ICUs and the Electronic Health Record: Friends or Foes?

Jennifer A. LaRosa, FCCM, FCCP

Objectives
- Understand the basic components of an electronic health record (EHR)
- Appreciate some of the more relevant benefits and pitfalls of EHRs
- Discuss the limited data that exist regarding the effects of EHRs on critical care patient safety, quality, and outcome metrics

Key words: electronic health record; quality, safety, and outcome metrics; computerized provider order entry; clinical decision support

Technological advances have exploded over the last century and a half in nearly all walks of life. The use of computer technology in the ICU is no exception, and providers have struggled to appreciate, understand, and adapt to the rapid pace of these advances. The purpose of this chapter is to familiarize the reader with the basic elements of an electronic health record (EHR), to discuss the benefits and pitfalls of such systems, and to highlight some of the more relevant ways in which EHRs may affect ICU quality, safety, and outcomes. This chapter is by no means exhaustive, and a number of areas of computer technology, such as telemedicine and EHR implementation, are beyond the scope of this chapter.

History

Before the EHR was created, the organization of medical thought processes and subsequent documentation were understood to be imperative to meaningful care. An innovator regarding the interaction of this thought process with electronics was Dr Lawrence Weed, a physician at the University of Vermont, who in the 1960s pioneered the “problem-oriented medical record.” Dr Weed believed that the computer, in addition to organizing findings, ancillary studies, differential diagnoses, and treatment plans, was a critical element in storing and sharing this information. In the early 1970s the Regenstrief Institute of Indiana became one of the first medical centers to formally launch an electronic medical record, but it was not until 1991 that the Institute of Medicine recommended that all physicians adopt formal EHRs before the year 2000 (a recommendation that was repeated in 1999 in the Institute of Medicine’s To Err Is Human®). This goal was not realized. In fact, most medical centers, acute and chronic healthcare facilities, and private offices fell far short. Between 2004 and 2005, the Agency for Healthcare Research and Quality, a division of the Department of Health and Human Services, grant-funded more than $166 million to explore the impact of healthcare information technology on safety, quality, and outcome metrics. In 2009, the Health Information Technology for Economic and Clinical Health Act (HITECH Act) was passed, which allocated more than $24 billion to incentivize providers and medical centers to adopt EHRs. The Centers for Medicare and Medicaid Services (CMS; another division of the Department of Health and Human Services) echoed this effort by launching meaningful use, a 3-stage plan (intended to be completed in 2016) to implement and integrate EHRs ubiquitously and to use the EHR as a platform for reducing patient harm, ensuring quality of care, optimizing outcomes, and measuring these metrics. Of those acute care centers that are eligible for the CMS meaningful use program, an estimated 95% participate. Despite these compelling data and generous incentives, EHRs have not been universally implemented, and their impact on safety and quality metrics remains controversial. The United States lags far behind many industrialized countries in this effort. A 2012 study estimated that only 46% of US office-based practices were using EHRs. At the end of 2015, the estimate reached 56%,
a rather impotent increase for a 3-year period. Acute care hospitals fared better than ambulatory settings, in part because such hospitals have more financial resources to support the implementation of such a costly endeavor. Figure 1 illustrates the notable increase in implementation and use of EHR systems in different types of US acute care hospitals. Figure 2 lists the nearly 200 EHRs from which acute care hospitals can choose; unfortunately, few if any of the available EHR systems are able to communicate with each other.

In stark contrast, Denmark has had a single, fully functioning EHR since 2008; all providers and patients in the country have access to this EHR, and it communicates fluidly with hospitals, outpatient clinics, pharmacies, and other satellite providers.

Definitions

Although the terms electronic medical record (EMR) and electronic health record (EHR) are often used interchangeably, these systems are considerably different entities. An EMR is a patient- and practice-specific digital system that organizes and houses patient data: provider notes, ancillary studies, and registration details. However, the EMR is not transferable outside of the practice in which it resides. The EHR, in contrast, is a considerably more comprehensive system that essentially houses the same information but can be shared between practices, can download and synthesize data and trends in direct concert with meaningful use goals, and can include interactions and communications with the patient. Because a variety of EHRs are available and because these EHRs rarely talk to one another, even the most comprehensive system has limitations. The remainder of this chapter focuses on EHRs.

Figure 1. Adoption of commercially available acute care electronic health records

Office of the National Coordinator for Health Information Technology. ‘Non-federal Acute Care Hospital Electronic Health Record Adoption,’ Health IT Quick-Stat #47. dashboard.healthit.gov/quickstats/pages/FIG-Hospital-EHR-Adoption.php. May 2016.
EHRs, as stated above, are essentially comprehensive, detailed versions of the old paper medical record. They contain several components:

- Patient demographics and registration data, which may include, but are not limited to, the patient’s name, birthdate, contact information, insurance, advance directives, and next of kin or healthcare proxy information

- Clinical data, which make up the largest component of the EHR and include provider and consultant notes, admission status, medication orders, and clinical decision support platforms (discussed below)

- Patient prescription platform, wherein medication management and adjustments are made directly with the patient and pharmacy

- Patient portal, wherein patients and providers can access data and communicate with each other

Two of the most important elements of the EHR are computerized provider order entry (CPOE) and clinical decision support (CDS). Both are part of the stage 2 meaningful use guidelines as published and recommended by CMS.

**Computerized Provider Order Entry**

Errors related to ordering, particularly of medications, can (and often do) have serious and even fatal consequences. CMS defines an adverse event as “an untoward, undesirable, and usually unanticipated event that causes death, serious injury, harm, or the risk thereof” and further defines an adverse drug event (ADE) as “an injury resulting from drug-related medical interventions.” Rates of medication errors are difficult to consistently assess, and there is enormous variability in reporting. Estimates range from 1.2 to 947 errors per 1,000 patient ICU days in adults, with an overall estimate of 6% of all medication administrations being associated with 1 or more errors. In the critical care
setting, the most common offenders are sedatives, analgesics, antibiotics, and cardiovascular medications.\textsuperscript{12}

CPOE was initially developed as a response to such events and to reduce medication errors and subsequent harm. Currently, CMS recommends that CPOE be used for all provider orders related to all medications; laboratory, radiological, and other ancillary testing; and consultation requests for other providers. The alternatives to placing medication orders digitally are variable (and arguably archaic) and include writing on paper and having someone else transcribe, giving nurses telephone or verbal orders, and faxing orders, again for transcription. Of the 4 stages of medication delivery (prescribing, transcribing, dispensing, and administering), both ordering and transcribing are considerably safer with CPOE than with older methods.\textsuperscript{13} Medication CPOE also offers the advantage of incorporating dosing and frequency guidelines and limitations as well as drug interactions and allergies, most of which are shared with physicians by pop-up alert. Given that medication errors are considerably more common than other types of medical errors (or at least reported with greater frequency) and often incur greater morbidity and mortality in ICUs,\textsuperscript{14} the importance of an effective and consistent CPOE platform cannot be overstated. A 2004 study by Potts and colleagues\textsuperscript{15} revealed that implementation of CPOE virtually eliminated prescribing errors and rule violations but had little impact on the frequency of ADEs. This finding is not particularly surprising since ADEs are typically the result of the medication itself and not the manner in which it was prescribed. A study by Poon and colleagues\textsuperscript{16} published in The New England Journal Medicine in 2010 demonstrated that the addition of bar coding technology to a CPOE system could reduce administration errors by up to 41% and cut overall ADEs by up to 51%. A widely recognized study by Mullett and colleagues\textsuperscript{17} in the pediatric population demonstrated a 55% decrease in medication safety events after a CPOE was installed and implemented.

CPOE is, however, not without fallibility. A 2006 review by van der Sijs and colleagues\textsuperscript{18} revealed that prescribers may ignore or bypass medication safety alerts as frequently as 49% to 96% of time. This staggering figure is only partially offset by the safety limitations in dosing and frequency that are inherent in most EHRs.

CMS currently measures the compliance rate of hospitals that are participating in the incentive program (see above) and reimbursing appropriately. Those providers or systems that do not participate in meaningful use are not measured with regard to CPOE, but it can be surmised that their rates of compliance may be considerably lower since they have variable operating systems and lack financial incentive to achieve this goal consistently.

**Clinical Decision Support**

Similar to CPOE, at least in theory, CDS platforms are probably the most relevant and applicable elements of the modern EHR. Like CPOE, CDS platforms are intended to maximize compliance with disease-specific guidelines, to alert providers to potential or existing means of harm, and to guide the progression of patient care, thereby optimizing quality, safety, and efficiency. CPOE is, in fact, incorporated into CMS’s definition of CDS. CDS programs take many forms and can include disease-specific references and order sets, templated notes, pop-up alerts, and more. Such programs are intended to be evidence based, widely accepted, and to augment a provider’s clinical acumen, not replace it. An example in this author’s practice, and among many other ICUs in the United States, is the Surviving Sepsis Campaign guidelines to reduce morbidity and mortality related to severe sepsis and septic shock.\textsuperscript{19} The Cerner EHR (Cerner Corp, North Kansas City, MO) supports an alert for patients with known or suspected severe sepsis or septic shock. The software (known as the St. John Sepsis Agent) works by setting a number of factors (vital signs, laboratory values, documentation of known or suspected infection) at levels whereby
the computer will alert the provider if 3 or more
criteria are met within a given time period. For
example, the St. John system may designate
heart rate, respiratory rate, temperature, blood
pressure, and white blood cell count as triggers,
and when 3 or more of these parameters fall out-
side of range (which can be determined by each
practice), the system notifies the provider that a
patient may be septic. This, in turn, prompts the
provider to investigate the abnormalities, poten-
tially diagnose a patient as having septic shock,
and then use the Sepsis Order Set to complete
the 3- and 6-hour bundle elements as recom-
pended by the Surviving Sepsis Campaign.
The order set is site specific, developed by
each facility in concert with Cerner, and based
on the Surviving Sepsis Campaign guidelines.
Although the provider’s independent assessment
is not bypassed, this system supports his or her
ability to effectively and efficiently implement
the best, evidence-based care for the patient.

When investigating an electronic trigger-based
intervention, Murphy and colleagues21 noted
a statistically significant reduction in times to
complete diagnostic evaluation in patients at
risk for colorectal, prostate, and lung cancer.
Twice-monthly triggers alerted providers to
patients in their practice at risk of delayed
cancer screening. These triggers prompted pro-
vider intervention and resulted in more timely
completion of diagnostic testing for patients
at risk for colorectal and prostate cancers. The
study did not achieve statistical significance
with regard to those patients at risk for lung
cancer.

Similarly, a 2016 study by Churpek and col-
leagues22 investigated several computer-based
scoring systems that alert providers to subtle
signs of patient deterioration. The alerts were
1 of 3 types: single parameters (1 abnormal
value triggers the alert), multiple parameters
(2 or more abnormal values trigger the alert),
and aggregate weighted systems (2 or more
abnormal values are given weights of applicabil-
ity and severity to predict clinical significance).
Not surprisingly, the aggregate weighted
systems were the gold standard and were best at
accurately predicting cardiac arrest, the need for
ICU transfer, and even mortality.

The Pros And Cons Of The EHR

Copy and Paste

The function of copying and pasting another
provider’s notes is extraordinarily common and
probably the single biggest drawback of EHRs.
The risks of this function clearly outweigh the
benefits. In addition to enabling a provider to
commit an ethical violation (ie, not doing one’s
own work), this function carries other untoward
effects, notably “(in)accuracy” and “note bloat.”

• (In)accuracy: The copy and paste function
allows providers to copy others work and cite
it as their own. It also allows overwhelmed
trainees to “take a history” by copying another
provider’s history into their own note, thereby
reducing patient-provider contact and decreas-
ing the usefulness of different providers
getting the “same story.” Providers may not
even take a history or do a physical exam and
just copy someone else’s work. This example
is applicable not only to history taking but
to all aspects of the patient evaluation and
assessment. Not only does this practice lead to
serious potential confusion regarding author-
ship and responsibility, it greatly reduces
the likelihood that a different examiner or
history-taker will obtain critical information
that someone else missed.

• Note bloat: Copy and paste allows providers
to populate a note with enormous amounts of
information, a phenomenon known as “note
bloat.” Readers find themselves lost in a sea of
vital signs and laboratory values and are often
unable to determine what, if any, actual diag-
noses or recommendations are being made.

Academic medical centers are often the greatest
offenders regarding the copy and paste (dys-
function. In a 2013 publication, Thornton and
colleagues23 reported that 82% of house staff
and 74% of attending physician staff used the
copy and paste function in at least 20% of each
note. All aspects of the medical chart were
implicated in some copy and paste function.23
The ultimate impact of the copy and paste function on actual safety events or harmful errors is unknown. Dr William Hersh of the Oregon Health Sciences University and Dr Robert Hirschtick of Northwest University Medical Center have been two of the most prolific writers on this subject, and they have provided direct examples of patient harm and poor-quality care as a result of the copy and paste function.\(^{24,25}\)

Randomized controlled trials, although challenging to undertake, may be necessary to prove harm and to incentivize hospitals and EHR leaders to remove or modify this function. In the meantime, virtually every healthcare agency involved in the dissemination of quality excellence and best practices has released guidelines as to the safe use of the copy and paste function. Unfortunately, these are rarely followed.

**Order Sets, Templates, and Alerts**

CDS and CPOE are constructs for which order sets and template notes were created. CDS and CPOE are based largely on the success of the checklist\(^{26}\) and have clearly improved safety measures in distinct areas. Both order sets and template notes save time, avoid errors due to “doctor handwriting,” increase the accuracy of coding and billing, and remind providers of critical elements to include in their care plans and narratives. Various studies have demonstrated increased compliance with vaccine administration, skin breakdown prevention, and venous thromboembolism prophylaxis and reductions in duplicate testing through the use of order sets and alerts.\(^{27}\) Similarly, a 2016 study by Moon and colleagues\(^{28}\) demonstrated that the combination of a mnemonic handover reminder and templated tool increased provider satisfaction when transferring care from the postanesthesia care unit to the ICU.

However, these functions of the EHR are not without liability and risk. Order sets and templates are typically based on the patient’s chief complaint or what the first provider perceives the chief complaint to be. This may ultimately have little or nothing to do with the patient’s actual medical problem and may lead erroneously to the use of an order set or a template, or both, that have nothing to do with the problem at hand. For example, if a patient is admitted to the ICU with chest pain and the admitting physician’s working diagnosis is non-ST-segment elevation myocardial infarction, he or she will likely use an “acute coronary syndrome” (ACS) order set and the patient will likely receive both aspirin and heparin (or equivalents). If the patient in fact has an aortic dissection (as demonstrated after further investigation with bilateral blood pressure measurements, chest radiography, or even computed tomography of the chest), the choice of the ACS order set (and, to a lesser extent, template) may be disastrous. Similarly, one EHR screens charts for predetermined parameters that may trigger an early alert for sepsis; the EHR then sends the provider an alert to use the sepsis order set based on the Surviving Sepsis Campaign guidelines, which has been shown to save lives. Understandably, busy providers may not remember every bundle element, may be reminded by the order set, and may thereby complete a combination of diagnostics and treatments that collectively have demonstrated increased survival. Of note, CMS has recently amplified its efforts in sepsis treatment, and sepsis chart reviews are subject to the all-or-none phenomenon. Either all bundle elements are met and the chart passes, or any one element may be missed and the chart fails. The benefit of the sepsis order set to both the patient and the provider, in this instance, cannot be overstated. As with the copy and paste function, there are numerous anecdotal reports of both roaring success and unmitigated disaster with such order sets, templates, and alerts. This aspect of the EHR requires more sophisticated investigations to determine its true impact on safety and quality.

**Communication and Currency**

Among the ways to improve the EHR, the following are worth noting: Ensure that EHR order sets and templates are updated regularly with the most recent evidence-based guidelines, state how critical values are managed to ensure safety, and note that different EHRs do (or do not) communicate with one another. This latter
is particularly relevant in US medicine. As of June 2016, there were 632 office-based and almost 175 hospital-based EHRs from which to choose, and few of them can communicate with each other. Even when hospital-based EHRs share the same vendor as their contiguous ambulatory providers, the two systems may not communicate with each other. This clearly reduces the benefits promised by the EHR vision, and the impact on safety and quality is unknown.\textsuperscript{5}

**The EHR and ICU Quality, Safety, and Outcome Measures**

Patient safety, quality of care, and outcome measures in the ICU are areas of certain and considerable impact in the age of the EHR. How goals for improvement will be accomplished is not completely understood. Following is a discussion of 5 investigations of interest to intensivists. Both trainees and seasoned practitioners alike would be wise to consider engaging in research in this discipline.

In a 2011 randomized crossover investigation, Ahmed and colleagues\textsuperscript{29} compared 2 EHR user interfaces. One of these interfaces presented ICU data in the traditional EHR format wherein the provider has to sift through data points and pick out those that are relevant; the other interface presented ICU-specific “need to know” data points that the EHR considered relevant. The end points included task load, as measured by a modified NASA Task Load Index (TLX) tool; cognitive errors; and the time required to complete a task or series of tasks. Task completion time, task overload, and the number of errors were significantly reduced with the second interface. Although promising, the second type of interface (not unlike order sets and templates) guides providers toward a diagnostic and treatment plan that may, ultimately, be far from applicable.

Kahn and colleagues\textsuperscript{30} reported a quality improvement study led by the nursing staff at the University of Pittsburgh. The investigators hypothesized that direct and immediate communication reminders, gleaned from the EHR and delivered to the bedside ICU nurse, could increase compliance with best practice standards in the ICU. The study included 13,277 patients over an 18-month period, and end points included frequency of sedation vacations, rates of hospital-acquired infections, days on mechanical ventilation, ICU and hospital length of stay, and mortality. Although rates of hospital-acquired infections and mortality were not statistically different before and after the intervention, all other endpoints did achieve statistical significance. Had Dr Atul Gawande written *The Checklist Manifesto*\textsuperscript{26} after this manuscript was published, he might have used it as further evidence that checklists can be enormously effective.

Shaw and colleagues\textsuperscript{31} used an EHR to trigger updates to a patient safety dashboard in a pediatric ICU. The study team hypothesized that such updates would increase compliance with best practice guidelines. This hypothesis proved true with regard to obtaining informed consent, completing medicine reconciliation, and reducing the use of intravenous catheters. The study failed to show a difference with regard to venous thromboembolism prophylaxis, use of restraints, or prevention of skin breakdown. This study highlights the importance of not only provider communication but also EHR communication as a means of maximizing best practice compliance.

In a retrospective chart review, Flatow and colleagues\textsuperscript{32} sought to determine changes in the rates of central line–associated bloodstream infections, *Clostridium difficile* infection, and readmission, as well as length of stay, mortality, and number of diagnoses coded per case. The preintervention period was 2 years prior to implementation of an EHR, and the postintervention period was 2 years after implementation. Only reduced rates of mortality and central line–associated bloodstream infections reached statistical significance, and the impact of the EHR on these findings cannot be conclusively determined. However, this is one of very
few investigations using outcomes measures as a metric for EHRs.

In a prospective observational study, Hans and others33 investigated more than 700 patients in a medical ICU for 1 year and compared the purported effects of an EHR on mortality, length of stay (ICU and hospital), and medication errors. ICU length of stay, mortality, and medication errors all declined in a statistically significant fashion, but overall hospital length of stay did not. While this investigation is promising, it is difficult to unequivocally state that the EHR was the only factor responsible for this effect.

Future Aims and Expectations
The EHR of the future, at least for the ICU, looks something like this: A critical care nurse is assigned to evaluate a newly admitted patient. Before the nurse even enters the treatment room, she receives an alert that the last time the patient was in the ICU, he fell and sustained a head injury, and she is prompted to complete a fall risk assessment on him. After completing the fall risk assessment, she then measures his vital signs using an electronic device that feeds the information directly into the EHR. These vital signs are tracked along with laboratory and radiographic studies. Predetermined combinations of values and values consistent with early warning signs are synthesized, and real-time alerts are sent to providers when the computer finds a worrisome match. Providers are alerted as to likely causes of the abnormal values and are presented with order set and template options. When completed, such orders are communicated directly to pharmacy, nursing, radiology, and other relevant departments, wherein the urgency of the orders determines the next steps and how rapidly they must be completed. Data regarding compliance with quality metrics are collected, and reminders are generated to determine adherence to best practice guidelines. Ultimately, the patient receives the most efficient and effective care, errors are reduced, and safety is maximized. The finest and most modern tele-ICUs are beginning to resemble this scenario, one in which these factors operate seamlessly and efficiently. However, this is overwhelmingly the exception, not the rule, and it has been an enormously costly endeavor for those who have bravely gone first.

Summary
In addition to providing considerable organizational benefits, EHRs were developed in a concerted effort to reduce harm, to optimize the quality and consistency of care, to remind providers of best practice without robbing them of their autonomy, and to ultimately improve outcomes while simultaneously reducing healthcare costs. We are still truly at the inception of the age of technology in medical documentation and data sharing, at least in the United States. This discipline is ripe for study, modification, and optimization, and I am confident that many years from now, a discussion of the EHR will bear very little resemblance to this review.

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