Impact of Electronic Acute Kidney Injury (AKI) Alerts With Automated Nephrologist Consultation on Detection and Severity of AKI: A Quality Improvement Study

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Background: Several electronic alert systems for acute kidney injury (AKI) have been introduced. However, their clinical benefits require further investigation.

Study Design: Before-and-after quality improvement study.

Setting & Participants: A tertiary teaching hospital in Korea, which adopted an AKI alert system on June 1, 2014. Before and after launch of the alert system, 1,884 and 1,309 patients with AKI were included in the usual-care and alert groups, respectively.

Quality Improvement Plan: Implementation of an AKI alert system through which clinicians could generate automated consultations to the nephrology division for all hospitalized patients.

Outcomes: Primary outcomes included overlooked AKI events, defined as not measuring the follow-up creatinine value, and the consultation pattern of clinicians. Secondary outcomes were severe AKI events; AKI recovery, defined based on the creatinine-based criterion; and patient mortality.

Measurements: ORs for events of overlooked AKI, early consultation, and severe AKI were calculated with logistic regression. AKI recovery rate and patient mortality were assessed using Cox regression.

Results: After introduction of the alert system, the odds of overlooked AKI events were significantly lower (adjusted OR, 0.40; 95% CI, 0.30-0.52), and the odds of an early consultation with a nephrologist were greater (adjusted OR, 6.13; 95% CI, 4.80-7.82). The odds of a severe AKI event was reduced after implementation of the alerts (adjusted OR, 0.75; 95% CI, 0.64-0.89). Furthermore, the likelihood of AKI recovery was improved in the alert group (adjusted HR, 1.70; 95% CI, 1.53-1.88). Mortality was not affected by the AKI alert system (adjusted HR, 1.07; 95% CI, 0.68-1.68).

Limitations: Possible unreported differences between the alert and usual-care groups.

Conclusions: Implementation of the AKI alert system was associated with beneficial effects in terms of an improved rate of recovery from AKI. Therefore, widespread adoption of such systems could be considered in general hospitals.

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Am J Kidney Dis. 71(1): 9-19. Published online July 25, 2017.

doi: 10.1053/j.ajkd.2017.06.008

Acute kidney injury (AKI) is closely associated with deterioration of kidney function and increased mortality.[1-3] Many studies have addressed the necessity of improving AKI outcomes, and its risk factors and prognosis have been widely investigated.[4-6] Although several therapeutic and preventive interventions for AKI have been developed, universal treatment for AKI has not been established.[7-9] Instead, an individualized approach with optimal fluid balance and avoidance of nephrotoxic events is suggested.[10-12] There is a consensus that early detection of AKI events is crucial to improving patients' outcomes.[13,14] The role of a nephrologist has also been previously highlighted.[14-16]

Editorial, p. 1

Mainly, AKI is defined by serum creatinine (Scr)-based criteria.[17,18] Because Scr is widely tested and can be quickly reported using comprehensible numeric values, there have been attempts to build an efficient surveillance system for AKI, also known as an AKI alert.[19-22] However, the only published randomized controlled trial of AKI alerts that we are aware of showed negative results,[22] and other studies identified several limitations despite promising preliminary outcomes.[20,21,23] In previous studies, change in clinicians' behavior was commonly suggested to be crucial for the success of an alert system.[23]

We implemented an AKI alert system in our hospital in 2014. An important difference between our system and those previously reported is that the attending clinicians could easily generate automatic direct consultation with the nephrology division. Here, we assessed the impact of the system by comparing outcomes of patients who had AKI events before and after launch of the system.

Methods

Ethics Considerations

The Food and Drug Administration of Korea approved the development and launch of the AKI alert system (KCT0002010). The Institutional Review Board (IRB) of Seoul National University Bundang Hospital approved the study (IRB number: B-1402/238-006) and waived the need for informed consents. This study was conducted in accordance with the principles of the Declaration of Helsinki.

Study Design and Study Population

This before-and-after study was conducted at a tertiary referral hospital in Korea with more than 1,000 general admission beds. After approval by the hospital's leadership for the quality improvement activity, an AKI alert system was launched on June 1, 2014. No other major AKI-related activities or laboratory changes were implemented.

In the study cohort, we included index admission cases of adult patients with Scr measured during hospitalization in the first year after the system was introduced. The historical cohort consisted of index admission cases with the same criteria that were admitted from January 1 to December 31, 2013, before introduction of the alert system. Patients who had AKI in the study cohort were included in the alert group, and those with AKI events in the historical cohort, identified based on the same criteria used for the alert group, were included in the usual-care group.

Exclusion criteria were as follows: (1) ongoing renal replacement therapy, (2) impending end-stage renal disease (baseline estimated glomerular filtration rate < 15 mL/min/1.73 m^2), (3) admission to the nephrology division because these patients were already receiving care from the attending nephrologists, (4) death events on the day of AKI development were also excluded because these cases were beyond the reach of our system because the alerts were generated around midnight and reported to clinicians on the following day, and (5) patients who were already enrolled in the historical cohort were excluded from the alert group.

AKI Alert System With Automatically Generated Nephrology Consultation

The AKI alert system used the minimum Scr concentration within 2 weeks before the admission date as the baseline Scr concentration. When an earlier laboratory value was not available, the first Scr concentration measured during hospitalization was used as the baseline value. To minimize the information-processing burden of a real-time system, our system screened AKI events every midnight, defining AKI events as Scr concentration elevation of at least 1.5-fold or 0.3 mg/dL from baseline.[17,24] When physicians opened the patient's electronic medical record (EMR) the following morning, a pop-up window (screenshot in Fig S1, available as online supplementary material) displayed with the following message: "(Mild/Moderate/Severe) acute kidney injury (stage X). Do you want to send a consultation request to nephrology division?". An explanatory note is provided below the notification, reading "As the patient is diagnosed with acute kidney injury according to the international clinical practice guidelines, we ask the nephrology division for further evaluation and treatment." The clinician could choose either "yes" or "no" on the display, and if he or she clicked "yes," the following nephrology consultation was generated automatically (Fig S2): "We ask the nephrology division for further evaluation and treatment plan as the patient is suspected to have acute kidney injury, relative to the baseline serum creatinine level measured within 2 weeks before admission or sampled for the first time after hospitalization." The clinicians could also click the "no" button and request a consultation with a more detailed description, request a consultation later, or not consult the nephrology division at all. The board-certified nephrologists at our hospital were encouraged to answer all requests within 1 day.

Data Collection

The following demographic data were collected from the study and historical cohorts: age, sex, and baseline body mass index at the time of admission. The last laboratory values for hemoglobin and albumin before the AKI event were defined as the baseline levels. Anemia was defined as hemoglobin concentration < 11 g/dL, and hypoalbuminemia was defined as baseline albumin concentration < 3.0 g/dL. Comorbid conditions of hypertension, diabetes mellitus, ischemic heart disease, heart failure, and cancer were reviewed by the designated *International Classification of Diseases, Tenth Revision* diagnostic codes and the use of relevant medications. Information for medication use within 2 weeks before the AKI event was collected, including the use of renin-angiotensin-aldosterone system blockers, diuretics, and nonsteroidal anti-inflammatory drugs (NSAIDs).[4] The admitting department at the time of AKI development and any surgeries during hospitalization were recorded. Community-acquired AKI events were defined by the first Scr concentration measured after admission fulfilling the criteria for AKI. The study and historical cohorts were collected over 1 year, and the year was further divided into quarters in order to examine a possible time-phase variation in outcomes. Dates of consultations to the nephrology division were collected. Follow-up Scr concentrations and patient mortality within 30 days after the AKI event were also recorded to further assess clinical outcomes. Estimated glomerular filtration rates were calculated using the CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) creatinine equation.[25]

Clinical Outcomes and Their Definitions

The first category of outcomes was change in clinicians' behavior, including instances of overlooked AKI and clinicians' consultation patterns. Overlooked AKI was defined as the absence of a follow-up Scr measurement within 2 weeks after AKI. Consultation to the nephrology division was classified into the following 3 outcomes: no consultation, early consultation, and late consultation. Early consultation was defined as consultation within 3 days from the AKI event. Consults issued more than 3 days after the AKI were considered late consultations.

The second category of outcomes aimed to assess AKI characteristics, including AKI recovery and the severity of Scr concentration elevation. Among several criteria used to define AKI recovery,[26-28] we chose a conservative criterion of return of Scr to <1.2 times the baseline level. We found that among patients with high baseline Scr concentrations