

REVIEWS

Integration of health information technology to improve patient safety

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Abstract

Background: Medical errors and unsafe care continue to harm and kill thousands of patients every year, exceeding deaths attributed to motor vehicle accidents, heart failure and breast cancer. It has been more than ten years since the Institute of Medicine (IOM) released two landmark reports that galvanized attention on the scope and severity of the problem and started a national movement to improve patient safety in healthcare. Both of these reports emphasized the role that health information technology (HIT) can play in improving the quality and safety of patient care. This has lead federal and state legislators to prominently feature HIT, patient safety, and quality outcomes in the current health care debate, laws, and payment schemes. The objective of this systematic literature review is to assess current and proposed use of technology to prevent adverse events and the regulatory drivers that are promoting the use of technology for patient safety.

Methods: A systematic literature search from 2010-2013 using CINAHL, Cochrane Library, Medline and Ovid (via EBSCO), Google Scholar and government web sites, was conducted to identify technology drivers, advancements and effects in the patient safety areas of electronic health records, patient identification, patient falls, pressure ulcers, and medication errors.

Results: Forty four articles were selected for inclusion in this review addressing legal and regulatory drivers for use of technology to support patient safety, and specific technologies to prevent adverse events related to patient identification, patient falls, pressure ulcers, and medication errors. Search criteria included technology to prevent each of these event types, and the Affordable Care Act (ACA), American Reinvestment and Recovery Act (ARRA), and the Health Information Technology for Economic and Clinical Health (HITECH) provisions related to patient safety.

Conclusion: Healthcare reform initiatives are promoting an expanded role for HIT in improving the safety and quality of patient care in the U.S. healthcare system. Findings suggest that there are several technologies currently in development and use to prevent adverse events in patients. While patient safety technology shows great promise in preventing error and injury, it also presents potential to harm if not effectively developed, implemented and used. It is an adjunct to, not a replacement of, a skilled and attentive care giver.

Key words

Patient safety, Technology and patient safety, Falls, Pressure ulcers, Medication errors, Patient ID, Electronic Medical Record and patient safety, Electronic Health Record and patient safety

1 Introduction

Health information technology (HIT) is not one specific product, but is rather a system of computers, software and devices that functions within an organization of people, processes and workflow. While use of technology cannot assure patient safety, when designed and used appropriately, it can help to create an environment of safer care and improve clinical performance, communication, and operational efficiency ^[1].

The push for technology as a support for patient safety has been driven by several momentous studies and national legislation in the last fifteen years, starting when the Institute of Medicine (IOM) published *To Err is Human: Building a Safer Health System* in 2000. *To Err is Human* was a wake-up call to the American public and the healthcare industry to the hazards facing patients during hospitalization in the United States. The report estimated that 44,000 to 98,000 deaths per year were due to hospital errors and that such errors resulted in hundreds of thousands of avoidable injuries and extra days of hospitalization. This seminal work started the patient safety movement in the United States and resulted in calls for reform ^[2].

2 Methods

A systematic literature search from 2010 to 2013 was conducted by the author using CINAHL, Cochrane Library, Medline and Ovid (via EBSCO), Google Scholar and government web sites to identify technology drivers, advancements and effects in the patient safety areas of electronic health records, patient identification, patient falls, pressure ulcers, and medication errors. Forty four articles were selected for inclusion in this review.

3 Regulatory drivers of technology in healthcare quality and patient safety

3.1 Health Information Technology for Economic and Clinical Health (HITECH)

In 2009, the call to action was answered with passage of the American Recovery and Reinvestment Act (ARRA) and its Health Information Technology for Economic and Clinical Health (HITECH) provisions. HITECH was designed to stimulate the adoption of health information technology, but in a broader sense, it provides the framework for efforts to restructure healthcare delivery ^[3].

Working toward the goal of bringing electronic health records to all Americans by 2014, HITECH is laying the groundwork for health care reform by providing approximately \$30 billion in incentive payments to eligible providers and hospitals for demonstrating meaningful use of certified health care technology. The aims of meaningful use include improving quality, safety and efficiency of care while reducing disparities in access and health; promoting public and population health; engaging patients and families in their own care; improving care coordination; and promoting the privacy and security of electronic health records. The legislation made clear that meaningful use of health IT can make quality measurement and improvement efforts more relevant, timely and effective ^[3].

HITECH's goal is not adoption alone but significant improvements in care. In order to qualify for incentive payments, eligible providers must use a certified electronic health records and meet a set of core objectives that enable the EHR to support improved health care. In addition, the provider can choose any five of ten additional tasks to implement in 2011-2012. The entire program will roll out in three stages: Stage 1 (2011-2012) - Data capture and sharing; Stage 2 (2014) – Advanced clinical processes; Stage 3 (2016) – Improved outcomes ^[4].

3.2 The Patient Protection and Affordable Care Act (ACA)

The Patient Protection and Affordable Care Act (ACA), signed into law in 2010, builds on the infrastructure started by the HITECH act, leveraging the expanded use of HIT to collect and aggregate data. Along with the goal of near-universal healthcare coverage, the ACA intends to realign the healthcare system for long-term changes in healthcare quality, health information transparency and the design of healthcare practice^[3].

Several sections of the ACA discuss health care quality and its measurement, including the use of technology to collect, aggregate, and report data on population health in an effort to improve quality, effectiveness, transparency and outcomes. Section 3013 mandates development of quality measures and use of information technology to promote safety, effectiveness, patient-centeredness, appropriateness, timeliness and efficiency of patient care^[2].

These initiatives are intended to push health professionals to work in a more clinically integrated way, measure the quality of their care, report their performance, and target serious and chronic conditions that result in frequent hospital admissions and readmission. A provision in the law requires health plans to submit an annual report of their efforts to improve health outcomes, prevent hospital readmissions, ensure patient safety and reduce medical errors, and implement wellness and health promotion activities^[5].

The ACA also established the Hospital Value-based Purchasing (VBP) Program, a pay-for-performance approach that is now a Centers for Medicare and Medicaid Services (CMS) initiative to reward acute-care hospitals with incentive payments for the quality of care they provide to Medicare patients. VBP has accelerated adoption of quality and outcomes-based contracting with payment linked to performance, reporting or participation in regional and multistate collaborative^[6].

Specifically, the program measures how closely best clinical practices are followed and how well hospitals enhance the patient care experience during a hospital stay. Under this program, hospitals are rewarded based on either how well they perform or how much they improve their performance on a set of measures and dimensions, grouped into specific quality domains: Clinical process of care, patient experience, outcome, and efficiency. The domains are weighted and become progressively more focused on patient outcomes over the three years of implementation, 2013-2015. Clinical outcomes account for 30% of Medicare payments in 2015^[7].

The VBP program assesses quality and value through a set of 12 clinical quality measures and a composite measure of patient experience that center on reducing readmissions rates, preventing surgical and hospital errors and linking payment to patient experience scores, specifically the Hospital Consumer Assessment of Healthcare Providers and Suppliers (HCAHPS) scores. Hospitals that achieve specified quality measures will receive higher payment, while those that fail will see payment reductions. This creates a powerful financial incentive to improve quality and patient safety^[8].

The ACA mandates use of information technologies as tools to improve quality, integrate care among care givers and ease transitions in care. While technology is not the answer in and of itself, it can be used to support clinical, financial and operational decisions that can improve quality and outcomes^[9].

Technology includes information systems and a wide range of medical devices that have been developed to prevent hospital acquired conditions (HAC). ACA and HITECH have linked quality and technology, and ACA has linked quality to reimbursement. This has resulted in increased interest in technology to support patient safety and prevent patient harm. At the core of these technologies is the electronic health record (EHR).

3.3 Electronic Health Record (EHR)

Electronic Health Records (EHRs) are an essential component of the regulatory drivers to use technology to promote patient safety. Because of the legal and financial mandates to implement an EHR, the number of EHR certified vendors has increased from 60 in mid-1980 to more than 1000 in early-2013^[18].

While EHRs were originally created to collect, store and retrieve patient care data as a digital form of the paper medical record, they have evolved far beyond mere transactions and storage. Today's EHR provides clinical decision support that is vital to meeting regulatory requirements and supporting patient safety. Clinicians have come to expect their EHR to support delivery of high-quality patient care in a variety of ways, including data collection and reporting, facilitating communication, providing decision support, engaging patients, and reducing medical errors ^[1].

A clinical decision support system (CDS) embedded in an EHR can effectively screen and alert clinicians to adverse conditions. The CDS can monitor patient conditions, medications and treatments to provide evidence-based clinical suggestions to care givers at the point of care. A well designed CDS can suggest potential diagnoses and treatment, monitor patient condition, and through rules and algorithms, identify potential and actual adverse events. The system can then alert the clinician to changes in the patient condition. Alerts come in many forms, including audible sounds, flashing lights and pop-up messages on the screen. Finally, the CDS can facilitate aggregating and extracting the data required for regulatory reporting ^[1].

Implementation of an EHR and CDS has great potential to improve quality, safety and outcomes, and reduce costs. Although they may prevent common errors, they may also introduce new risks to patient care. They are dependent on their design, the training of their users, and a host of human errors, such as patient misidentification. Users can suffer from alert fatigue and override this feature ^[11]. Great care and leadership is essential to acquisition, development, implementation and use of an EHR. Done correctly, this technology can be used to more efficiently track, aggregate, and report patient data within and across organizations ^[12].

4 Technologies to prevent patient misidentification, medication errors, falls and pressure ulcers

4.1 Misidentification prevention

Patient identification is a fundamental building block of patient safety ^[13]. In fact, positive patient identification tops the list of National Patient Safety Goals set forth annually by the Joint Commission ^[14, 15]. Correctly identifying patients at the point of entry is the first step in patient safety, but too often patients are misidentified due to simple clerical errors, technological failures, and even misrepresentations by the patient ^[16].

Three scenarios exist in relation to identification of the patient upon admission: a correct registration results when a single patient has a single medical record, a duplicate record results when a single patient has more than one medical record, and a commingled record results when a single medical record consists of information about two or more patients. The latter two are associated with an increase in adverse outcomes. Common errors that result from misidentification of patients include mislabeled specimens, medication errors, and "wrong-patient" errors ^[17].

Several technological approaches to preventing misidentification of patients exist in today's healthcare market. Three of the most popular are bar-codes, radio frequency identification tags, and various forms of biometrics.

One-dimensional (1D) bar-codes are a vintage form of graphical encoding that uses a combination of black and white parallel and adjacent lines of varying thickness to represent information. The information is not descriptive, but is stored as a reference code that is associated with a database that contains relevant information. The codes are read and automatically decoded by special bar-code reading devices. The traditional 1D bar-code was first developed by IBM in 1967. It can be printed on labels and patient wrist bands and is an effective means to positively identify patients ^[18].

The next generation bar-codes are two-dimensional (2D) and are capable of storing alphanumeric characters by means of planar distributed graphic patterns like dots, squares and triangles, etc. The 2D bar-code allows a greater data storage

density than the 1D bar-code and uses approximately one-tenth of the area needed to store the same amount of data. Another advantage is that many 2D bar-codes can now be decoded with a smart phone, minimizing the need for special readers^[18].

Radio Frequency Identification (RFID) technology can automatically identify patients by placing RFID tags on them and then remotely reading the tag by use of a specialized reader. In the healthcare environment, RFID has been used for positive patient identification (PPI); real-time asset, staff and patient tracking; and medication control. RFID systems usually consist of a label (tag) containing a unique identification number (UIN) that is attached to the patient, the device that reads or writes information on the label, the transmitting antenna, and the computer system that processes the information captured on the label. RFID tags can store more data than a bar-code and do not require the short line-of-sight link between the reader and the tag that is required by bar-codes^[18]. An RFID tag can help track patients throughout a facility and collect data on queuing and wait times, while significantly improving PPI^[19]. Research is underway to imbed washable, wearable RFID antennas in material to create screen-printed textile-based RFID tags that can be worn by patients, eliminating the need to wear a separate RFID tag^[20].

Biometrics includes several technologies for verifying the identity of an individual according to physiological characteristics. Some of the more commonly used biometric identification techniques are fingerprint recognition, iris recognition and hand geometry.

Fingerprint recognition has been introduced in healthcare to identify patients by imaging and linking their unique fingerprints to their medical records. Developed by the FBI in the 1960s, automated fingerprint identification systems are based on fingerprint friction ridge details that are described in a hierarchical order at three levels: Level 1 (pattern), Level 2 (minutia points) and Level 3 (pores and ridge contours). Linking a patient's fingerprints to their records can be an effective asset in patient identification over time^[21].

Iris recognition utilizes technology to analyze the colored tissue surrounding the pupil. Hand geometry recognition measures the shape and geometric features of the human hand. While there is research into healthcare uses of these technologies, the cost of these systems is prohibitive in today's market^[21].

4.2 Medication error prevention

Medications represent the most common intervention in healthcare and account for an estimated 1.5 million adverse drug events each year^[22]. For this reason, hospital pharmacy practice was among the first in hospitals to adopt automation and information technology, and features prominently in several of the recent healthcare reform measures.

The American Recovery and Reinvestment Act (ARRA) and "meaningful use" regulations in 2009 and 2010 demonstrated a commitment by healthcare and government leadership to leverage HIT to improve the medication management process for safer medication administration. Specifically, these measures called for integration of an electronic medical record with a computerized provider order entry (CPOE) system and use of bar-code assisted medication administration (BCMA). After the meaningful use ruling in 2010, adoption of CPOE by hospitals increased from 19% in 2010 to 54% in 2012. Similar increases were seen in the use of BCMA, medication reconciliation systems and electronic medical records^[23].

While CPOE and an integrated decision support system can prevent errors in medication orders, most medication errors occur during medication administration. BCMA is a technology that is increasingly being adopted to prevent the incorrect administration of medications by improving compliance with checking the "five rights" of medication administration: Right patient, drug, route, dose and time. The right patient is identified by matching the unique bar-code on the patient's wristband to the patient identifiers in the patient's EHR. The right drug, route, dose and time are checked by matching the unique bar-code on every unit or multi-dose medication to those data in the electronic medication administration record (e-MAR). Used appropriately and consistently, BCMA has shown potential to reduce medication administration errors^[24].

Another technology that is reducing medication errors is the smart pump. Smart pumps are infusion pumps for administration of intravenous (IV) fluids and medications. They integrate advanced information technology with dose-error reduction software and an extensive IV drug library that contains safe dose ranges, recommended infusion rates, and medication and dilution factors. Many of these pumps can perform complex dosage calculations and alert care givers to a variety of potential errors before they result in an adverse event ^[25].

4.3 Fall prevention

The National Quality Forum (NQF) defines a patient fall as an unplanned descent to the floor or extension of the floor, like a trash can or piece of equipment, with or without injury to the patient ^[26]. Accidental patient falls are among the most common adverse events reported in hospitals and occur in approximately 2% of hospital stays. In U.S. hospitals the rate of falls ranges between 3.3 and 11.5 per 1000 admissions, with approximately 25% of those falls resulting in injury ^[27]. The result is increased cost, length of stay and exposure to liability.

Effective October 1, 2008, CMS deemed patient falls a preventable hospital-acquired condition and no longer paid for health care costs resulting from falls that occurred during hospitalization. Patient falls are now considered an event that should never happen during a hospital stay ^[28].

Many methods to prevent patient falls are in use today. Administrative controls, such as fall risk assessments, color coded identification of patients at risk for falls and signs in rooms have been implemented with mixed results. Engineering controls, such as bed rails, bed alarms and bed height adjustments, have also resulted in limited success ^[29]. A variety of technical controls are also being used, including bed and chair alarms, in-room webcams, and wearable sensors.

Alarms operate by use of one or two weight-sensitive sensor pads inside or on a bed, chair or even the commode. When contact with the sensor is broken, an alarm sounds in the patient room or at the nursing station. The belief is that activation of the alarm can reduce patient falls by alerting staff when patients at risk attempt to exit the bed or chair, and minimize or eliminate use of restraints; a CMS quality of care indicator ^[30].

Bed-directed webcams allow secure real-time video monitoring for continual observation of at risk patients by staff at the nurse's station. Use of infrared cameras provides night vision, allowing night viewing without disturbing the patient.

Virtual bedrails are invisible motion sensitive borders drawn on either side of the patient's bed. When the border is breached, it triggers an alarm which can be heard and seen on a monitor at the nurse's station. In trials, it was found that this technology most benefited elderly patients with dementia, post-surgical patients in their first twenty-four hours, alcohol withdrawal patients and psychiatric patients awaiting medical clearance. To make these systems cost effective, it is suggested that institutions have designated webcam rooms with virtual bed rails for high risk admissions ^[31].

Low-cost, light weight Body Sensor Networks (BSNs) consist of one or a combination of wearable sensors, such as accelerators and gyroscopes, and a data-transmission, data-logging, and data processing aggregator. These can be used to monitor temporal and spatial parameters of gait and can be an adjunct to assessment and monitoring of patients at risk for falls ^[32].

A small accelerator can be attached to the wrist and may, in the near future, be able to notify a remote party over the mobile phone network. Many of the new generation 'smart' phones are equipped with features such as built-in motion sensors and global positioning system (GPS) navigation that may make them useful to detect and report fall information via Bluetooth ^[33]. As computer software is perfected to acquire the appropriate accelerometer signals by and from mobile phones, this technology may become a viable option for consideration during discharge planning.

4.4 Pressure ulcer prevention

While pressure ulcers are highly preventable, their rate of occurrence continues to rise. It is estimated that in the United States each year, 2.5 million patients develop a hospital-acquired pressure ulcer and 60,000 patients die of pressure ulcer related complications ^[34].

The National Pressure Ulcer Advisory Panel (NPUAP) defines a pressure ulcer as a localized injury to the skin and/or underlying tissue, usually over a bony prominence, as the result of pressure or in combination with shear and/or friction. In 1989, the NPUAP developed a classification system for pressure ulcers to describe the appearance and severity of the wound ^[35]:

Stage I: Intact skin is reddened and does not blanch when light pressure is applied.

Stage II: Partial loss of thickness of the dermis.

Stage III: Loss of full thickness tissue.

Stage IV: Loss of full thickness tissue, with exposed bone, tendon or muscle.

Unstageable: Loss of full thickness tissue, but covered by slough and/or eschar.

Suspected Deep Tissue Injury: Localized, discolored, intact skin caused by damage by pressure or shear.

Development of a pressure ulcer is considered an indicator of overall poor quality care in a hospital. In 2003, NQF created Never Events; adverse patient events that should never happen during a hospitalization. The NQF considers Stage III and IV pressure ulcers as such events. In response, in 2008, CMS announced that it would no longer pay the additional cost of treating Never Events, including Stage III and IV pressure ulcers ^[36].

The incentives for preventing development of an inpatient pressure ulcer are many, resulting in an increased interest in technology to assist in preventive interventions. The Institute for Clinical Systems Improvement (ICSI) states that a pressure ulcer prevention plan should include interventions to minimize pressure with off-loading, reduce or eliminate shear and friction, manage moisture, and maintain nutrition and hydration ^[37]. Technology solutions begin with a decision support system to identify patients at risk.

The ICSI reports that determinants of tissue tolerance include age, tissue mass, corticosteroid use, stress, temperature, medications, smoking and diseases that affect oxygen supply, hydration, protein and vitamin C deficiency, and blood pressure ^[37]. The decision support system of an electronic health record can be used to flag patients at risk for development of a pressure ulcer based on these criteria. Coupled with a skin assessment, early preventive measures can then be implemented to minimize pressure, friction, shear and moisture.

Shear occurs when a patient is positioned in a way that allows the patient to slide, causing stretching of capillaries and tissue, resulting in more tissue ischemia than would have occurred with pressure alone. Friction affects the outermost layers of skin by movement of the epidermis against an external surface ^[37]. Technology solutions include support surfaces that have been developed to alleviate pressure and support positioning.

The goal of pressure ulcer prevention interventions is to reduce the magnitude or the duration of pressure between a patient and a surface. Specialized support surfaces are used to redistribute pressure, reducing shear and controlling the local microclimate. These support surfaces can be broadly categorized as low-tech and high-tech ^[38].

Low-tech pressure relieving devices are designed to mold around the shape of the patient to distribute the patient's weight over a larger contact area, thus relieving localized pressure. These constant low-pressure devices (CLPs) are divided into types based on the level of their technological specifications. CLP devices such as foam, gel, foam and gel, air or water suspension overlays, mattresses or beds are classified as low-tech CLPs. High-tech CLPs include air-fluidized beds, in

which warmed air circulates through fine ceramic beads covered by a permeable sheet, and low-air loss beds, in which patient are supported by a series of air sacs in which warmed air passes ^[38].

High-tech pressure relieving devices vary the pressure beneath a patient mechanically, thereby reducing the duration of applied pressure. These alternating pressure (AP) devices create alternating high and low interface pressures between the patient's body and the support by sequential inflation and deflation of air-filled cells in the cushion, bed overlay or mattress. The depth of the air-cells, inflation cycle time, and mechanical strength varies between devices and should be taken into consideration when choosing the best application for the patient. Use of AP mattresses has been shown to reduce the onset of a pressure ulcer in hospitalized patients and reduce the associated cost of an ulcer by as much as 80% ^[38]. Further, AP mattresses have been found to be more effective than AP overlays at reducing pressure ulcers ^[39].

In addition to pressure relieving devices, the use of technology to monitor whether a patient is wet or dry is also gaining increased attention. Wetness detection in incontinent patients is accomplished through sensors built into a pad that is placed under the patient. When moisture is detected, the information can be wirelessly transmitted to a receiver at the nurses' station ^[40].

5 Conclusion

The cost of measurable medical errors is estimated to be \$17 billion per year. Incomplete, fragmented and poorly structured communications contribute to more than half of the errors that result in adverse and sentinel events. Communication software, technology and devices are rapidly expanding into all areas of health care and offer great promise to improve quality, safety and efficiency. While there are areas where patient care has clearly been enhanced by technology, its overall influence to improve care remains uncertain ^[41].

The healthcare industry is going through a period of rapid redesign in regulatory requirements, payment models, and traditional relationships. In a time of transition, where patients are becoming partners and compliance is becoming active participation, nursing sits at the forefront of change.

The nursing profession is the largest segment of the nation's health care workforce, with more than three million members. Nurses should be full partners in the redesign of health care, including its use of technology. Nursing leaders must plan for fundamental wide-ranging changes in staff education and skill sets to meet the challenges of a technological workplace ^[42].

Two essential requirements for the use of patient safety technology exist. Existing technology must be used to its fullest potential and new technology must be designed to be safe, patient-centered, efficient, and effective ^[43].

Several patient safety technologies are already available, but like any technology, they are effective only if they are used correctly. New technologies require that effort and time be invested to assure that staff is aware of the technologies, know when and whether they are indicated and understand how to use them to maximum effectiveness. This calls for leadership ^[43].

Nursing leaders have a responsibility to enable safer patient care by leveraging HIT. As the care givers who are closest to the patient, nurses will play a critical role in working with and benefitting from patient safety technologies. Nurse leaders must be involved with all HIT discussions and decisions. All nurses will need an enhanced level of competency in HIT in order to translate, synthesize, interpret and manage clinical data and devices for positive patient outcomes. The demands of increasingly sophisticated and technologically advanced patient care and the realities of pay-for-performance will be demanding, but the rewards will be many and long-term ^[44].

Healthcare reform initiatives are promoting an expanded role for HIT in improving the safety and quality of patient care in the U.S. healthcare system. Findings suggest that there are several technologies currently in development and use to prevent adverse events in patients. While patient safety technology shows great promise in preventing error and injury, it

also presents potential to harm if not effectively developed, implemented and used. It is an adjunct to, not a replacement of, a skilled and attentive care giver.

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