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Mini-review & Commentary

Impact of Health Information Technologies on Medical Errors and Patient Safety: Primary Advantages and Limitations

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Abstract

Medical error-induced injuries and deaths have been constantly reported in a high rate around the world during the past decades, which stimulated the development of health information technology (HIT). Currently, several HIT-derivatives, including electronic health record (EHR), computerized physician order entry (CPOE), clinical decision support systems (CDSS), and bar-coded medication administration (BCMA), have been introduced as both life and cost saver technologies. Unfortunately, however, the increasing adoption and implantation of these technologies have not produced the desired outcomes.

This mini-review attempts to critically analyze the reported impact of these information technologies on medical errors and patient safety, focused on their primary advantages and limitations. This mini-review also attempts to present the authors' personal point of view on possible reasons why the wide adoption of HIT-derivatives has not produce the desired results and the intended direction of the HIT.

Introduction

In 2000, a report from the Institute of Medicine (IOM), and two other independent reports, estimated that medical errors in U.S. hospitals resulted in about 44,000 to 98,000 preventable deaths and in excess of 1,000,000 preventable injuries each year [1-3]. In 2006, a follow-up to the IOM study estimated that 400,000 preventable drug-related injuries occurred in hospitals, 800,000 in long-term care settings, and roughly 530,000 amongst MEDICARE recipients in outpatient clinics each year, which incurred about

$887 million extra medical costs annually [4]. These reports have stimulated the development of health information technology (HIT). During the past two decades, several specific techniques and approaches, including electronic health record (EHR), computerized physician order entry (CPOE), clinical decision support systems (CDSS), and bar-coded medication administration (BCMA), have been introduced as intended life and cost savers aimed at reducing medical error-related injuries and deaths. This mini-review attempts to critically analyze the reported impact of these HIT technologies on medical errors and patient safety, focused on their primary advantages and limitations. This mini-review also attempts to present the authors' personal point of review on the future direction of these health information technologies.

A. Electronic Health Record (EHR)

I. Definition:

The EHR is defined as an electronic record of a range of health information about an individual or a population, including medical history, medication and allergies, immunization status, laboratory test results, radiology images, vital signs, age, weight, and billing information [5-7]. This record is in digital format, which can be shared across various health care settings, enterprise-wide information systems, and other information networks or exchanges connected by internet.

II. Primary advantages:

The EHR is designed to accurately capture the health information of a given patient at all times across the continuum of care, allowing for an entire patient history to be viewed without the need to track down the patient's previous medical record. One of the important features of the modern EHR includes symptoms, family history, ethnicity, automated drug-drug/drug-food interaction checks and allergy checks, standard drug dosage and patient education information. As all the information exists within a single file, it makes it much more effective when extracting medical data for the examination of possible trends, and long term changes in the patient. It is expected that EHR may reduce several types of errors, including those related to prescription drugs, to emergent and preventive care, and also to different tests and procedures.

III. Primary limitations or drawbacks:

The main areas of concern with the implementation of a fully integrated EHR system are:

1. Document accuracy, completeness, uniformity, and clarity: As the regulations of health systems among different states and medical organizations differ substantially, along with the significant variations of the patients' medical history, the construction of a complete file will be a very expensive and time-consuming process. It may be extremely difficult to fully or adequately convert some of the medical records, such as diagnostic imaging, or histological slides into digital files in an acceptable size. More importantly, the EHR itself could be associated with unintended adverse events. The Joint Commission cited the United States Pharmacopeia MEDMARX database as an example, in which 43,372 (about 25%) of 176,409 medication errors for 2006 involved some aspect of computer technology as at least one root cause of the error [8]. The National Health Service (NHS) in the UK reported specific examples of potential and actual EHR-attributable unintended consequences in their 2009 document on the management of clinical risk relating to the deployment and use of health information system software, including errors in data analysis incompatibility between multivendor of software applications or systems [9].

2. Accessibility and efficiency: As the digital file for some patients may be large, it may take a longer time to query, search and extract the information needed. A recent survey of American College of Physicians member sample found that family practice physicians spent 48 minutes more a day on EMRs. Of the physicians surveyed, 90% reported that at least one data management function was slower after EMRs were adopted, and 64% reported that note writing took longer. A third (34%) of those surveyed reported that it took longer to find and review medical record data, and 32% reported that it was slower to read other clinicians' notes [10].

3. Privacy and confidentiality: In 2011, there were 380 major data breaches involving 500 or more patients' records listed on the website kept by the United States Department of Health and Human Services (HHS) Office [11]. From September 2009 through December 2012, there were 18,059,831 "individuals affected," and even that massive number is an underestimate of the data security breach problem, not including those breaches impacting fewer than 500 patients per incident [12].

B. Computerized Physician Order Entry (CPOE)

I. Definition:

CPOE (also referred as Computerized Provider Order Management or Computerized Provider Order Entry) is a form of patient management software that facilitates the process of electronic entry of medical practitioner instructions for the treatment of patients (particularly hospitalized patients) under his or her care. These orders are communicated over a computer network to the medical staff or to the related departments (pharmacy, laboratory, or radiology) responsible for filling the order.

II. Primary advantages:

Physicians have traditionally hand-written or verbally communicated orders for patient care. Handwritten reports or notes, manual order entry, non-standard abbreviations and poor legibility lead to medical errors. Studies of CPOE have suggested that the medication error rate can be reduced by 80%, and errors that have potential for serious harm or death for patients can be reduced by 55%, and other studies have also suggested similar benefits with computerized methodology [13-15].

III. Primary limitations or drawbacks:

CPOE presents several potential dangers by introducing new types of errors. Prescriber and staff inexperience may cause slower entry of orders at first, consume more staff time, and be a slower process than person-to-person communication in an emergency situation. Physician-to-nurse communication can worsen if each group works alone at their respective workstations. Automation may cause a false sense of security. It reported that these factors contributed to an *increased* mortality rate in the Children's Hospital of Pittsburgh's Pediatric ICU when a CPOE system was adopted [16].

C. Clinical Decision Support Systems (CDSS)

I. Definition:

CDSS is interactive computer software designed to assist physicians and other health professionals with decision-making tasks, such as determining diagnosis based on patient data. CDSS links health observations with health knowledge to influence health choices by clinicians for improved health care.

II. Primary advantages:

Most CDSS consist of three parts: the knowledge base, inference engine, and mechanism to communicate. The knowledge base contains the rules and associations of compiled data, which most often take the form of IF-THEN rules. If this was a system for determining drug interactions, then a rule might be that IF drug X is taken AND drug Y is taken THEN alert user. Using another interface, an advanced user could edit the knowledge base to keep it up-to-date with new drugs. The inference engine combines the rules from the knowledge base with the patient's data. The communication mechanism will allow the system to show the results to the user as well as have input into the system [17,18]. A systematic review of 100 studies concluded that CDSS improved practitioner performance in 64% of studies, and improved patient outcomes in 13% of the studies analyzed [19]. Another systematic review of 70 studies concluded "Decision support systems significantly improved clinical practice in 68% of trials" [20].

III. Primary limitations or drawbacks:

CDSS face steep technical challenges in a number of areas. Biological systems are profoundly complicated, and a clinical decision may utilize an enormous range of potentially relevant data. For example, an electronic evidence-based medicine system may potentially consider a patient's symptoms, medical history, family history and genetics, as well as historical and geographical trends of disease occurrence, and published clinical data on medicinal effectiveness from PUBMED and other databases, which are numerous and sometimes contradictory.

Clinically, a large deterrent to CDSS acceptance is workflow integration. The inclination to focus only on functional decision making of the CDSS capability can challenge the clinician as to how s/he will actually utilize the system in certain situations. Extra steps are required of the clinician, which then may cause a disruption in clinical workflow, thereby affecting efficiency. Generally, these clinical decision support systems are stand-alone applications and not integrated with existing healthcare information technology systems. Thus, the clinical users must stop working on their traditional system and switch to the CDSS and then return to the EMR.

Another source of contention with CDSS is the possible production of mass amounts of alerts. When systems produce high volume of warnings (especially those that do not require escalation to next level review), aside from the annoyance, clinicians may pay less attention to or miss potentially critical warnings that may impact patient safety.

One of the core challenges facing CDSS is difficulty in incorporating the extensive quantity of evidence rapidly emerging from clinical research being published on an ongoing basis. In a given year, results of tens of thousands of clinical trials are published. Currently, each one of these studies must be manually read, evaluated for scientific legitimacy and incorporated into the CDSS in an accurate and clinically meaningful way. In addition to being laborious, integration of new evidence can sometimes be difficult to quantify, or incorporate into the existing decision support schema, particularly in instances where different clinical papers may present conflicting information on the same medical condition.

D. Bar-Coded Medication Administration (BCMA)

I. Definition:

BCMA is a barcode system designed to prevent medication errors in healthcare settings and to improve the quality and safety of medication administration. The overall goals of BCMA are to improve accuracy, prevent errors, and generate online records of medication administration.

II. Primary advantages:

BCMA consists of a barcode reader, a portable or desktop computer with wireless connection, a computer server, and supporting software system. When a nurse gives medicines to a patient in a healthcare setting, the nurse can scan the barcode on the patient's wristband and make sure that the patient is the right patient intended to receive medication at a particular time. The nurse can then scan the barcode on the medicine, the nurse and the software can then verify if it is the right medicine being administered to the right patient at the right dose and at the right time by the right route ("Five rights"). BCMA is designed as an additional check to aid the nurse in administering medications.

III. Primary limitations:

BCMA cannot replace the expertise and professional judgment of the nurse. A misplacement of the barcode may cause misidentification of the patient.

E. Medical errors

I. Definition

Medical errors are often described as human errors, occurring when a health-care provider chooses an inappropriate method of care or improperly executes an appropriate method of care. During the past, multiple terms, including error, failure, near miss, rule violation, deviation, preventable adverse effect and potential adverse effect, have been used define medical errors [21,22]. The following three approaches are most commonly used to define medical errors: (1) Using the word, "Error", (2) Using the NCC MERP definition, and (3). Using words "failure, deviation, adverse effect, or adverse event" [21-23].

II. Difficulties in defining medical errors:

Medical error definitions are subject to debate, as there are many types of medical errors, ranging from minor to major, and the causality is often poorly determined [22,23]. Thus, compared to other epidemiological fields in health care, no single definition is currently being used to determine medical errors, which has contributed to the substantial variation in the reported occurrences of medical errors.

III. Difficulties in measuring frequency of errors

A previous study revealed that about 1% of hospital admissions results in an adverse event due to negligence [24]. However, medical errors are likely much more common, as these studies identify only mistakes that led to measurable adverse events occurring soon after the errors. Independent review of doctors' treatment plans suggests that decision-making could be improved in 14% of admissions; many of the benefits would have delayed manifestations [25]. One study suggests that, in the United States, adults receive only 55% of recommended care [26]. At the same time, another study found that 30% of care in the United States might be unnecessary [27]. For example, if a doctor fails to order a mammogram that is past due, this mistake will not show up in the first type of study; and because no adverse event occurred

during the short-term follow-up of the study, the mistake also would not show up in the second type of study, because only the principal treatment plans were critiqued. However, the mistake would be recorded in the ensuing third type of study. If a doctor recommends an unnecessary treatment or test, it may not show in any of these types of studies.

F. Patient Safety

I. Definition:

Patient safety is a new healthcare discipline that emphasizes the reporting, analysis, and prevention of medical error that often leads to adverse healthcare events [28].

II. Potential factors impacting patient safety:

A number of factors have been identified that could significantly impact patient safety, including

1. Human Factors:
    a) Variations in healthcare provider training & experience, fatigue, depression and burnout.
    b) Diverse patients, unfamiliar settings, time pressures.
    c) Failure to acknowledge the prevalence and seriousness of medical errors.

2. Medical complexity
    a) Complicated technologies, powerful drugs.
    b) Intensive care, prolonged hospital stay.

3. System failures
    a) Poor communication, unclear lines of authority amongst physicians, nurses, and other care providers.
    b) Complications increase as patient-to-nurse staffing ratio increases.
    c) Disconnected reporting systems within a hospital: fragmented systems in which numerous hand-offs of patients' results in lack of coordination and errors.
    d) Drug names that look alike or sound alike.
    e) The impression that action is being taken by other groups within the institution.
    f) Reliance on automated systems to prevent error.
    g) Inadequate systems to share information about errors hamper analysis of contributory causes and performance improvement strategies.
    h) Cost-cutting measures by hospitals in response to reimbursement cutbacks.
    i) Environment and design factors. In emergencies, patient care may be rendered in areas poorly suited for safe monitoring. The American Institute of Architects has identified concerns for the safe design and construction of health care facilities

j) Infrastructure failure. According to the WHO, 50% of medical equipment in developing countries is only partly usable due to lack of skilled operators or parts. As a result, diagnostic procedures or treatments cannot be performed, leading to substandard treatment.

G. Impact of EHR, CPOF, CDSS, and BCMA on medical errors and patient safety

Although EHR and CPOE have existed for more than 30 years, fewer than 10% of hospitals had a fully integrated system as of 2006 [29]. The EHR and other HIT adoption rates, however, have steadily increased in recent years [30]. A 2009 National Ambulatory Medical Care Survey of 5,200 physicians by the National Center for Health Statistics showed that 52% of office-based physicians did not use any EMR/EHR system [30]. According to the CDC, as of 2013, 78% of office physicians are using basic EMR, and other health information technologies [31]. Unfortunately, however, the increasing adoption and implantation of EHR, CPOF, CDSS, and BCMA have not produced the desired outcomes as intended, that is to be a both a life- and cost-saver.

A 2006 report systematically searched the English-language literature indexed in MEDLINE and other databases from 1995 to 2005 to assess the impact of health information technology on the quality, efficiency, and costs of health care. Of 257 studies that met the inclusion criteria, approximately 25% of the studies from 4 academic institutions demonstrated three major benefits on quality: increased adherence to guideline-based care, enhanced surveillance and monitoring, and decreased medication errors [32]. The impact on the cost, however, was limited [32].

In 2010, the Office of Inspector General for the Department of Health and Human Services estimated that bad hospital care contributed to the deaths of 180,000 patients in Medicare alone in a given year [33]. In 2014, Journal of Patient Safety and two independent nonprofit health organizations reported that between 210,000 and 440,000 patients who go to hospitals for care suffer some type(s) of preventable harm(s) that contribute to their death each year [34-36], which would make medical errors the third-leading cause of death in America.

E. Future directions of HIT

It is not known why the adoption of health information technology has not produced the desired results as a life and cost saver nationwide. Based on the author's over 30-year collective personal experience, the following factors may be significant contributors:

a) The lack of uniform definition or standard to define or appropriately categorize medical errors.

b) The lack of objective and reliable means to determine the frequency of medical errors and their impact on patient safety across the care continuum.
c) The lack of patients' participation in the process. It has been well documented that a great percentage of the medical errors involve inappropriate education of or adherence by patients, while this issue has not been adequately addressed.
d) The lack of focus on this most important issue, and the lack of competition based on value amongst US healthcare systems. It has been well documented that misdiagnosis is the most common error with the most deadly consequence to patient safety, while it has not adequately addressed.
e) The lack of effective medical protocols to prevent or reduce the consequences of potential errors.

References

1. Institute of Medicine (2000). "To Err Is Human: Building a Safer Health System (2000)". The National Academies Press. Retrieved 2006-06-20.
2. Charatan, Fred (2000). "Clinton acts to reduce medical mistakes". BMJ Publishing Group. doi:10.1136/bmj.320.7235.597. Retrieved 2006-03-17.
3. Weingart SN, Wilson RM, Gibberd RW, Harrison B (March 2000). "Epidemiology of medical error". BMJ 320 (7237): 774–7. doi:10.1136/bmj.320.7237.774. PMC 1117772. PMID 10720365.
4. "Medication Errors Injure 1.5 Million People and Cost Billions of Dollars Annually". The National Academy of Science. 2006. Retrieved 2006.
5. Gunter, Tracy D; Terry, Nicolas P (2005). "The Emergence of National Electronic Health Record Architectures in the United States and Australia: Models, Costs, and Questions". Journal of Medical Internet Research 7 (1): e3. doi:10.2196/jmir.7.1.e3. PMC 1550638. PMID 15829475.
6. "Mobile Tech Contributions to Healthcare and Patient Experience". Top Mobile Trends. Retrieved 29 May 2014.
7. Habib, J. L. (2010). "EHRs, meaningful use, and a model EMR". Drug Benefit Trends 22 (4): 99–101.
8. *MEDMARX Adverse Drug Event Reporting database*
9. Health informatics - Guidance on the management of clinical risk relating to the deployment and use of health software (formerly ISO/TR 29322:2008(E)). DSCN18/2009, Examples of potential harm presented by health software, Annex A, p. 38.
10. Clement J. McDonald, Fiona M. Callaghan, Arlene Weissman, Rebecca M. Goodwin, Mallika Mundkur, Thomson Kuhn (September 08, 2014 (Online first)). "Use of

Internist's Free Time by Ambulatory Care Electronic Medical Record Systems". JAMA Intern Med. doi:10.1001/jamainternmed.2014.4506.
11. "Breaches Affecting 500 or More Individuals". Hhs.gov. Retrieved 4 September 2013.
12. "Year closes on a note of breach shame | IT Everything, the Healthcare IT blog by Modern Healthcare's Joe Conn". Modernhealthcare.com. 2011-12-22. Retrieved 4 September 2013.
13. "Electronic Health Records Overview". www.himss.org/electronic-health-records-overview-nih-national-center-rese...
14. U.S. Department of Health and Human Services Centers for Medicare & Medicaid Services 42 CFR Parts 412, 413, 422 et al. Medicare and Medicaid Programs; Electronic Health Record Incentive Program; Final Rule
15. Evans, Dwight C.; Nichol, W. Paul; Perlin, Jonathan B. (2006). "Effect of the implementation of an enterprise-wide Electronic Health Record on productivity in the Veterans Health Administration". Health Economics, Policy and Law 1 (2): 163–9. doi:10.1017/S1744133105001210. PMID 18634688.
16. Yong Y. Han, Joseph A. Carcillo, Shekhar T. Venkataraman, Robert S.B. Clark, R. Scott Watson, Trung C. Nguyen, Hülya Bayir, and Richard A. Orr (2005). "Unexpected Increased Mortality After Implementation of a Commercially Sold Computerized Physician Order Entry System". Pediatrics 116 (6): 1506–1512. doi:10.1542/peds.2005-1287. PMID 16322178. Retrieved 2006-07-30.
17. "Decision support systems ." 26 July 2005. 17 Feb. 2009 http://www.openclinical.org/dss.html
18. Berner, Eta S., ed. Clinical Decision Support Systems. New York, NY: Springer, 2007.
19. Garg AX, Adhikari NK, McDonald H, Rosas-Arellano MP, Devereaux PJ, Beyene J et al. (2005). "Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review." JAMA 293 (10): 1223–38. doi:10.1001/jama.293.10.1223. PMID 15755945.
20. Kensaku Kawamoto, Caitlin A Houlihan, E Andrew Balas, David F Lobach. (2005). "Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success." BMJ 330 (7494): 765. doi:10.1136/bmj.38398.500764.8F. PMC 555881. PMID 15767266.
21. Timothy P. Hofer, MD (November 2000). What Is an Error? Effective Clinical Practice (American College of Physicians).
22. Rodney A. Hayward, MD (July 25, 2001). "Estimating Hospital Deaths Due to Medical Errors: Preventability Is in the Eye of the Reviewer." JAMA 286 (4): 415–20. doi:10.1001/jama.286.4.415. PMID 11466119.

23. Timothy P. Hofer, MD (November 2000). What Is an Error? Effective Clinical Practice (American College of Physicians).
24. Brennan T, Leape L, Laird N, Hebert L, Localio A, Lawthers A, Newhouse J, Weiler P, Hiatt H (1991). "Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I". N Engl J Med 324 (6): 370–6. doi:10.1056/NEJM199102073240604. PMID 1987460.
25. Lucas B, Evans A, Reilly B, Khodakov Y, Perumal K, Rohr L, Akamah J, Alausa T, Smith C, Smith J (2004). "The Impact of Evidence on Physicians' Inpatient Treatment Decisions". J Gen Intern Med 19 (5 Pt 1): 402–9. doi:10.1111/j.1525-1497.2004.30306.x. PMC 1492243. PMID 15109337.
26. McGlynn EA, Asch SM, Adams J, Keesey J, Hicks J, DeCristofaro A, Kerr EA. The quality of health care delivered to adults in the United States. N Engl J Med. 2003;348 pp. 2635-45. PMID 12826639
27. Fisher ES (October 2003). "Medical Care — Is More Always Better?" N Engl J Med 349 (17): 1665–7. doi:10.1056/NEJMe038149. PMID 14573739.
28. The Anesthesia Patient Safety Foundation, A Brief History
29. Smaltz, Detlev and Eta Berner. The Executive's Guide to Electronic Health Records.' (2007, Health Administration Press) p.03
30. Hsiao, Chun-Ju; et al (Dec 8, 2010). "Electronic Medical Record/Electronic Health Record Systems of Office-based Physicians: United States, 2009 and Preliminary 2010 State Estimates". NCHS Health E-Stat. CDC/National Center for Health Statistics. Retrieved 31 October 2011.
31. "TechnologyAdvice EHR Buyer's Guide". TechnologyAdvice. Retrieved May 25, 2014.
32. Chaudhry B1, Wang J, Wu S, Maglione M, Mojica W, Roth E, Morton SC, Shekelle PG. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. Ann Intern Med. 2006 May 16; 144(10):742-52. Epub 2006 Apr 11.
33. https://oig.hhs.gov/United States Department of Health and Human Servi...The HHS OIG is the largest inspector general's office in the Federal ... of Health and Human Services • Department of Health and Human Services Logo.Exclusions - Reports & Publications - Compliance Guidance - Contact Us
34. www.propublica.org/.../how-many-die-from-medical-mistakes...ProPublica Sep 19, 2013 - An updated estimate says at least 210,000 patients die from medical mistakes in U.S. hospitals a year. (File, Scott Olson/Getty Images).
35. www.fiercehealthcare.com/story/hospital...death...to.../2013-09-20 Sep 20, 2013 - Medical errors leading to patient death are much higher than previously thought, and may be as high as 400000 deaths a year, according to a ...

36. www.forbes.com/.../stunning-news-on-preventable-deaths-in-hosp...Forbes. Sep 23, 2013 - According to a new study just out from the prestigious Journal of Patient Safety, four times as many people die from preventable medical errors ...