Utilities of Electronic Medical Records to Improve Quality of Care for Acute Kidney Injury: Past, Present, Future

Kianoush Kashani\textsuperscript{a, b} Vitaly Herasevich\textsuperscript{c}

\textsuperscript{a}Division of Pulmonary and Critical Care Medicine, Department of Medicine, \textsuperscript{b}Division of Nephrology and Hypertension, Department of Medicine, and \textsuperscript{c}Department of Anesthesiology, Division of Critical Care, Mayo Clinic, Rochester, Minn., USA

### Key Words

Acute kidney injury · Electronic surveillance · Electronic health records

### Abstract

Electronic health records (EHRs) have become an integrated part of medical practice in most clinical settings around the world. Appropriate use of EHR potentially improves patient care while poorly designed EHR can cause harm. In recent years, EHR has been used as a platform to identify patients who have or may develop acute kidney injury (AKI). The benefit of using EHR for a rule-based classification of AKI has been controversial. While some reports indicate improvement in the process of care provided to AKI patients, other studies do not show significant changes in the outcomes. Utilities of EHR in AKI should go beyond a rule-based detection of the AKI as a syndrome. There are several different potential applications for such tools including AKI forecasting models and clinical decision support systems, to improve the quality of care and outcome of the patients with AKI. Both clinical and investigative interest in the field is growing among clinicians, administrators and scientists. Appropriate utilization of intelligent EHR can provide timely, appropriate and accurate information to the clinicians in order to improve the quality of care provided to critically ill patients and assist investigators to generate new knowledge. In this review paper, we discuss the past and present states of EHR role in the field of AKI. We also share our views regarding the future potentials and directions of these devices.

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### Introduction

Following implementation of the American Recovery and Reinvestment Act and the Health Information Technology for Economic and Clinical Health Act in 2009, Electronic Health Record (EHR) utilization to improve the quality of care has become a nationwide priority \cite{1, 2}. The Health Information Management Systems Society defines the EHR as ‘a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. The EHR automates and streamlines the clinician’s workflow. The EHR can

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create a complete record of a clinical patient encounter as well as supporting other care-related activities directly or indirectly via an interface, including evidence-based decision support, quality management and outcomes reporting [3].

Rule-based algorithms, using efficient EHR, have been able to facilitate the appropriate and early diagnosis of multiple clinical syndromes. Such tools have been used by several investigators to detect acute kidney injury (AKI) [4–7]. The impact of these tools on the quality of care has been variable among different reports [8]. Here, we review the progress made in this domain and also present the direction that EHR tools need to take to improve the care of patients with AKI.

**Historical Perspective**

Although the first medical records were documented as early as 1600 BC by Egyptians, the EHR is still very young. Weil et al. [9] recorded the first digital computer system utilization within the intensive care units (ICUs) in 1966. This study contributed to the birth of first generation EHRs, called the ‘collectors’. Further progress in the field of microprocessors and information technology allowed a more advanced generation of EHR to be born. The natural progress of EHR has converted this technology from a mere collecting or documenting tool, to the helpers (3rd generation EHR can collect episodic and encounter data and provide necessary decision support tools to assist clinicians in ambulatory and inpatient settings), partners (4th generation provides advanced decision support capabilities with accessibility across the continuum of care and contains sufficient credibility to be used as patient’s legal medical record) and mentors (5th generation includes sophisticated and fully integrated systems and is the primary source of decision support for clinicians and consumers) [10].

**Current State**

From 1992 to the present time, the 3rd generation of EHR has been the most commonly used version at the bedside. This generation has excellent portability and graphic interfaces along with network abilities. One of the major issues associated with this breed of EHRs is its fragmented nature. It generally uses several different platforms including, but not limited to, admissions, discharge and transfer, electronic medical record, computer-based provider order entry, clinical decision support system, laboratory information system and picture archiving and communication system. Fragmentation often avoids linking all patient information together and, therefore, does not allow the utilization of higher levels of artificial intelligence.

Although the appropriate use of EHR has been proven to improve the quality of care in the ICU [11], poorly designed EHR could result in harm [12]. In a recent systematic analysis, authors reported significant decline in hospital mortality when electronic surveillance and clinical decision support systems were used. They reported that no other benefit in mortality, length of stay or cost was observed when other EHR fragments were evaluated [13].

As EHR provided a significantly more efficient method for gathering information, it has generated some obstacles as well. One of the most common concerns from clinicians is information overload. Increased number of sophisticated tests, enhanced archival capability, decreased cost of data storage and increased sophistication of data delivery methods (including fast computers and networks, efficient archival and remote access) have contributed to this growing problem. Higher generation EHRs may offer means to facilitate access to patient records for care providers.

The Center for Medicare and Medicaid Services has outlined the following 3 stages during the EHR implementation. First, information should be electronically captured in a coded format. The EHR must possess the ability to communicate with different caretakers to provide better care coordination and to track key clinical conditions and report clinical quality and public health. The second stage is enabling the EHR to provide clinicians with disease and medication management information along with clinical decision support. The EHR should be able to offer information access to patients and communicate information needed for quality improvement and research. The EHR needs to act as a bridge between medical centers and public health agencies, which adds significant value by saving cost and enhancing the quality of care. In the third stage, the EHR should be enabled to achieve and improve performance, support care process and enhance the key health system outcomes [14].

**Automated AKI Alerts**

Using rule-based algorithms within an efficient EHR allows for classification of patients based on predefined rules to AKI versus no-AKI or different stages of AKI. AKI definition provided by the Kidney Disease: Improv-
ing Global Outcomes criteria based on absolute or relative changes in the serum creatinine level and urine output has provided a unified platform for quality and research in the field [15]. In recent years, precise rules for AKI definition enabled investigators to design and test electronic algorithms to detect patients with AKI using EHR. In a feasibility study, Thomas et al. [16] used integrated clinical environment pathology management software to detect AKI by assessing a 75% rise in the serum creatinine from the previous measured creatinine (positive predictive value of 60.6%). In a second feasibility study, Selby et al. [17] used the Modified Diet in Renal Disease equation for estimation of baseline serum creatinine to detect AKI and its stages in hospitalized patients. Colpaert et al. [18] in a prospective interventional study showed that using an EHR driven, rule-based, electronic surveillance tool increased the number of therapeutic interventions (including administration of fluids, diuretics and vasopressors) within 60 min of the alert. Patients in the intervention group had a higher chance to return to baseline kidney function within 8 h [4, 18]. Recently, a single-blinded, randomized controlled trial of 2,393 patients indicated that using an electronic alert system for AKI was not associated with improvement in outcomes among hospitalized patients. Also, among the patients in surgical wards in the intervention group, the number of nephrology consultations and dialysis orders were significantly higher [7]. Although the results were encouraging for the use of rule-based electronic surveillance tools, the study limitations make it difficult to dismiss the potential role of these devices in the care of patients with AKI. The expected value of the automated surveillance tools for detection of AKI is to identify AKI earlier so that clinicians can provide such patients with appropriate preventive and therapeutic measures while kidney injury is still reversible. In the study mentioned above, using serum creatinine criterion alone for determination of AKI limits the results. The small frequency of serum creatinine measurements and intrinsic limitations of serum creatinine for early detection of AKI restrict the generalizability of this study. Also, the authors did not provide any information regarding the validity and reliability of their tool.

**Other Applications of EHR in the Care of AKI**

The role of EHR in AKI could also be beyond simple rule-based syndrome detection. Electronic tools can contribute to the interpretation of clinical scenarios by the assimilation of data resulting in a holistic conceptual understanding of the patient’s prognosis, by optimizing or simplifying human–computer interaction in order to critique human decision to verify appropriateness, to generate diagnostic suggestions or even to assist patient management by implementing the automatic generation of action-oriented decisions.

As the volume and quality of information in EHRs has grown to include both susceptibilities and exposures, they could be used to predict the occurrence of clinical syndromes, including AKI. There are several AKI clinical risk stratification and forecasting models available for particular clinical scenarios including cardiovascular, general surgery and contrast-induced nephropathy. Although these models have fair to excellent performance, they have not been widely implemented at the bedside mainly due to difficulties in the real-time calculation and bedside interpretation of scores. EHR and electronic algorithms can facilitate the utilization of such models to improve the quality of patient care.

There are 2 different types of forecasting models for patients in the hospital or ICU. Static forecasting models are built once at some point in time to be used for forecasting forever in the future. Dynamic prediction models, however, include parameters that are frequently adjusted when new data becomes available and account for changes in the behavior of the phenomenon. Dynamic models are more accurate, particularly, for entities that have dynamic or changing behavior (e.g., AKI). In a static AKI model, a score is assigned to each patient that would be directly correlated with the risk of AKI development in the future. In a dynamic AKI model, however, many baseline, physiologic, hemodynamic, pharmacologic and pathophysiological variables affect the prediction of AKI and risk categories based on the influx of new information. Correct and timely AKI forecasting allows appropriate resource allocation, earlier interventions (prophylactic or therapeutic), meaningful counselling with patients and their families, dynamic updated risk estimation based on clinical interventions and dynamic personalized health status assessment. They also allow ‘what if’ scenarios to evaluate the impact of each potential intervention in the forecast. These models are of sufficient complexity to limit their bedside utilization unless an automated EHR-dependent algorithm can streamline this information for clinical use. Ideally, through the development and validation of forecasting models, EHRs provide clinicians with information that is equivalent to the guidance that Global Positioning System provides to drivers. Global Positioning System, by integrating data and knowledge with excellent visualization and rule-based systems to provide appropriate alerts, have enhanced the safety and quality of driving.
Future

An ideal future EHR in the field of AKI should possess several characteristics. It needs to have the ability to not only detect AKI but also to evaluate patients within a clinical context. For example, if a patient with septic shock develops AKI and is not appropriately resuscitated or receives nephrotoxin, the EHR needs to generate an alert. In contrast, if the same patient has received appropriate care for AKI including discontinued nephrotoxins, no signal should be made. This level of sophistication would thus avoid clinician distraction, particularly when they provide an established standard of care. Also, a well-designed EHR can reduce information overload by configuring the user interface to display preferentially subsets of task-specific data to bedside providers at the point of care. It also provides system surveillance of healthcare delivery and provides real-time feedback on performance regarding established standards of care. The AKI-related EHR tools need to be seamlessly integrated into the environment and workflow in a manner that exploits our understanding of distributed cognitive function and ‘choice architecture’ to optimize patient-centered outcomes. Future EHR would generate simulated data to be used in the development of sophisticated models of critical illness syndromes that will form the basis of comparative effectiveness research and in-silico clinical trials. It also supports cost-effective administrative decision-making support through automated measurements and analysis of processes of care essential to quality improvement initiatives. And finally, any future EHR should support the identification and recognition of patients with potential or established critical illness outside critical care areas for the purpose of timely clinical interventions and enrollment in clinical research trials.

Conclusion

Despite significant progress in the field of medical informatics and growing utilities of EHR to improve the quality of care to the AKI patients, these domains remain in the very early stages of development. Following the development and validation of electronic rule-based syndrome recognition tools, there is a critical need to enhance the intelligence of such instruments to support clinicians and investigators with the best known standard of care for every single patient by providing concise, reliable and accurate feedback in each step of their care. Precise and timely identification of patients who already have AKI or those who are high risk for this deadly syndrome provides the clinicians with appropriate decision support aids and enhances the capability of researchers to conduct safer and more efficient investigations.

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References


