RESEARCH LETTER

Optimal Acute Kidney Injury Algorithm for Detecting Acute Kidney Injury at Emergency Department Presentation

To the Editor:

Acute kidney injury (AKI) is a common condition associated with excess morbidity, mortality, and health care costs. Mitigating AKI is achievable through early recognition and initiation of simple protective measures to prevent disease progression. Unfortunately, diagnosis of AKI is often delayed or missed.[1]

Consensus criteria define AKI as a change in serum creatinine (sCr) concentration or urine output over time.[2] Because urine output is not routinely measured in many settings, recognition of alterations in sCr concentration is practically important for AKI diagnosis in the acute care environment. Automated identification of AKI through real-time analysis of electronic health record (EHR) data has shown promise for improving diagnosis of AKI and is recommended as a potential quality improvement tool to improve AKI risk assessment and detection.[1] Because sCr-based AKI criteria are well-defined, performance of these AKI detection algorithms depends on the reliability of quantification of baseline sCr concentration. In addition to AKI detection, reliable determination of baseline kidney function is necessary for accurate estimation of AKI incidence, measurement of AKI-related outcomes, assessment of AKI quality improvement programs, and for the development and evaluation of tools to identify patients at increased risk of developing AKI in the future.

In this study, we evaluated the performance of 3 electronic AKI detection algorithms using a standard EHR phenotype validation approach.[3] AKI was defined using the 2012 Kidney Disease: Improving Global Outcomes (KDIGO) sCr-based criteria (≥ 0.3 mg/dL absolute increase or ≥ 1.5 times baseline).[2] Three different methods to determine baseline sCr were applied and compared (Table 1). Method 1, adapted from the UK National Health Service, defined baseline as the lowest sCr value measured less than 8 days pre-encounter, or, if sCr values less than 8 days pre-encounter were unavailable, as the median sCr value 8-180 days pre-encounter.[4] Method 2, adapted from the National Institute of Diabetes and Digestive and Kidney Diseases Kidney Precision Medicine Project, defined baseline as the median of the 3 most recent sCr values ≤ 180 days pre-encounter, or, if only 1 sCr value was available, as that sCr value.[5] A novel simplified Method 3 defined baseline as the median of all sCr values measured ≤ 180 days pre-encounter, or, if only 1 sCr value was available, as that sCr value. This study was approved by the Johns Hopkins University School of Medicine Institutional Review Board under a waiver of informed consent (IRB00125114).

Encounters to 3 adult emergency departments (N=105,553) over 1 year (July 1, 2020-June 30, 2021) were electronically labeled as AKI present or absent applying each of the 3 methods described above. To be included, encounters must have had sCr measured during their emergency department stay and at least once in any setting within our integrated health system in the preceding 180 days. A set of 200 expert-labeled cases (100 with AKI and 100 without) was generated for gold standard comparison, according to the referenced EHR phenotype validation approach using an a priori critical lower bound of 0.90 for negative and positive predictive values (Table S1).[3] Two physicians with content expertise (J.S.H. and M.R.E.) performed independent blinded review of EHR records for randomly selected cases and classified each as AKI present or absent. Reviewer disagreements were resolved through co-review, and a third expert physician reviewer (S.M.) was available to adjudicate. Diagnostic performance measures were computed by comparing the physician-generated labels (gold standard) to labels generated by each of the 3 electronic AKI detection algorithms using different baseline sCr determinations. All clinical data was extracted directly from a relational database underlying our EHRs (Epic). Algorithm development and statistical analysis was performed using Python 3.6.

Table 2 displays the diagnostic performance of each electronic AKI algorithm on the randomly selected sample relative to the gold standard blinded clinician consensus. Method 3, which employed the simplest criteria for baseline sCr determination, was most accurate at 91.5% (95% CI, 87.6-95.4), with a sensitivity of 0.93 (95% CI, 0.88-0.98) and specificity of 0.90 (95% CI, 0.84-0.96). Negative predictive value was 0.93 (95% CI, 0.88-0.98), positive predictive value was 0.90 (95% CI, 0.85-0.96) and agreement with physician review was high (Cohen's κ 0.83). For surveillance purposes, Method 3 slightly overestimated the prevalence of AKI (103 encounters detected; +3% relative difference to gold standard) compared to underestimates produced by Method 1 (97; -3%) and Method 2 (91; -9%).

Table 1. Three Definitions of Baseline Serum Creatinine

Method 1 (Adapted From NHS)	Method 2 (Adapted From KPMP)	Method 3
Lowest sCr value < 8 days pre-encounter or, if sCr values < 8 days pre-encounter are unavailable, the median sCr value 8-180 days pre-encounter	Median of 3 most recent sCr values ≤ 180 days pre-encounter or, if only 1 sCr value was available, the actual sCr value	Median of all sCr values ≤ 180 days pre-encounter or, if only 1 sCr value was available, the actual sCr value

Abbreviations: KPMP, National Institute of Diabetes and Digestive and Kidney Diseases Kidney Precision Medicine Project[5]; NHS, UK National Health Service[4]; sCr, serum creatinine.

Table 2. Performance of 3 Electronic Health Record-Based Algorithms for Detecting Acute Kidney Injury Based on Different Baseline Serum Creatinine Definitions Compared to Clinical Interpretation

N=200	Method 1[a]	Method 2[b]	Method 3[c]
True positive, n	87	84	93
True negative, n	90	93	90
False positive, n	10	7	10
False negative, n	13	16	7
Sensitivity (95% CI)	87.0 (80.4-93.6)	84.0 (76.8-91.2)	93.0 (88.0-98.0)
Specificity (95% CI)	90.0 (84.1-95.9)	93.0 (88.0-98.0)	90.0 (84.1-95.9)
Accuracy (95% CI)	88.5 (84.1-92.9)	88.5 (84.1-92.9)	91.5 (87.6-95.4)
Negative predictive value (95% CI)	87.4 (81.0-93.8)	85.3 (78.7-92.0)	92.8 (87.6-97.9)
Positive predictive value (95% CI)	89.7 (83.6-95.7)	92.3 (86.8-97.8)	90.3 (84.6-96.0)
Cohen's κ	0.77	0.77	0.83

Abbreviations: CI, confidence interval; KPMP, National Institute of Diabetes and Digestive and Kidney Diseases Kidney Precision Medicine Project; NHS, UK National Health Service; sCr, serum creatinine.
[a]Adapted from NHS[4]; baseline sCr defined as the lowest sCr value less than 8 days pre-encounter or, if sCr values less than 8 days pre-encounter were unavailable, the median sCr value 8-180 days pre-encounter
[b]Adapted from KPMP[5]; baseline sCr defined as the median of the 3 most recent sCr values or, if only 1 sCr value was available, the actual sCr value
[c]Baseline sCr defined as the median of all sCr values ≤ 180 days pre-encounter or, if only 1 sCr value was available, the actual sCr value

Structured analysis of 3 electronic algorithms for identifying AKI based on different baseline sCr definitions demonstrated the simplest criteria (Method 3, median of all sCr values ≤ 180 days pre-encounter) was most accurate. These findings highlight both the capacity to identify AKI electronically and methodological differences in defining AKI and suggest that future research should use this simple sCr baseline definition for superior accuracy and to enable cross-study comparisons. This definition is appropriate for use by EHR-integrated AKI detection algorithms to guide clinical management, and by clinicians—including non-nephrologists—seeking to determine whether an individual patient has manifested, or is at increased risk for, AKI.

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SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Table S1: Patient Demographics and Clinical Characteristics

ARTICLE INFORMATION

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