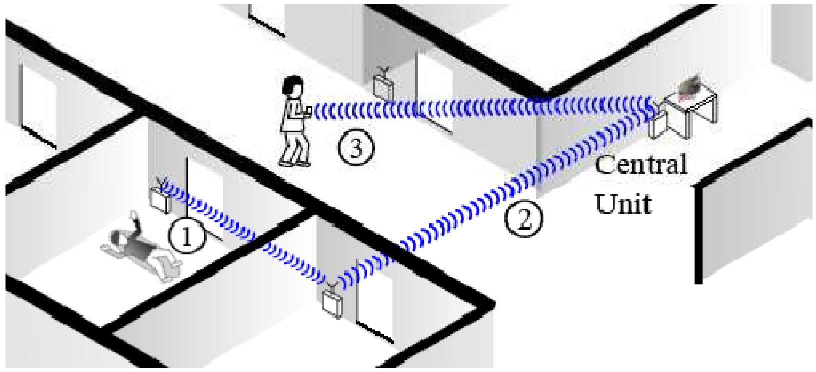

Figure 1. A person falls (1) and the information is sent to a central unit (2). The alarm then is sent by the central unit to the nearest nurse (3) [44]

RFID-based management has been used by physicians and nurses to design and/or consult the patient profile and the recommended insulin dosage board. These records are stored on the patient's personal health card. User data includes the patient's personal information such as: name, surname, age, height, weight, and the national or private health insurance number Dose information [49]. Family care-givers showed higher support for the use of Global Positioning Systems (GPS) and RFID both for their own peace of mind and for the safety of the elder in their care [50].

An innovative EMR system, RF-MediSys, was developed. It can perform medical information sharing and retrieval effectively and is accessible via a 'smart' medical card. Results showed a *medium* to *high* level of user satisfaction with the radiofrequency identification (RFID)-based EMR system [51].

The following shows some progress in combining RFID with an EMR system [51]:

RF-MediCard: A basic RFID medical card (known as an RF-MediCard) coupled with a software package to manage all the medical information of card-holders through the Internet. The RF-MediCard employs RFID technology and the Electronic Product Code (EPC), to format the dynamic patient data stored in the patient card in a unique and consistent manner. The RF-MediCard guarantees not only the uniqueness of patient identification but it also has the additional capability of recording simple medical information relating to the card holder.

RF-MediSys: The aim of RF-MediSys is to integrate the RF-MediCard and electronic medical records system (EMRS) concepts. It was designed to enhance the effectiveness of medical information retrieval and other routine healthcare delivery processes (e.g. patient registration, prescription and location).

Design of the RF-MediCard: Each patient is issued a RF-MediCard (a RFID-tagged smart card), which stores the holder's personal and medical information. The function of the RF-MediCard is to store basic medical information (e.g. drug allergies, major or chronic diseases, medical history, blood type), for quick and easy access when the patient presents the card. Basically, the RFID tag is embedded in the RF-MediCard and a barcode is printed on the front. The barcode that stores the same unique code of the RFID tag will be used when the RFID tag does not work properly. By presenting the RF-MediCard to an authenticated RFID reader, all the information stored in the card can be retrieved and used in the RF-MediSys.

3.3.4. RFID applications in the emergency room

RFID applications in the emergency room include the alert of an excessively prolonged queue, patient location tracking, and the alert of excessively prolonged stay. Semi-active tags of UHF frequency are used on the patients in the emergency room. Upon the arrival of a patient at an emergency room for triage, an RFID wristband, gown, or bracelet is mounted on the patient. All following procedures must be reconfirmed with a reader, including diagnosis by physician, medication distribution by a nurse, injection, examination, urgent operation, etc.

The first problem with this system is the potential for the excessively long waiting time for diagnosis of the patient by the physician after triage and registration. The second problem is a patient's excessively long stay in the provisional observation area, resulting in a left without treatment (LWOT).

An RFID tag is mounted immediately on the patient at triage by the medical personnel before the patient is redirected to the waiting area. If a physician fails to diagnose the patient in the time stipulated by the hospital, a short message is immediately sent to the management center where upper management may initiate an emergency protocol.

The introduction of RFID not only assures the six-step medical safety checklist (the right patient, the right medication, the right dosage, the right approach, the right timing, and the right documentation), but also solves the problem of an excessively long waiting time to diagnosis, excessively long provisional observation periods, patients who are left unattended by medical personnel, excessively long delays in transfer to the floors or other facilities, and left without treatment or against medical advice (AMA) [45].

3.3.5. RFID applications in operating rooms [52]

The operating room (OR) is one of the most complex work environments in health care. Errors in the operating room can be particularly catastrophic. Active RFID detects and prevents errors in the OR. The RFID-based OR system decreases the probability of medical errors such as wrong patient, wrong location, wrong medical staff, and wrong procedure.

Surgical site verification: by integrating RFID with the hospital information system (HIS), the digital chart, some critical patient information automatically shown on the monitor when the patient is brought to the scheduled OR, and verbalization and physical verification by providers from the OR, the adverse events of wrong site in surgery can be significantly reduced.

OR verification: if a patient is brought for an unscheduled operation, the system will create a warning on the monitor. Thus, the system checks the wrong-location event to prevent the potential wrong-site surgery.

Patient status update: in the system, the status will be updated automatically by integrating RFID with the back-end HIS.

RFID-enabled OR Process: the system provides hospitals with a means to: 1) correctly identify surgical patients; 2) track the ORs in which patients and medical staff enter; and 3) furnish critical information to ensure patients get the right surgeries at the right time and place.

Admission into the operating suite: when a surgical patient is scheduled to be operated on, the nurse assigns the patient an RFID-embedded wearable tag encoded with a unique ID. When the surgical patient is brought to the holding area in the OR suite, an RFID reader automatically verifies the identity of the patient.

Admission into operating room: the RFID readers in the OR automatically capture the information on the patient's tag to identify the patient on entering the OR. Subsequently, the system automatically changes the patient's status information to "in surgery" after confirming that the correct patient has entered the assigned OR.

Transfer to recovery: after surgery, patients are transferred to the recovery area. Here, the RFID readers detect the patient's RFID tags and the system automatically changes the patient's status to "in recovery."

Discharge from operating suite: after a patient recovers from anesthesia, the patient is transported by medical personnel from the recovery room back to the unit. At this time, the system automatically updates the patient's status information to "returned to unit."

3.3.6. RFID applications in workflow

Workflow is becoming a key factor. People are now entering a stage where both bar coding and RFID technologies can be applied to improve workflow. Medical device connectivity and related device-setup workflows – whereby clinicians are required to set up devices at the bedside to enable integration – is becoming much more challenging because of changing requirements for connectivity. Currently, all devices at the bedside are candidates for integration, including ventilators, infusion pumps, pulse oximeters, and wireless smart beds. The challenge now is clearly how to optimize the clinical workflow.

- The scope of clinical care areas that have devices requiring integration with EMRs is increasing.
- The use of wireless and mobile devices is expanding rapidly and a lack of patient context limits the ability to integrate the data. The issue for clinicians is how the patient-to-device association will get established to ensure the data gets to the right patient record.

The optimal workflow is highly dependent on the type of clinical care area (ICU, OR, ED, etc.), the number and type of medical devices requiring connectivity to the EMR and the design of the device-connectivity application. A single bar-code scan of the patient's wristband and a confirmation of the patient ID is all that would be required to enable the vital signs data to be sent to the EMR [39]. Most hospitals already have EMR-integrated devices available.

3.3.7. Limitations and challenges of the applications of RFID in EHR/EMR

Data can be captured by any RFID reader in the vicinity (which of course varies depending on the tag type – unpowered *versus* battery-powered tags). Environmental factors, such as reflective surfaces (e.g., swinging metal doors) or leaky protective devices (e.g., carrying cases with ill-fitting lids) can compound this problem by misdirecting RFID signals. Moving metal doors block or reflect RFID signals. These factors result in a much “noisier” data environment [41].

Data verification can be difficult in some RFID implementations because some readers capture unexpected or unwanted data. Because RFID systems are much more susceptible to environmental noise, they work in a much “noisier” data environment. RFID systems can read tags at the rate of a thousand times per second. These high read rates lead to data explosions. An automated data filtering facility would improve the reliability and integrity of the RFID data [41].

Security and privacy in RFID technology is a very active research field that has the challenge to design scalable and cheap protocols to guarantee the privacy and security of RFID users [38]. Information on the person’s health status can be gained by intruding on the communication channels. This can be avoided by encrypted communication protocols at the different levels of communication and encrypted storage [53].

4. CONCLUSION

An EHR/EMR is a confidential digital recording of an individual’s medical and healthcare information. It offers benefits such as convenience, high efficiency, and reduced clerical errors. Privacy, data integrity, and accountability are important factors to ensure the acceptance and spread of EHR/EMR.

A barcode identification system has worked well to meet bedside check requirements and barcode-assisted administration can reduce medication administration errors. Biometrics can authenticate the identity of a patient; provide the best means of securing information while granting authorized people access to it. RFID has been used to identify patients, track medical equipment, and manage medication administration in hospitals. Both barcodes and RFID can improve workflow in hospitals. Data security and privacy are key issues in RFID applications in EHR/EMR. Encrypted communication protocols can be used to stop unauthorized people’s intrusions and protect data and privacy.

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