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Impact of e-alert systems on the care of patients with acute kidney injury☆

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With the recent advancement in electronic health record systems and meaningful use of information technology incentive programs (i.e., the American Recovery and Reinvestment Act, the Health Information Technology for Economic and Clinical Health Act, and the Centers for Medicare & Medicaid Services), interest in clinical decision support systems has risen. These systems have been used to examine a variety of different syndromes with variable reported effects. In recent years, electronic alerts (e-alerts) have been implemented at various institutions to decrease the morbidity associated with acute kidney injury (AKI).

AKI is common, accounting for 1 in 7 hospital admissions, and is associated with increased length of hospital stay and mortality. AKI is often underrecognized, causing delayed intervention. The use of e-alerts may result in earlier recognition and intervention, as well as decreased morbidity and mortality. This must be balanced with the possibility of increased resource utilization that e-alerts may cause. Before widespread implementation, the ethical and legal consequences of not following e-alert recommendations must be established, and the optimal algorithm for AKI e-alert detection must be determined.

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Introduction

An automated electronic alert (e-alert) system that allows real-time reporting may facilitate early recognition of acute kidney injury (AKI), allowing for timely intervention and improved patient outcomes [1]. The e-alert is considered to be under the umbrella term of computerized clinical decision support systems (CCDSSs). CCDSSs use the electronic health record (EHR) to assist physicians in diagnosing and treating patients; in particular, these systems present physicians with individualized, point-of-care information with the goal of enhancing the quality and safety of care [2]. The impacts of e-alerts on the quality of care and patient safety have been tested in a variety of settings; however, most of the reports lack information on patient outcome, were designed with small sample size or retrospective structure, and focused mainly on the process of care. In the United States, the utilization of EHRs to collect and analyze patient-related information (i.e., the process of care and patient outcome) has progressively increased since the implementation of incentive programs by the Centers for Medicare & Medicaid Services. However, the majority of institutions in the US still use the basic form of EHR for patient care, without any capacity to implement e-alerts for clinical utilization [2–4].

Because AKI is a known complication of acute illness and has a substantial impact on patient outcome and hospital cost, it recently has been under consideration for the development and validation of e-alerts [1,2,5]. However, modern studies have shown contradicting results on the impact of AKI e-alerts on the process of care and patient outcome [5]. In this review, we outline the current state of AKI e-alert systems and future steps in advancing the field.

CCDSS characteristics

To plan and implement a successful CCDSS for any clinical syndrome, the infrastructure needs to have several characteristics, referred to as the “10 commandments” by Bates et al. [6], which are summarized in the following paragraphs.

Time sensitivity

AKI is a silent disease until it is not silent anymore. The diagnosis of AKI is often delayed because of the limitations of kidney functional biomarkers, and this precludes implementation of effective preventive measures [7]. As e-alerts have the capacity to use complex mathematical models to predict AKI (or at least detect it in a timely fashion), their use in the management of patients with AKI seems logical [8,9]. For providers to receive timely alerts, relevant data need to be available to the e-alert in real time, the software that handles this information needs to be fast, and the alerts need to be sent to the clinician immediately in an easy-to-access manner. Oh et al. [10] reported a qualitative set of interviews from providers who dealt with the AKI e-alert in a study that showed it to be unsuccessful. One provider stated, “The alert comes much too late. I have always recognized an AKI before getting the alert” [11].

Access to baseline information

When an e-alert submits a message to a clinician, it should be concise and informative, and the provider should have immediate access to the data that resulted in the alert. For example, if an AKI e-alert is sent with a statement that “Mr. Adams has AKI stage III,” the clinician should be able to access the patient's baseline information, including baseline serum creatinine, current creatinine, urine output, and the patient's weight with the click of a button. This information should also be linked to the patient data and knowledge content to outline the potential reasons for AKI, including a list of medications or recent exposures (e.g., sepsis, contrast, trauma). If the related information can provide recommendations (e.g., the need for antibiotic dose adjustments, suggesting alternative, less nephrotoxic medication [12]), it may have an even bigger impact on the prevention of AKI.

Incorporation into the workflow

AKI e-alerts need to be incorporated into the clinician's workflow. In most situations, the need to carry an additional communication device or to open separate software outside of the EHR platform decreases the ability of the provider receiving the alert or comply with its recommendations.

Additional devices or software are rarely utilized if they have not been incorporated into the workflow; hence, studying the workflow to design e-alerts that are included within it seems essential to the success of AKI e-alerts [13–15]. According to one of the providers in the study by Oh et al., "If it [the AKI e-alert] could be integrated with (electronic health record user interface), it would be much more noticeable to a majority of the medicine residents rather than as a text page" [11].

Enhancement in usability

Even minor changes in the alert's design can impact its clinical effects. Human–computer interaction studies are necessary to evaluate the usability of these tools. Examining the ways that providers interact with computers and their interfaces holds significant value when it comes to the usability of e-alerts. If a provider is expected to react to a visual alert and the alert is provided in an appropriate size and color font and is within the eye's stationary field (30° horizontal from the normal viewing angle), there is a better chance that the alert will be noticed [16,17].

Interruptions and options

Clinicians may become distracted by any command that asks them to stop what they are about to do [18]. However, providers generally follow an e-alert and its recommendation if it provides an alternative to the "hard stop" rule; therefore, the use of such alternatives is recommended in the design of AKI e-alerts. If the nature of the alert requires a provider to stop a risky intervention (e.g., exposing a patient with stage IV chronic kidney disease to a large dose of contrast) or an expensive and redundant medication (e.g., administering *N*-acetylcysteine intravenously for prophylaxis of contrast nephropathy), the designers should consider one of the following paths: (1) allow clinicians to override the recommendation (e.g., "computed tomography scan with contrast provides vital information"), (2) recommend a safer or less costly intervention (e.g., "administer *N*-acetylcysteine orally for contrast-associated nephropathy prevention"), or (3) place a hard stop rule on the recommendation so the clinician cannot override it (e.g., using growth hormones to treat a patient with failure to thrive in an intensive care unit) [6].

Providing alternatives

An effective e-alert should not only avoid unsafe practices, but it should also provide alternatives that are safer and less costly. For example, for patients with AKI who are receiving amphotericin B, the e-alert should include information regarding the dose adjustments of amphotericin B or suggest using its liposomal form to avoid further toxicity.

Practical and simple recommendations

Many established guidelines were designed to decrease the risk of the development, progression, and complications of AKI. Unfortunately, compliance with these guidelines remains poor, despite growing evidence regarding their ability to prevent AKI-related complications [19]. AKI e-alerts should provide recommendations that are timely, patient specific, and based on established guidelines. Therefore, summarizing recommendations in a practical and simple one-paragraph list (preferably with links to the order entry embedded in each recommendation) would potentially improve compliance and patient outcome [19,20].

Using medical records data

AKI e-alerts should mainly use the extant data in the patient's medical record. If an alert requires additional information to be entered manually in order to provide a recommendation, the opportunity for its favorable impact may be limited. In a clinical trial of AKI CCDSS, the need for entering patient weight for dose adjustments was identified as a factor that negatively affected the impact of the e-alert [21].

Controlling the impact

Ensuring provider compliance and patient process of care and outcome is an essential, yet often overlooked, step following implementation of an AKI e-alert. In a recent study by Oh et al. [11], 30 (31%) of 98 providers included in this study did not approve access to the e-alert, and among those who did, the majority believed that the alert added to the clinical information and was novel.

Access to a knowledge-based system

To set CCDSS for AKI, the e-alert system should have access not only to patient-specific information but also to a knowledge-based system, which, when combined, could be used to create a more informed recommendation. As the body of knowledge regarding AKI diagnosis, prediction, and management constantly changes, it is essential to update the system to provide the highest level of evidence-based medicine for patients with AKI.

In summary, an effective CCDSS should be able to provide the right information to the right person, in the right format, through a right channel, and at the right time (referred to as the *CCDSS 5 rights*) [22].

Our discussion would not be complete without addressing the challenges in development, implementation, and clinical utility of CCDSS programs. As computation abilities grow and the potential impact of CCDSSs in the care of patients with AKI is increasingly recognized, the number of such programs continues to grow. On the other hand, adding a considerable number of alerts to an ever-increasing amount of patient data may result in alert fatigue or habituation and lead to decreased efficacy of such tools. In their study of provider acceptance of AKI e-alerts, Oh et al. [11] noted that during the course of AKI e-alert implementation, the odds of e-alert approval fell incrementally by 20% with every 30-day period ($P = .02$). Therefore, incorporating the 10 commandments of CCDSSs into the design and implementation phase of AKI e-alerts would be beneficial. Having alerts target patients either at higher risk of relevant outcomes (e.g., those receiving nephrotoxic medications) or whose risk of AKI is high but undetected (e.g., those with low baseline creatinine concentrations) may improve the efficacy of the alert and reduce alert fatigue [11].

AKI e-alert applications

Like other critical care-related syndromes, AKI e-alerts could have different applications [2,23]. Each application of e-alert could require a certain level of infrastructure for implementation and have a different impact on the patient process of care and outcome.

AKI detection

The most common application for the AKI e-alert has been the identification of patients with AKI in intensive care units, hospitals, and, recently, in community settings [5,24–27]. The Acute Dialysis Quality Initiative investigators have suggested that AKI is a process that starts with damage in high-risk individuals and progresses to decreased glomerular filtration rate, kidney failure, and death [28]. Low blood pressure, volume depletion, sepsis, use of diagnostic imaging contrast media, and/or nephrotoxic drug exposure are all considered as AKI risk factors. The definition for AKI varies, making a comparison among different studies difficult and the field progress slow. The most commonly used definition is from the Kidney Disease: Improving Global Outcomes criteria, which are based on changes in serum creatinine during 7 days following insult and a decline in urine output [29]. Other staging systems that are occasionally used include the risk, injury, failure, loss, and end-stage kidney disease [30] and the Acute Kidney Injury Network definitions [31]. AKI e-alerts abstract data from laboratory data sets to identify an increase in serum creatinine, and some also acquire urine output criteria for AKI.

It should be noted that the standard criteria for AKI are not specifically tailored to suit the criteria that AKI e-alerts could utilize. For example, insufficient data from baseline serum creatinine levels (e.g., too many or too few levels measured) and information gaps in urine output data have been used as criteria for the design of highly sensitive and specific e-alerts [24]. Investigators also deal with these issues in different ways, which limits the generalizability of the alerts. Such mixed interpretations and iterations may lead to a trade-off between identifying patients with clinically relevant AKI against the potential for misclassifying patients who do not have AKI.

The impact of such devices on the process of care and clinical outcome of patients with AKI has been debated in the literature. Colpaert et al. [26] showed that when staff intensivists were made aware of AKI and its progression, more patients received appropriate therapeutic intervention within 60 min (i.e., fluid therapy, diuretics, vasopressors), which resulted in a higher chance of return to baseline kidney function within 8 h. In comparison, Wilson et al. [10] did not find any improvement in the process of care or clinical outcome in intensive care units or hospital wards as a result of an AKI e-alert. Indeed, the authors reported that the AKI e-alert group in surgical wards had a substantially higher

incidence of nephrology consultation and dialysis. This variance in outcome could be due to multiple factors, including technology, human factors, and delivery methods [5].

Outside the clinical utilization, AKI e-alerts have been used in large-scale epidemiology studies. In a recent report, AKI e-alerts based on the National Health Services in the United Kingdom were tested using three different criteria: (1) hospital-acquired AKI, (2) community-acquired AKI in patients admitted to the hospital within 7 days, and (3) community-acquired AKI in patients not admitted within 7 days. Authors noted that the mortality rate among patients with community-acquired AKI who were not admitted to the hospital, although high, was substantially lower than those with community-acquired AKI who were admitted to the hospital or those with hospital-acquired AKI [27]. Kashani et al. [32] recently reported a population-based evaluation of AKI incidence temporal trends using a previously validated AKI e-alert [24] to adjudicate patients who developed AKI in intensive care units or hospital wards. They also reported that temporal trends in AKI incidence in a well-defined population remained flat over the 9-year course of their study.

Other applications of the AKI e-alert

AKI e-alerts are used for AKI detection, but they could also serve as CCDSSs. By definition, CCDSSs need to link patient-specific data with the current body of knowledge to be able to provide appropriate clinical aids to clinicians. An AKI CCDSS could serve several functions: (1) as a reminder (e.g., to alert providers of a nephrotoxin exposure during AKI [12]), (2) as a critique (e.g., to impose an interruptive e-alert for AKI to enforce compliance with a care bundle [19]), (3) to interpret (e.g., an AKI e-alert can provide interpretation of all clinical and laboratory extant data to reach a list of differential diagnoses for the current episode of AKI), or (4) to predict (e.g., an AKI e-alert can identify patients who are at risk of AKI development or progression). Currently, most AKI e-alerts are focused on AKI detection; however, for a preventive measure to succeed in the time-sensitive setting of AKI, it is important to risk stratify patients based on comorbidities and exposures. Most of the current prediction models are designed for the bedside manual calculation. A complex model that considers multiple factors would not be clinically useful unless the calculation power of computers could be utilized [33] (e.g., to assist in the dose management of patients with AKI [12] or to make treatment suggestions based on a collection of behavioral variations of AKI [2]).

Future directions

For the widespread implementation of AKI e-alert systems to succeed, future research will need to address provider autonomy, the legal and ethical consequences of not following CCDSS recommendations, technology availability, training support, and the variability in accuracy of these programs. Giving dynamic feedback to clinicians regarding the improved quality of care and patient outcome when they follow CCDSS recommendations will increase its utilization [2]. Determining the optimal algorithm for the detection of AKI needs further investigation [28].

Ideally, an AKI alerting system would be able to change the delivery method of the alert based on its severity and the need for a clinical response. It would be able to make suggestions for AKI prevention, management, or treatment based on the clinician's actions rather than just a flag notification. Incorporating the AKI alert system into a registry for tracking AKI quality indicators and resource planning would help improve care and speed research [28].

Practice points

- AKI diagnosis, risk stratification, prevention, and management remain major challenges in critically ill patients.
- AKI e-alerts have the potential to assist clinicians, investigators, and administrators to enhance the quality of care provided to patients who are at risk of, or who have already developed, AKI or experienced its consequences.
- Appropriate design and implementation of AKI e-alerts and CCDSSs play an important role in provider acceptance and the potential impact on the process of care and patient outcome.

Research agenda

- Legal and ethical consequences of not following CCDSS/e-alert recommendations.
- Determining the optimal algorithm for prediction, detection, and management of AKI by CCDSS.
- Constructing intelligent AKI e-alert systems to be dynamic, specifically modifying the alert based on the severity of disease in each individual patient and the prior interventions provided by the clinician.

Conflict of interest

None.

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