The impact of e-alerts on inpatient diagnosis and management of acute kidney injury

Sebastian Spencer[1]
Fay Dickson[1]
Sofia Sofroniadou[1]
Sarah Naudeer[1]
Sunil Bhandari[1,2]
Adil M Hazara[1,2]

Author details can be found at the end of this article

Correspondence to:
Adil M Hazara;
adilhazara@nhs.net

Abstract

Aims/Background Electronic alerts can help with the early detection of acute kidney injury in hospitalised patients. Evidence for their role in improving patient care is limited. The authors have completed an audit loop to evaluate the impact of electronic alerts, and an associated acute kidney injury management pathway, on patient care.

Methods The audits were conducted at a large tertiary care hospital in the UK. Case notes were reviewed for 99 patients over two periods: pre-alert (in 2013; *n*=55) and post-alert (in 2018; *n*=44), using the same methodology. Patients for case note reviews were randomly chosen from the list of acute kidney injury alerts generated by the local laboratory information management system.

Results Recognition of acute kidney injury, as documented in the case notes, increased from 15% to 43% between the two periods. Time to first medical review (following electronic alerts) improved by 17 minutes (median 4 hours 4 minutes in 2013 vs 3 hours 47 minutes in 2018). Completion of pre-defined acute kidney injury assessment tasks (review of vital signs, biochemistry and acid–base parameters, evidence of fluid balance assessment, consideration of possible sepsis, and examination or requesting urinalysis) improved in 2018. However, acute kidney injury management tasks (correction of hypovolaemia, addressing or investigating obstruction, medications review, renal referral, requesting of further biochemical tests, addressing possible sepsis) showed very little or no improvement.

Conclusions The introduction of acute kidney injury electronic alerts and management pathway resulted in improved recognition and initial assessment of patients with acute kidney injury. Further steps are needed to translate this in to improved patient management.

Key words: Acute kidney injury, Audit, E-alerts, Epidemiology, Outcome, Quality improvement audit

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Introduction

Acute kidney injury is the term used to describe a rapid deterioration in kidney function that develops over hours or days. Acute kidney injury is frequently detected in patients presenting to hospitals with acute illnesses (community-acquired), but can also develop post-hospitalisation (hospital-acquired) when it is associated with significantly worse morbidity and mortality (Huang et al, 2019). The incidence of acute kidney injury in hospitals varies according to the characteristics of the service and base population; in acute district general hospitals in the UK, acute kidney injuries reportedly affect 6.4% of all hospital admissions (Wonnacott et al, 2014), whereas in a large academic tertiary care centre in the USA, rates were as high as 22.7% (Wang et al, 2012). The median duration of hospitalisation and inpatient mortality rates for patients with community-acquired acute kidney injury are 7 days and 22% respectively (Hazara et al, 2017), and in those with hospital-acquired acute kidney injury, 15 days and 43% respectively.

Early recognition of acute kidney injury is critical in preventing its progression. It enables the institution of corrective measures at an early stage where such interventions can potentially change the disease course and prevent adverse outcomes (Bagshaw and Bellomo, 2007). Deficiencies and challenges associated with inpatient management of acute kidney injury in the UK were highlighted in a national audit (retrospective case note reviews) related to 976 hospitalised patients who died with acute kidney injury (National

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Confidential Enquiry into Patient Outcome and Death (NCEPOD), 2009). In this audit, only 50% of patients were considered to have received a good standard of care, dropping to a third when acute kidney injury was hospital-acquired. These failings were partly ascribed to deficiencies in the appropriate recognition of acute kidney injury. In a survey of hospital-based trainee doctors, awareness of the diagnostic criteria for acute kidney injury (judged on whether trainees could recall any of the components that make up these diagnostic criteria) was low (Muniraju et al, 2012).

With poor rates of recognition of acute kidney injury, particularly at the early stages when changes in serum creatinine levels may not be large, the opportunity to act early can be missed. The clear and objective nature of current acute kidney injury diagnostic criteria (Kidney Disease: Improving Global Outcomes Acute Kidney Injury Work Group, 2012; National Institute of Health and Care Excellence, 2019), which are based on changes in serum creatinine levels, has enabled the development of computer algorithms that automate the process of acute kidney injury detection. These algorithms, built in to the laboratory information management systems (LIMS) software, generate e-alerts when serum creatinine levels in any new blood sample meet diagnostic thresholds for acute kidney injury (Hazara et al, 2014).

Ten years after the NCEPOD (2009) report was published, the authors investigated whether the implementation of e-alerts for acute kidney injury have resulted in improved care in hospitalised patients with acute kidney injury. This quality improvement project describes the outcomes of implementing acute kidney injury e-alerts on the recognition of acute kidney injury and quality of care by the first reviewer (the first medical review) following the diagnosis of acute kidney injury in hospitalised patients.

Materials and methods

Settings

This study was completed at a tertiary care hospital, Hull University Teaching Hospitals NHS Trust, in the UK.

Inclusion and exclusion criteria

Hospitalised patients aged 18 years and older, who met the criteria for diagnosis of acute kidney injury as identified through the hospital-wide e-alerts system, were eligible for inclusion. For patients with more than one episode of acute kidney injury during an admission, only the first episode was considered. Patients with known end-stage renal disease, those admitted to the specialist renal ward at the time of acute kidney injury diagnosis, and patients who were diagnosed with acute kidney injury in outpatient or general practice settings were excluded. The sample included both elective and acute admissions.

Identification of acute kidney injury through electronic alerts

Hospital-wide acute kidney injury e-alerts have been fully operational at this hospital since 2014 following an upgrade to the pathology reporting system Lorenzo (DXC Technology, USA). All blood samples received at the biochemistry labs from anywhere in the hospital are automatically screened for acute kidney injury using the NHS England e-alerts algorithm (NHS England, 2014) which is programmed into the hospital's LIMS software. This algorithm compares the latest serum creatinine result to previous readings; if changes in the creatinine level meet acute kidney injury diagnostic criteria, an e-alert is issued. Separately, all acute kidney injury e-alerts issued during a 24-hour period are automatically saved in a spreadsheet that also contains relevant patient details and information relating to the origins of the blood sample. This report is only accessible to selected hospital personnel and is used mainly for auditing purposes.

In 2013, limited testing of the e-alerts was carried out at the hospital. During this phase, the e-alerts were only visible to the team testing its implementation through daily reports and were not issued to the clinical teams. Hence, the clinical team only had routine biochemistry tests available for viewing. There are minor differences in the determination of baseline creatinine level in the two alert systems (ie pre- and post-2014): the former relied on lowest creatinine level of the previous year as the baseline whereas the latter uses the

Urea level, serum	↑	12.1	mmol/L	3.0-7.6
Creatinine level, serum	↑	152	umol/L	55-87
AKI Warning Stage	↓	2		
Comments		Alert - probable ACUTE KIDNEY INJURY.		
Estimated GFR, serum		32	mL/min/1.73m2	

Figure 1. Screenshot of an acute kidney injury e-alert. AKI = acute kidney injury; GFR = glomerular flow rate.

median in line with NHS England guidance. For the purposes of this study, all acute kidney injuries recognised using e-alerts were manually verified and staged to ensure uniformity.

The e-alert system is non-interruptive; the output from the e-alert is displayed alongside routine biochemistry results (Figure 1). A link to the hospital's intranet page, directing users to an inpatient acute kidney injury management pathway, is displayed alongside the e-alerts. This management pathway was not available to users before the upgrades in 2014. As an additional safety measure, laboratory staff routinely contact clinicians when blood test results are grossly out of range.

The authors' Trust provides a full range of urgent and planned secondary care services to a catchment area population of 600 000 (137 555 emergency department visits in 2018–19) and selected tertiary care services (including specialist nephrology cover) to an extended population of up to 1.25 million (Hull University Teaching Hospitals NHS Trust, 2019). Patients can either self-refer to the emergency department or are referred in by other healthcare professionals (most commonly, GPs). First medical assessments are usually performed by junior doctors based at the emergency department or specialist acute units (eg acute medical, surgical or oncology units) and then reviewed by consultants in those areas (usually non-renal). The 'renal team' (consultants and junior trainees), based on-site, see acute patients on an on-call basis following telephone referrals from admitting doctor(s). Admitting doctors use clinical judgement to decide the appropriateness and timing of renal referrals; there are no protocols or criteria for making these. The structure of renal services remained stable throughout the study period.

Patient selection

Daily acute kidney injury reports were combined to build a database of all e-alerts during a given period. In 2013, a baseline audit of practices in the inpatient management of acute kidney injury was conducted. During this phase, the e-alerts were not visible to the clinical teams. Patients were chosen randomly using MS Excel (Microsoft, USA) from the spreadsheet of daily acute kidney injuries. A study investigator reviewed patient paper-based case notes and obtained data on a pre-designed proforma. Following this baseline audit, the e-alerts became freely available to all users. In the second phase in 2018, the investigators re-audited practices in acute kidney injury management from case notes and collected data using the same proforma. Patients were selected from all acute kidney injuries reported between 13 February–12 March 2013 and 1–31 May 2018 respectively.

Data items

The data collection proforma used in this study (Appendix) was based on the NCEPOD audit tool collecting the most important data items in relation to the assessment and management of patients with acute kidney injury. In addition to basic demographic data, acute kidney injury stage at the time of diagnosis and times of first medical and consultant reviews were recorded. Acute kidney injury episodes were classed as hospital-acquired if diagnosed more than 48 hours after first presentation; all others were regarded as community-acquired. The completion rates of specific tasks related to the assessment and management of patients with acute kidney injury were documented for each patient. Two authors independently reviewed case notes while the senior author reviewed all proformas for quality assurance and consistency.

Analysis

Key patient characteristics and outcomes were compared between the 2013 and 2018 cohorts. Patient characteristics at baseline are summarised either as means (with standard deviations) or medians (with inter-quartile ranges) as appropriate. Fisher's exact test was used when comparing categorical data at baseline including the proportion of females, acute kidney injury stage at diagnosis, whether the acute kidney injury was hospital or community acquired and the grade of first reviewers. The Mann–Whitney U-test was used when comparing continuous data at baseline including age and time to first reviews. P values are reported to demonstrate the probability of deviation from null ('no difference'). Time intervals (eg 'time to first consultant review') are reported with reference to when the e-alerts first became available on the pathology reporting system for clinicians to review. Completion rates of various tasks (eg 'biochemistry reviewed') are reported as percentages. Statistical comparisons for completed assessment and management tasks have not been carried out because this was an exploratory project. A sample size calculation was not performed a priori. Analyses and statistical tests were completed in Medcalc version 19.4.1 (Medcalc Software Ltd., Belgium) and MS Excel (Microsoft, USA).

Approval

The study was approved by the Trust's audit department (Audit refs 2013.038 and 2018.176).

Results

In total, 99 case notes were reviewed. This included 55 case notes from 2013 and 44 from 2018. Baseline characteristics of patients are shown in Table 1. Median age and gender distribution were similar in both cohorts; however, patients in the 2013 cohort generally had a milder disease at the time of diagnosis with a higher proportion of patients in the stage 1 acute kidney injury category (70% vs 34%). Proportion of patients with community- and hospital-acquired acute kidney injuries were similar in both groups.

The grade of first medical reviewer following the issue of an e-alert, which lead to the patient being diagnosed with acute kidney injury, were: foundation year and core trainees 40%, registrar grade 18%, consultant 12%, other 1%, not documented 29%. The median time from the reporting of e-alerts to first medical review (where review time was documented) improved by 17 minutes (4 hours 4 minutes in 2013 vs 3 hour 47 minutes in 2018); time of medical review was not documented in 22% of cases. Similarly, time of

Table 1. Summary of patient characteristics

		All	2013	2018	Difference (*P* value)
n		99	55	44	
Age, median (interquartile range)		81 (65–86)	81 (66–86)	80 (62–86)	0.52
Female, *n* (%)		47 (48%)	26 (47%)	21 (48%)	1.00
Acute kidney injury stage at diagnosis	Stage 1, *n* (%)	54 (55%)	39 (70%)	15 (34%)	<0.05
	Stage 2, *n* (%)	26 (26%)	8 (15%)	18 (41%)	<0.05
	Stage 3, *n* (%)	19 (19%)	8 (15%)	11 (25%)	0.21
Acute kidney injury type	Community-acquired	58	29 (53%)	29 (66%)	0.18
	Hospital-acquired	41	26 (47%)	15 (34%)	0.18
Grade of first reviewing doctor	Consultant, *n* (%)	12 (12%)	5 (9%)	7 (16%)	0.36
	Specialist registrar grade, *n* (%)	19 (19%)	10 (18%)	9 (20%)	0.80
	Specialist trainee 1–2 grade, *n* (%)	21 (21%)	12 (22%)	9 (20%)	1.00
	Foundation, *n* (%)	29 (29%)	14 (25%)	15 (34%)	0.38
	Other/undocumented, *n* (%)	18 (18%)	14 (25%)	4 (9%)	<0.05

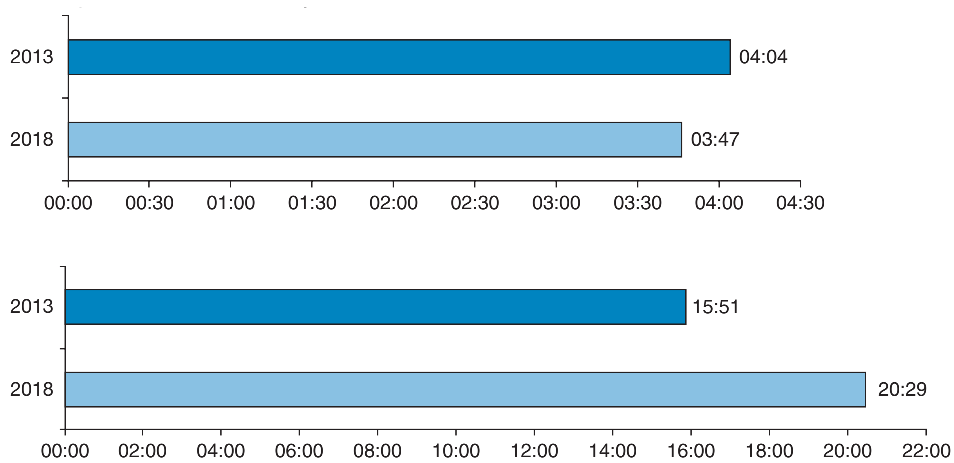

Figure 2. Time to (a) first medical review and (b) first consultant review. Available number of observations for first review: 2013 [36/55, 65%], 2018 [41/44, 93.2%], and consultant review 2013 [22/55, 40%], 2018 [39/44, 88.6%].

first consultant review following the reporting of e-alerts was not documented in 38% of cases. Where documented, it showed a lengthening of this interval by 4 hours 37 minutes (15 hours 15 minutes in 2013 vs 20 hours 29 minutes in 2018) (**Figure 2**).

The recognition of acute kidney injury, as documented in the case notes, improved from 15% to 43% between 2013 and 2018. The acute kidney injury risk assessment section, which is part of the admissions clerking booklet at the authors' Trust, was only completed in 1% of all cases.

The relative changes in the performance of the most important assessment and management tasks between 2013 and 2018 are presented in **Figure 3**. These tasks all relate to the first medical review only. All acute kidney injury assessment tasks that were audited were completed more frequently by the first reviewer in 2018, indicating an improvement relative to 2013 (**Figure 3a**). The completion of acute kidney injury management tasks either showed very small improvement (correction of hypovolaemia, addressing or investigating obstruction, review of nephrotoxins, renal referrals) or did not improve at all (requesting of further biochemical tests, addressing possible sepsis, stopping of diuretics) (**Figure 3b**).

Discussion

In this quality improvement project based at a large teaching hospital in the UK, the introduction of automated e-alerts and an associated acute kidney injury management pathway was associated with improved recognition of acute kidney injury by the first medical assessor. E-alerts were also associated with earlier medical reviews and increased completion rates of patient assessment tasks. However, e-alerts did not result in improved patient management. These results indicate that introduction of e-alerts alone is unlikely to influence outcomes and must be supported by other measures such as improvements in doctors' training and availability of decision support tools.

Two randomised controlled trials (Wilson et al, 2015, 2021) found that there was no improvement in clinical outcomes associated with the use of e-alerts. Wilson et al (2021) randomised 6030 hospitalised adults with acute kidney injury to either an e-alerts or standard care group. For patients in the e-alerts group, healthcare professionals were shown a pop-up alert upon opening a patient's electronic health record prompting users to acknowledge (or disagree with) the diagnosis of acute kidney injury with prompts for further actions. These alerts were not displayed in the standard care group. Healthcare professionals were blind to randomisation since the electronic health record software internally allocated groups to eligible patients. Results of this study revealed no significant differences between the two groups in the primary outcome measure – a composite of deaths, requirement for dialysis and progression of acute kidney injury (Wilson et al, 2021). Randomised controlled trials are difficult to perform in this area since the introduction of e-alerts in clinical areas (and randomising at patient level) influence the standard of care for all acute kidney injury

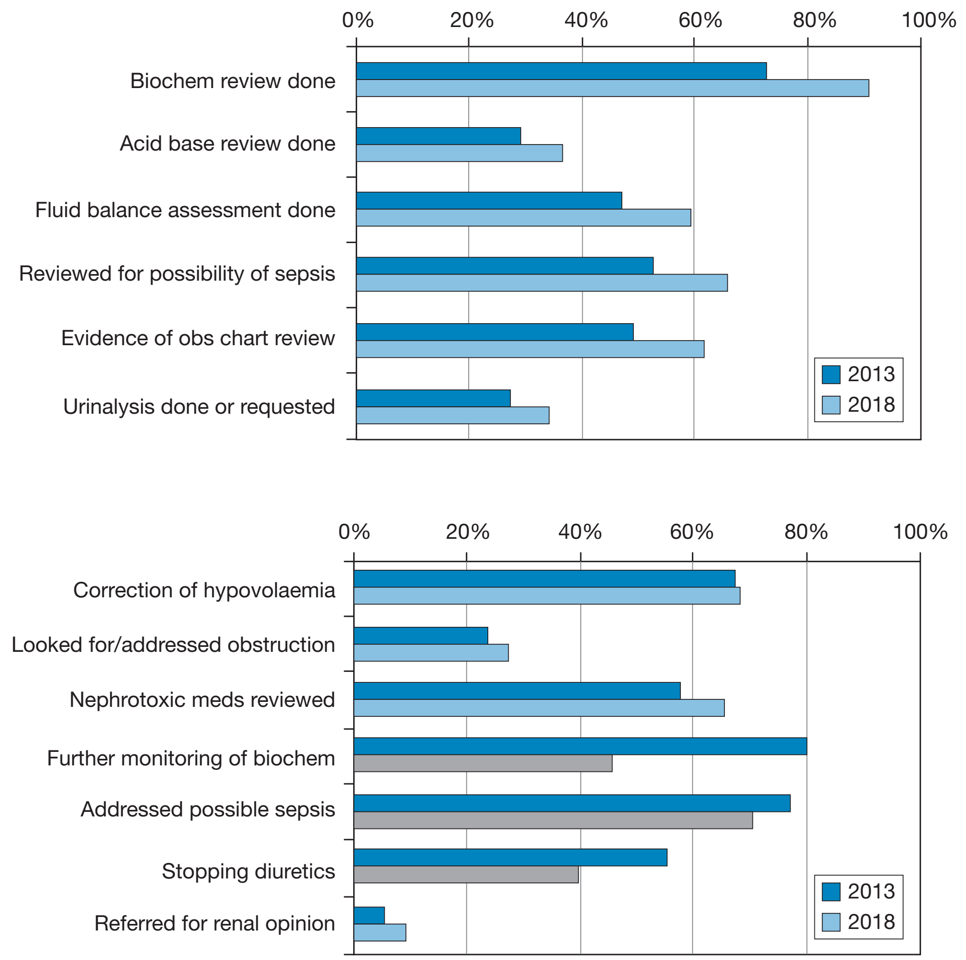

Figure 3. The performance of acute kidney injury assessment and management tasks in 2013 and 2018. Pale blue indicates improvement and grey indicates decline relative to 2013. a. Specific acute kidney injury assessment tasks and (b) acute kidney injury management tasks are listed along the vertical axis.

patients when the same clinical team is responsible for both the alert-positive and alert-negative groups (Horne and Selby, 2015); a limitation that is also acknowledged by Wilson et al (2021). Although the present study was designed and completed before publication of the latest evidence, observational pre- and post- studies like this study still have a role in understanding the utility of acute kidney injury e-alerts within local contexts.

E-alerts are a relatively low-cost intervention with a significant potential role, ie highlighting the occurrence of acute kidney injury an early stage. However, these alerts must be evaluated in the context of an already crowded field of information technology-based alert systems each competing for users' attention, eg venous thromboembolism assessment reminders and medicines mismatch alerts. Some have voiced concern about 'alert fatigue' where clinicians may just override the alerts, diminishing their usefulness (Ancker et al, 2017). Hence, even a relatively easy to implement alert system must earn its place among the myriad of other alerts facing frontline staff.

This study compared the care received by two cohorts of patients with acute kidney injury, pre- and post-alert implementation. The patients were not matched; although there were no significant differences in patients' age and gender distribution, the latter group (2018 cohort) had more severe acute kidney injuries. This could be accounted for by the small number of patients included in the study and a seasonal variation in the presentation of acute kidney injuries. Patient comorbidities were not compared. Patients with acute kidney injuries of greater severity might have elicited a more urgent response from the initial assessors in this study, who in the case of rotational trainees will have potentially had 3 months more experience in managing acute kidney injury in the latter group; this could have had further implications for these findings. However, the aim of this study was to examine the approach taken by the first assessor when dealing with an acute kidney injury – examining the process not the outcomes (ie mortality rates or duration of hospitalisation) of care. Initial measures taken as a result of acute kidney injury diagnosis by the first reviewer and their response to early stages of acute kidney injury, well before the need for more specialist input, were the key areas that this study focused on.

The use of e-alerts has shown a modest reduction of 17 minutes in the time to first review following diagnosis with acute kidney injury (time of medical review was not documented in 22% of cases). From this work, it is not possible to show if shorter review times are associated with improvements in outcomes such as mortality, requirement for dialysis, duration of hospitalisation or recovery of acute kidney injury since these outcomes were not studied. As seen in the care of patients with sepsis, the implementation of treatment targets (eg administration of intravenous antibiotic within the first hour) can improve overall patient care (Daniels et al, 2011). These results should stimulate further research in examining the impact of timeliness of completing acute kidney injury tasks on clinical outcomes.

The use of a proforma helped standardise data collection in this study; this was particularly relevant when examining the completion rates of certain tasks such as correction of hypovolaemia or stopping nephrotoxic medication. However, the appropriateness of these measures was not reviewed since the focus was mainly on completion rates of pre-defined tasks. For instance, if diuretics were stopped immediately after a diagnosis of acute kidney injury, this was classed as a 'completed task', although in some cases of acute kidney injury (those presenting with severe fluid overload), this may not have been appropriate. Future studies could take a more nuanced approach to data collection and include measures of appropriateness of acute kidney injury tasks as well as completion rates.

NHS care providers are mandated by NHS England to embed acute kidney injury e-alerts within their local LIMS (NHS England, 2014). As such, these alerting systems now form part of routine care in many hospitals across England and Wales. However, their uptake and use among hospital staff (which has direct implications for their effectiveness) has been sub-optimal. Scott et al (2019) studied possible reasons for the underuse of e-alerts among clinicians and reported that although familiarity with alert systems was good, many did not know how to incorporate the output into their routine practice and the impact that their response to e-alerts would have on patient care. Along with the present study, these findings are an important reminder that e-alerts themselves are unlikely to lead to significant improvements without measures to support frontline clinicians in decision making and ensuring that they receive regular feedback on the outcomes of e-alerts.

This work is limited because of its single-centre design. The time lapse between the two observations was long, meaning that overall results may not just have been influenced by implementation of alerts but also by increased awareness of acute kidney injury among doctors and changes in training. In addition, structural changes to the care environment, including the configuration and staffing of patient assessment areas, and inpatient flows may have differed during the two audit periods. The prolongation in the consultant review time may be reflective of this. However, the strengths of this study are the use of standardised forms and uniform methodology in the two audit periods, including training of personnel involved in data collection in advance, and its single-centre design which meant that patient care environment and support services were relatively constant.

Areas to build on in the future include targeted improvements in the early management of acute kidney injury by the first medical reviewer, who can often be a newly qualified doctor. In this regard, training junior doctors at induction and incentives for continued maintenance of competence in acute kidney injury management are critical steps. The risk assessment section of the admission clerking proforma was only used in 1% of cases. Consultant 'post-take' reviews could help address this by taking every available opportunity to teach new trainees about acute kidney injury risk assessment, in line with the NCEPOD recommendations. These findings only relate to non-interruptive (passive) e-alerts. Alerts that interrupt clinician workflow, through text messages or mobile phone apps, have limited effectiveness on their own (Wilson et al, 2015; Haase et al, 2017; Connell et al, 2019). However, directing the output of such e-alerts to a single care coordinator (eg acute kidney injury specialist nurse) in real time could help to improve the care of patients with acute kidney injury.

Key points

- E-alerts can potentially assist in the earlier diagnosis of acute kidney injuries, but evidence for their usefulness is limited.
- This study found that while acute kidney injury e-alerts were associated with earlier reviews and improved patient assessment they did not result in better patient management.
- The use of e-alerts alone is unlikely to influence outcomes and must be supported by other measures such as clinician education and easy access to support tools.
- Further research is required to examine the impact of the timeliness of completion acute kidney injury-related tasks on patients' clinical outcomes and long-term renal function.

Conclusions

This project was conducted to test if implementation of e-alerts has improved the process of care. Although the e-alerts have helped increase earlier acute kidney injury recognition, improvements in the process of care will require a more comprehensive programme of change including the better availability of and adherence to support tools such as acute kidney injury care bundles, improved junior doctors training and a continued process of audit and quality improvement.

Author details

[1]Department of Renal Medicine, Hull University Teaching Hospitals NHS Trust, Hull, UK

[2]Hull York Medical School, Hull, UK

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Conflicts of interest

The authors declare no conflicts of interest.

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Appendix. Auditing acute kidney injury (AKI)

Date completed……………………… Time……………………………………

Section 1

Casenote number:

Initials:

Age

Gender

Date and time of hospital admission

Date and time of AKI diagnosis

AKI stage at diagnosis: 1 2 3

Is this a (select one):

- New diagnosis of AKI
- Acute on chronic   If Acute on chronic: CKD stage 1 – 2 – 3a – 3b – 4 – 5

Date and time of medical review (after AKI diagnosis)

Grade of admitting doctor:

FY1

FY2

SHO/ST1-2

FTSTA

ST3+

Con

Date and time of consultant review

Section 2: Identifying risk factors

Was AKI risk assessment completed on the admission proforma? (Yes / No)

Section 3: Assessment

Was a note made in medical records stating the diagnosis? (Yes/No)

Indicate the assessment of the first doctor who saw patient after AKI diagnosis

	Done	Not done	Not applicable
Biochemistry reviewed			
Acid–base balance reviewed			
Fluid balance (including urine output) reviewed			
Sepsis review			
Obs chart / Early warning score reviewed			
Urinalysis done/requested			
Radiology reviewed/requested			
A possible cause for AKI identified			

Section 4: Management
Management of patient with AKI diagnosis

	Done	Not done	Not applicable
Frequency of observations altered?			
Fluid balance monitoring, including urine output chart (started or continued)			
Daily weight chart			
Attempt made to rule-out obstruction			
Correction of hypovolaemia			
Medication altered to renal dose			
Cessation of nephrotoxic drugs (excluding diuretics)			
Cessation of diuretics			
Review by renal dietician or nutritional team requested			
Further monitoring of biochemistry planned			
Addressing sepsis; Antibiotics (if appropriate)			
Administration of diuretics			
Other			

Section 5: Referral
Was patient referred to nephrology? (Yes / No)

Was it a timely referral? (within 24 hours) (Yes / No / Not applicable)

Where was the patient looked after following recognition of AKI (Renal ward / Level 3 / Level 2 / Level 1 non-renal / other)