Acute kidney injury (AKI) identification for pharmacoepidemiologic studies: use of laboratory electronic AKI alerts versus electronic health records in Hospital Episode Statistics (HES)

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Abstract

Purpose

A laboratory-based acute kidney injury (AKI) electronic-alert (e-alert) system, with e-alerts sent to the UK Renal Registry (UKRR) and collated in a master patient index (MPI), has recently been implemented in England. The aim of this study was to determine the degree of correspondence between the UKRR-MPI and AKI International Classification Disease-10 (ICD-10) N17 coding in Hospital Episode Statistics (HES) and whether hospital N17 coding correlated with 30-day mortality and emergency re-admission after AKI.

Methods

AKI e-alerts in people aged ≥18 years, collated in the UKRR-MPI during 2017, were linked to HES data to identify a hospitalised AKI population. Multivariable logistic regression was used to analyse associations between absence/presence of N17 codes and clinicodemographic features. Correlation of the percentage coded with N17 and 30-day mortality and emergency re-admission after AKI were calculated at hospital level.

Results

In 2017, there were 301,540 adult episodes of hospitalised AKI in England. AKI severity was positively associated with coding in HES, with a high degree of inter-hospital variability – AKI stage 1 mean of 48.2% [SD 14.0], vs AKI stage 3 mean of 83.3% [SD 7.3]. N17 coding in HES depended on demographic features, especially age (18-29 years vs ≥85 years OR 0.22, 95% CI 0.21-0.23), as well as sex and ethnicity. There was no evidence of association between the proportion of episodes coded for AKI with short-term AKI outcomes.

Conclusion

Coding of AKI in HES is influenced by many factors that result in an underestimation of AKI. Using e-alerts to triangulate the true incidence of AKI could provide a better understanding of the factors that affect hospital coding, potentially leading to improved coding, patient care and pharmacoepidemiologic research.

Key words: AKI, e-alerts, epidemiology, pharmacoepidemiology, HES, MPI, UKRR

Key Points

- Using creatinine-based acute kidney injury (AKI) electronic alerts (e-alerts) in England, high inter-hospital variability of International Classification Disease-10 (ICD-10) N17 coding of discharge letters was found. Increasing age was associated with better coding.
- N17 codes for AKI stage 3 were present for 80% of people of White ethnicity; coding for people of South Asian (OR 0.56, 95% CI 0.49-0.63) and Black ethnicity (OR 0.60, 95% CI 0.52-0.71) was lower.
- Men with AKI stage 1 were more often coded than women.
- Systematic differences in coding by demographic factors will need to be considered in pharmacoepidemiologic studies.
- Future research should investigate how the lack of communication about AKI affects patients' medium and long-term outcomes.

Introduction

Acute kidney injury (AKI) refers to an abrupt decline in the glomerular filtration rate (GFR) and may be associated with significant morbidity and mortality. Several consensus AKI definitions have been developed based upon serum creatinine values and urine output. The

Kidney Disease: Improving Global Outcomes (KDIGO) definition and staging system is the most used [1].

As a consequence of differences in definition, the incidence and prevalence of AKI are not yet well described [2]. AKI incidence seems to be growing [3]: contributing factors include aging populations, rising rates of comorbidities and polypharmacy that enhance susceptibility to AKI, increasing clinician awareness, and more sensitive definitions and detection systems for diagnosis [3,4].

Polypharmacy and use of nephrotoxic agents, in particular, are thought to be major contributing factors to the development of AKI. During recent years, to overcome this issue, the field of pharmacoepidemiology has started using artificial intelligence technology to explore 'big data' in order to advance medication safety surveillance and improve pharmacovigilance tools [5,6,7]. However, high quality data are the precondition for robust analysis using 'big data'.

Historically, the only way to routinely measure AKI incidence in hospitals in England was to analyse the ICD-10 code held in the Hospital Episode Statistics (HES) database, a data warehouse containing records of all patients admitted to National Health Service (NHS) hospitals in England. The 2009 National Confidential Enquiry into Patient Outcome and Death (NCEPOD) audit found that up to 100,000 hospital deaths per year were associated with AKI and a quarter to a third could be prevented by better recognition of AKI [5]. As a consequence, with the aim to improve AKI recognition and subsequently AKI outcomes, in April 2015, an automated real-time e-alert system for AKI (triggered by a short-term change in serum creatinine level) was introduced and progressively implemented in England, with alert data being sent to the UK Renal Registry (UKRR) for collation into a master patient

index (MPI) [8,9]. The algorithm has been validated with a high degree of sensitivity and specificity in different hospital settings [10].

The aims of this cross-sectional study were (1) to compare how identification of AKI differed between the laboratory e-alerts collated in the UKRR-MPI and administrative coding in HES, and to examine whether this varied by demographic factors; and (2) to analyse whether differences in coding between the two databases correlated with short-term AKI outcomes: 30 days mortality and emergency re-admission within 90 days post-discharge, both at a hospital level.

Methods

Study population

AKI e-alerts (stages 1, 2 and 3) from the UKRR-MPI were used to identify AKI episodes in adults starting between 1st January 2017 and 31st December 2017. An AKI episode was defined by one or more e-alerts separated by no more than 30 days, i.e. if more than one alert was present, all alerts following the first were considered part of the episode unless a 30-day alert-free period had passed. AKI episodes identified from the UKRR-MPI were linked to HES data to identify a hospitalised population with AKI.

During 2017, 108 laboratories sent AKI data to the UKRR for adult patients. Only laboratories that submitted good quality data in a timely fashion for HES linkage and that were related to acute hospitals were included in the analyses. Laboratories were red/amber/green (RAG) rated according to the completeness of four key data items (NHS number, sex, postcode and AKI stage) [9].

Individuals were included in the cohort multiple times if they had more than one hospitalised AKI episode during 2017. The analysis of re-admissions was based on the first detectable episode of each patient in 2017.

AKI episodes linked to day cases, regular hospital attendances, maternity admissions, or unknown method of admission, were excluded from the analysis. Prevalent patients with established kidney failure on long-term kidney replacement therapy were identified and excluded through linkage between the UKRR-MPI and the UKRR's established kidney failure dataset.

Variable definitions

AKI episodes with a first e-alert occurring before or within the first 2 days of admission to hospital were defined as community-acquired-hospitalised (CAH) AKI, while AKI episodes that started in hospital from the third day of admission onwards were defined as hospital-acquired (HA) AKI. Peak AKI was derived from the UKRR-MPI as the highest stage reached within 30 days from the start of the AKI episode.

Patient ethnicity and method of admission (elective or emergency) were obtained from the linked HES data. Sex, age and deprivation-quintile were obtained from the UKRR-MPI. Age is presented as median age and age-groups were chosen that balanced numbers of patients with width of age ranges (<30, 30-49, 50-64, 65-74, 75-84, ≥85 years).

Primary and secondary diagnostic ICD-10 codes were used to calculate a Charlson comorbidity score for each hospitalised AKI episode (supplementary methods). Using NHS number and date of birth, the NHS Demographics Batch Service was used to retrieve date of death within 30 days from the start of an AKI episode. Linked HES data were used to inform the date of emergency re-admission within 90 days after discharge.

Statistical analysis

Descriptive analyses were performed to investigate if those with an AKI episode derived from e-alerts also had an ICD-10 N17 code for AKI in HES and to describe

clinicodemographic differences by peak stage of AKI. Unadjusted hospital variation in percentage of AKI episodes coded with N17, by stage of AKI, is presented in funnel plots. For all included episodes, the frequency of primary diagnosis codes in HES immediately prior to discharge, was investigated for episodes both with and without N17 coding, overall and by AKI stage.

Multivariable logistic regression, stratified by hospital demographic strata to account for differences in case-mix, was used to analyse associations between N17 coding in HES and clinicodemographic features by peak AKI stage. Sex, age group, ethnicity, type of AKI (CAH vs HA) and admission method (elective vs emergency) were included in the logistic model.

Scatterplots were used to investigate the correlation between N17 coding in HES and both short-term (30 day) mortality and emergency re-admission to hospital within 90 days post-discharge, at a hospital level. Correlation between AKI coding in HES and 30-day mortality, crude and adjusted by age, sex and comorbidity score, were assessed for all stages of AKI and separately by peak AKI stage (supplementary figure 1). Similarly, scatterplots for correlation between AKI coding in HES and hospital emergency re-admission within 90 days post-discharge, crude and adjusted by age, sex and comorbidity score, were assessed for all stages of AKI, and separately by peak AKI stage (supplementary figure 2). People who had died by the end of their AKI episode were excluded from this analysis.

All analyses were conducted using SAS version 9.4.

Results

From 01/01/2017 to 31/12/2017, there were 301,540 hospitalisations in adults who triggered laboratory AKI e-alerts (Figure 1). 10% of the AKI episodes included in the study were recurrent episodes of AKI for the same individuals.

AKI severity was positively associated with the percentage of AKI episodes that were coded in HES (Figure 2). There was variation in the percentage of AKI episodes coded in HES between hospitals; this variation was most pronounced for AKI stage 1, with a mean of 48.2% (SD 14), versus AKI stage 3, with a mean of 83.3 % (SD 7.30) (Figure 2).

Demographic factors were associated with levels of coding in HES. In particular, younger adults' AKI episodes were less frequently coded in HES and this was true for all three AKI stages. For people aged 18-29 years, just 33.3% of AKI episodes were coded in HES compared to 64.5% for people aged ≥85 years old (Table 1). Results from the multivariable logistic regression analysis stratified by hospital are presented in figure 3. Younger adults had lower odds of coded AKI episodes compared to people aged ≥85 years (18-29 years OR 0.22, 95% CI 0.21-0.23) and individuals of South Asian and Black ethnicity were also less likely to be coded compared to individuals of White ethnic background for stage 3 AKI (South Asian OR 0.56, 95% CI 0.49-0.63, Black 0.60, 0.52-0.71). Females were less likely to be coded than males (females OR 0.85, 95% CI 0.83-0.87). Elective admissions had lower odds ratios across all stages of AKI compared to emergency admissions (elective OR 0.51, 95% CI 0.50-0.53), while CAH AKI episodes were more likely to be coded than HA AKI episodes and this was the same for all three stages (CAH OR 2.23, 95% CI 2.19-2.26). Socioeconomic deprivation was not significantly associated with differences in coding.

Although underlying chronic kidney disease (CKD) is an important risk factor for AKI, and the frequency of AKI in people with CKD is known to be high, coding of AKI stage 1 was rare and even for AKI stages 2 and 3, only 25% of episodes were recorded (supplementary Tables 1, 2, 3). Coding of AKI was also less frequent in clinically complex contexts, such as severe neoplastic diseases or where there were concomitant urological/surgical conditions.

Both crude and sex-age-comorbidity score adjusted scatterplots for short-term mortality show that, at a hospital level, there was no evidence of correlation between coding in HES and 30-day mortality (Figure 4). Similarly, crude and sex-age-comorbidity score adjusted scatterplots for emergency re-admission within 90 days of an AKI episode end, for those who survived, show no evidence of correlation (Figure 5).

Discussion

In 2017, less severe AKI episodes were poorly coded in HES, with a high degree of inter-hospital variability. However, a high proportion of stage 3 AKI episodes were coded, with much less variation between hospitals seen. AKI episodes were less frequently coded in HES in younger adults compared to older people for all three stages of AKI. Females were less likely to be coded than males, especially in the earlier stages, and people of South Asian and Black ethnic backgrounds were less likely to be coded for AKI stage 3 than people of White ethnicity.

Under-coding of AKI in administrative hospital datasets has been reported previously [11,12,13,14]. Distortions between AKI identified by more objective criteria (a change in baseline serum creatinine value) and AKI identified by the assigned ICD-10 N17 code may be a consequence of poor clinical recognition and documentation in medical records, and subsequent clinical coding. Alternatively, an AKI that develops in a more complex clinical context may not be coded, with the underlying condition, for example, a severe neoplastic disease, coded instead. Ongoing studies at the UKRR are exploring this possibility and preliminary results show that although CKD is recognised as a major risk factor for AKI, only about 25% of AKI episodes, mainly stage 2 and 3, were coded in people with underlying CKD.

It is widely acknowledged that administrative hospital reports do not code a large amount of medical information and recently this has led to advances in automated methods of textual analysis to better retrieve diagnoses and other medical information of importance [15,16]. However, given our findings, there is a significant risk that an automated approach that does not take into account factors relating to clinicians and/or coders, as well as the potential impact of pre-existing comorbidities, may miss cases of AKI and consequently increase already existing inequities.

Associations seen by ethnicity in our study are not driven by poor ethnicity coding, because ethnicity coding in HES has improved in the last 20 years, for example, from 1998–2003 to 2008–2013, the category 'not known' fell from 33.7% to 5.5% [6].

An AKI episode is often the result of a combination of factors, such as the combined effect of infection, fluid loss and medicines that lead to reduced perfusion of the kidneys [17,18]. Frail older people are at highest risk because of multiple long-term conditions and polypharmacy [19]. Although medication-induced AKI is assumed to be common [20], a systematic review concluded that the quality of evidence describing the association between medication combinations and development of AKI is weak [21]. Our findings reinforce the idea that, despite the sensitivity of coding in HES having improved over time [22], the underestimation of AKI in HES, especially the earlier stages and in certain demographic groups (ethnicity, age and sex), highlights the need to use HES data carefully when identifying AKI.

AKI is known to be associated with prolonged stays, development or progression of chronic kidney disease, cardiovascular events and early death [8,23,24] across several clinical settings [25,26,27]. To date, national and international consensus-based recommendations emphasise the importance of following up AKI episodes to develop interventions that prevent medium and long-term adverse outcomes, through monitoring kidney function, optimising medicines

management and communicating the diagnosis with patients [22,27,29]. To improve the care of a patient with an AKI moving from hospital to primary care, the AKI episode needs to be identified and documented in discharge summaries. Otherwise, post-discharge clinicians in both primary and secondary outpatient care settings are not aware of a previous AKI episode.

We investigated how N17 coding in HES at hospital level was related to 30-day mortality since the beginning of the AKI episode and emergency re-admission within 90 days post-discharge. It was reassuring that we did not find correlations between coding level and these short-term outcomes. However, considering a potential underestimation of AKI incidence in HES and how this impacts the follow-up of AKI episodes post-discharge, studies of longer-term outcomes and outpatient medicines management are needed.

Strengths and limitations

Strengths of our study are the use of large datasets, a validated AKI e-alert algorithm and good capture of ethnicity from HES. Conversely, a limitation of our study is that the UKRR-MPI does not receive AKI flags produced by the algorithm when a baseline creatinine value is not available. However, this problem mainly affects community-acquired rather than hospital-acquired forms of AKI. Furthermore, AKI related to day-case admission to hospital were excluded, because these cases, that are likely to develop in less frail patients and to correspond to less severe forms of AKI, are mostly classifiable as community-acquired.

The UKRR unfortunately does not have the ethical/legal basis to obtain data on every patient but can only analyse the data of those with kidney impairment treated in secondary care. This currently limits the ability to compute an agreement analysis and report how frequently an ICD-10 occurrence in HES does not find a similar episode in the UKRR-MPI.

Conclusion

This study shows that coding of AKI in a hospital administrative dataset can be influenced by many factors that may result in an underestimation of AKI. In England, coded diagnoses on the discharge record held in HES are created when patients are moved from secondary to primary care. If AKI is not recorded in a discharge letter, general practitioners are unable to perform adequate clinical follow-up. Using laboratory e-alerts to triangulate the true incidence of AKI could provide a better understanding of which factors affect hospital coding, potentially leading to improved coding, patient care and pharmacoepidemiologic research.

Ethics statement

On behalf of the Renal Association, the UK Renal Registry (UKRR) collects patient-level AKI data without individual patient consent under section 251 of the NHS Act (2006), granted by the Health Research Authority's Confidentiality Advisory Group (ref 16/CAG/0153). Data are always pseudonymised prior to analyses.

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Table 1: Percentage of AKI episodes coded with the ICD-10 N17 code in HES by demographics (age, sex, deprivation and ethnicity), type of AKI and type of hospital admission and stratified by peak stage of AKI.

AKI warning staging alerts	peak-1 AKI	peak-2 AKI	peak-3 AKI	ALL-stages AKI
N	194,796	59,645	47,099	301,540
%	64.6	19.8	15.6	
% of AKI warning staging alerts coded with N17 in HES by demographics				
All	47.2	70.2	82.0	57.2
Age group				
18- 29	25.0	48.2	64.5	33.3
30- 49	29.3	57.5	72.3	42.0
50- 64	37.5	64.0	78.2	50.4
65 - 74	44.3	68.8	82.2	56.0
75 - 84	51.4	73.6	84.6	60.9
≥85	57.1	76.4	87.2	64.5
Sex				
Female	46.2	69.9	82.3	55.9
Male	48.2	70.4	81.8	58.4
Deprivation quintile scores*				
deprivation score-1	47.4	70.2	81.7	57.0
deprivation score-2	47.0	70.3	82.3	56.9
deprivation score-3	47.6	70.4	83.2	57.6
deprivation score-4	47.7	70.8	81.7	57.7
deprivation score-5	46.2	69.2	81.3	56.5
Ethnicity**				
South Asian	43.2	66.4	71.0	51.6
Black	43.6	64.5	72.1	52.9
Other	39.0	62.1	74.7	48.6
White	48.0	70.9	82.9	58.0
Type-AKI				
CA	53.7	76.0	84.7	65.0
HA	41.1	60.3	75.4	47.6
Type-admission				
Elective	30.0	54.0	63.1	37.5
Emergency	49.2	71.6	83.3	59.2

*missing deprivation 0.3%; score-1 = least deprived.

**missing ethnicity 7.0% (missing/not given in the HES code).

Fig. 1: Flowchart explaining how the hospitalised population with AKI during 2017 in England were identified.

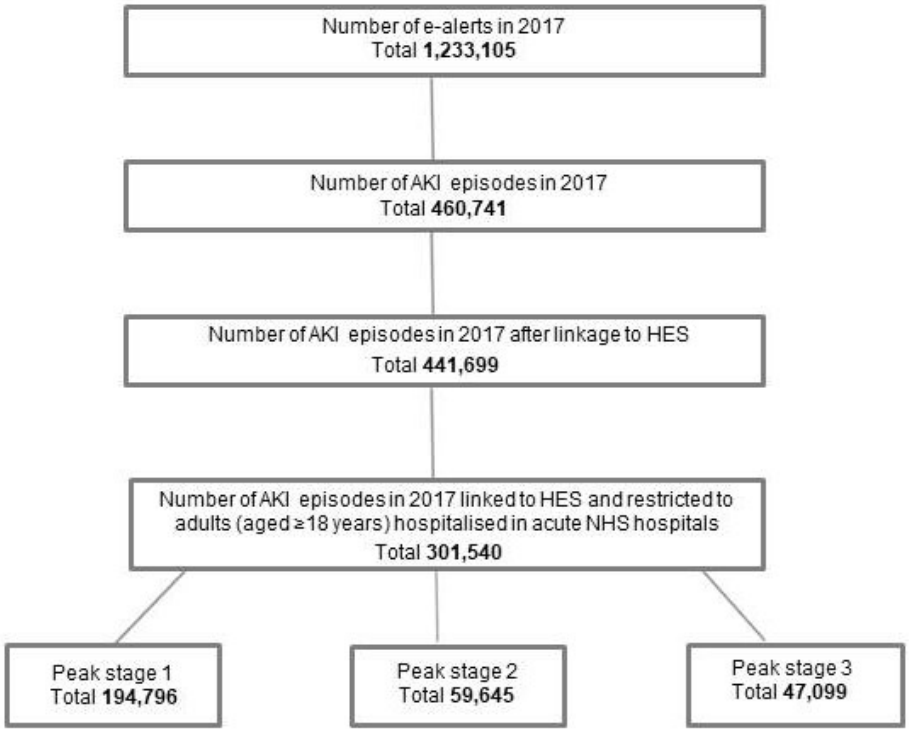


Fig. 2: Funnel plots showing variation between hospitals (green triangles) in the percentage of AKI episodes coded with the ICD-10 N17 code in HES, by peak AKI stage.

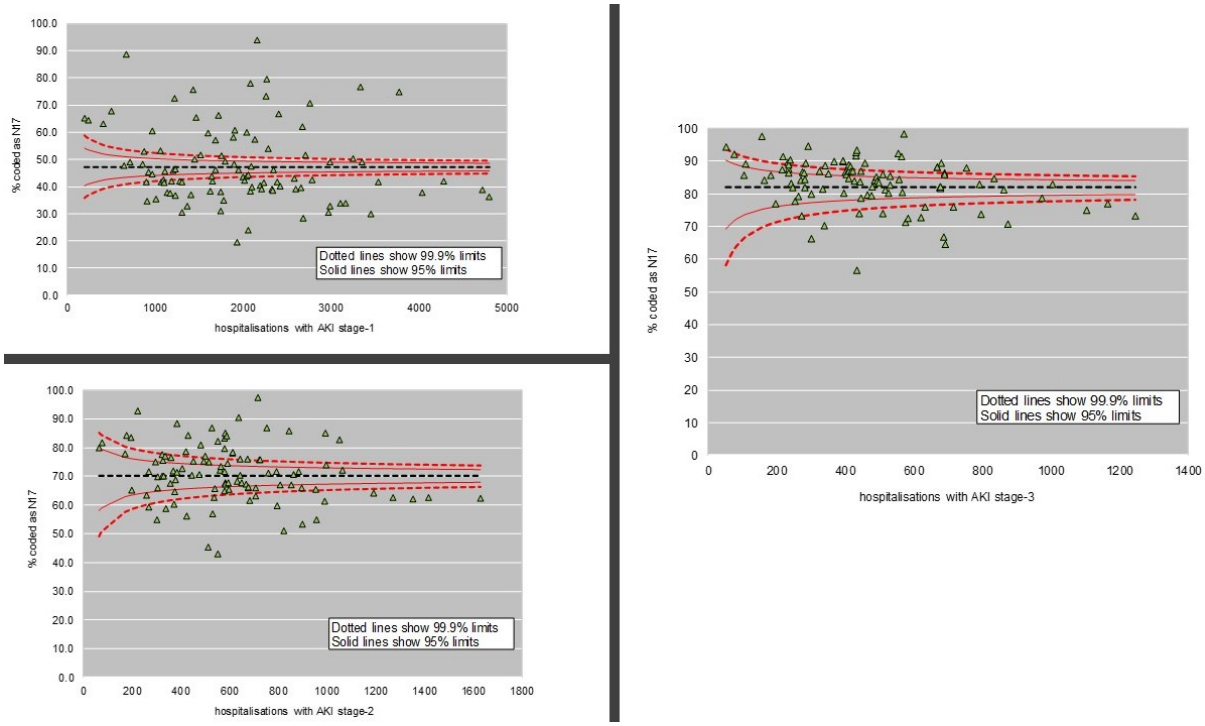


Fig. 3: Forest plots showing multivariable logistic regression stratified by hospital of the associations between AKI episodes coded with the ICD-10 N17 code in HES and clinicodemographic characteristics (ethnicity, age, sex, type of hospital admission and type of AKI) for all AKI stages and by peak AKI stage. All associations shown are mutually adjusted.

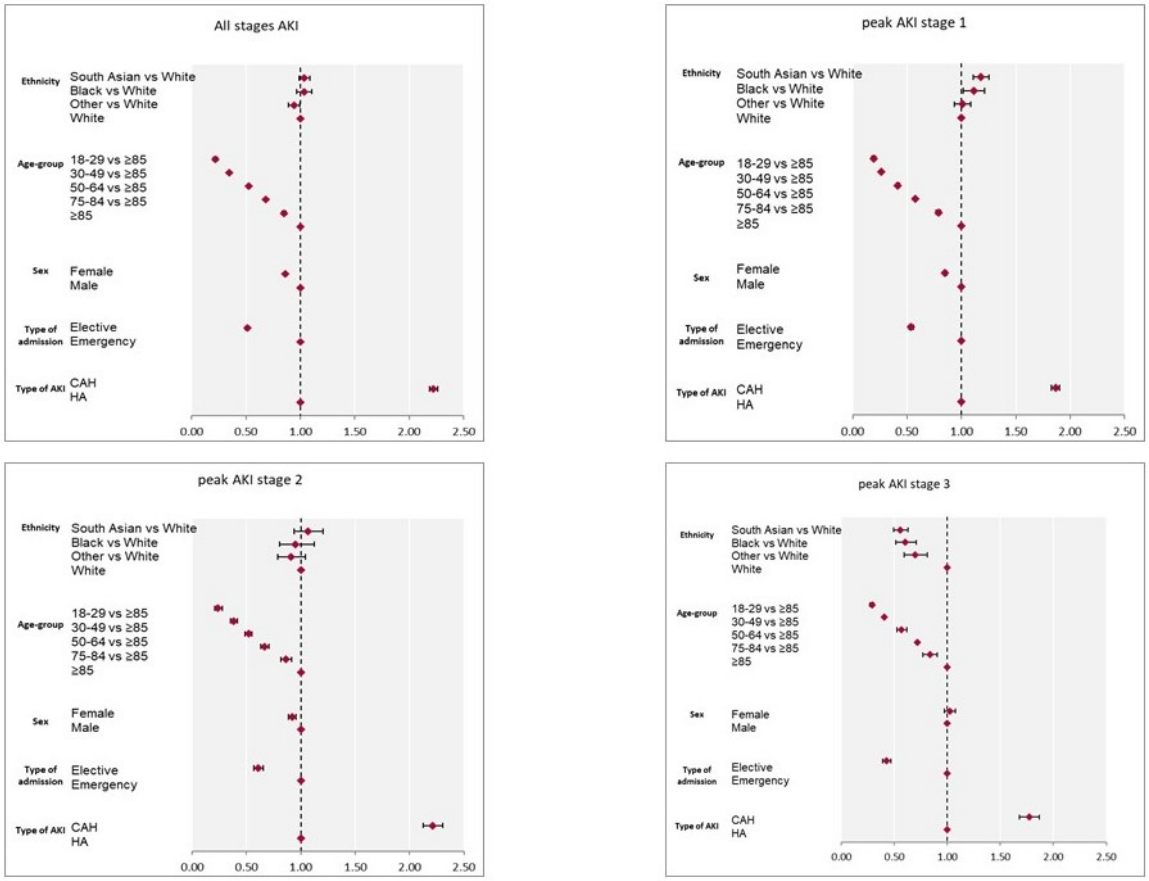


Fig. 4: Scatterplots showing variation between hospitals in the percentage of AKI episodes coded with the ICD-10 N17 code in HES and 30-day mortality (all stages of AKI) – crude (left graph) and sex-age-comorbidity score adjusted (right graph).

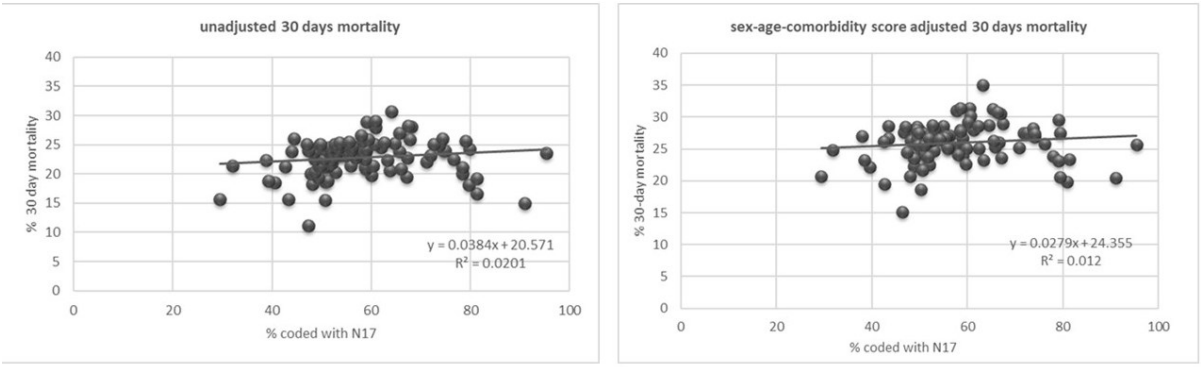
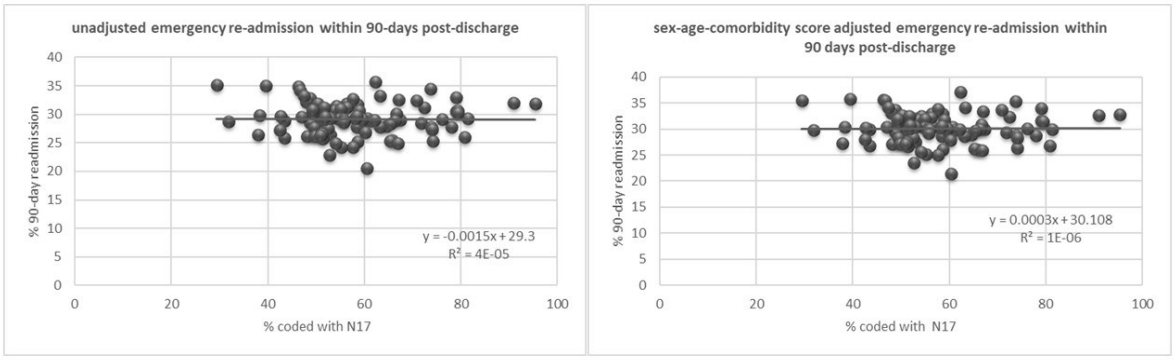


Fig. 5: Scatterplots showing variation between hospitals in the percentage of AKI episodes coded with the ICD-10 N17 code in HES and emergency re-admission within 90 days post-discharge (all stages of AKI) – crude (left graph) and sex-age-comorbidity score adjusted (right graph).



Supplementary Table 1: Percentage of primary diagnosis codes coded in both episodes with and without the ICD-10 N17 code in HES, in all stages.

Primary_diagnosis CODE	code_name	N17 Not coded	N17 Coded	Total*	% N17 Coded
A04	Enteropathogenic Escherichia coli infection	287	908	1195	76.0
A09	Infectious gastroenteritis and colitis, unspecified	818	2214	3032	73.0
A40	Streptococcal sepsis	303	720	1023	70.4
A41	Other sepsis	7843	19903	27746	71.7
C18	Malignant neoplasm of colon	1284	870	2154	40.4
C25	Malignant neoplasm of pancreas	640	555	1195	46.4
C34	Malignant neoplasm of bronchus and lung	1155	984	2139	46.0
C61	Malignant neoplasm of prostate	530	641	1171	54.7
C64	Malignant neoplasm of kidney. except renal pelvis	1456	594	2050	29.0
C67	Malignant neoplasm of trigone of bladder	848	789	1637	48.2
C78	Secondary malignant neoplasm of unspecified lung	859	812	1671	48.6
C90	Multiple myeloma not having achieved remission	449	715	1164	61.4
C92	Myeloid leukaemia	678	469	1147	40.9
E10	Type 1 diabetes mellitus with ketoacidosis without coma	1061	1040	2101	49.5
E11	Type 2 diabetes w hyperosm. w/o non-ket. hypergly-hyperosm. coma	690	1238	1928	64.2
E87	Hyperosmolality and hypernatremia	1615	1637	3252	50.3
F05	Delirium due to known physiological condition	467	766	1233	62.1
F10	Alcohol related disorders	621	452	1073	42.1
I21	Acute myocardial infarction	3468	3757	7225	52.0
I25	Chronic ischemic heart disease	1312	897	2209	40.6
I26	Pulmonary embolism	669	758	1427	53.1
I35	Nonrheumatic aortic valve disorders	604	499	1103	45.2
I48	Atrial fibrillation	1060	1161	2221	52.3
I50	Heart failure	4978	8353	13331	62.7
I63	Cerebral infarction	2200	2083	4283	48.6
I71	Dissection of aorta	737	673	1410	47.7
J18	Bronchopneumonia	9254	16223	25477	63.7
J22	Unspecified acute lower respiratory infection	1324	1885	3209	58.7
J44	Chronic obstructive pulmonary disease	2459	2536	4995	50.8
J69	Pneumonitis due to solids and liquids	1744	2242	3986	56.2
J96	Respiratory failure	594	865	1459	59.3
K55	Vascular disorders of intestine	590	642	1232	52.1
K56	Ileus	1779	1558	3337	46.7
K57	Diverticular disease of intestine	864	715	1579	45.3
K59	Other functional intestinal disorders	516	554	1070	51.8
K70	Alcoholic liver disease	1238	1925	3163	60.9
K80	Cholelithiasis	1676	1205	2881	41.8
K85	Pancreatitis	1043	950	1993	47.7
K92	Hematemesis	886	931	1817	51.2
L03	Cellulitis and acute lymphangitis	1268	2340	3608	64.9
M16	Osteoarthritis of hip	665	592	1257	47.1
M17	Osteoarthritis of knee	795	720	1515	47.5
N13	Obstructive and reflux uropathy	1686	2161	3847	56.2
N18	Chronic kidney disease	1083	294	1377	21.4
N20	Calculus of kidney and ureter	1209	617	1826	33.8
N39	Other disorders of urinary system	3715	7798	11513	67.7
R07	Pain in throat and chest	677	345	1022	33.8
R10	Abdominal and pelvic pain	982	456	1438	31.7
R29	Other symptoms and signs involving the nervous and musculoskeletal systems	816	1207	2023	59.7
R33	Retention of urine	605	854	1459	58.5

S06	Intracranial injury	815	488	1303	37.5
S72	Fracture of femur	3732	3966	7698	51.5
T81	Complications of procedures. not elsewhere classified	940	603	1543	39.1
T84	Complications of internal orthopaedic prosthetic devices.	669	578	1247	46.4

*primary diagnosis code included only if coded in N total >1000

Supplementary table 2: Percentage of primary diagnosis codes coded in both episodes with and without the ICD-10 N17 code in HES, in AKI stage 1.

Primary_diagnosis CODE	code_name	N17 Not coded	N17 Coded	Total*	% N17 Coded
A09	Infectious gastroenteritis and colitis, unspecified	647	1050	1697	61.9
A41	Other sepsis	5678	8746	14424	60.6
C18	Malignant neoplasm of colon	999	431	1430	30.1
C34	Malignant neoplasm of bronchus and lung	871	490	1361	36.0
C64	Malignant neoplasm of kidney. except renal pelvis	1256	397	1653	24.0
E10	Type 1 diabetes mellitus with ketoacidosis without coma	797	571	1368	41.7
E11	Type 2 diabetes with hyperosm. w/o non-ket. hypergly-hyperosm. coma	536	680	1216	55.9
E87	Hyperosmolality and hypernatremia	1296	939	2235	42.0
I21	Acute myocardial infarction	2856	2244	5100	44.0
I25	Chronic ischemic heart disease	1091	532	1623	32.8
I48	Atrial fibrillation	953	848	1801	47.1
I50	Heart failure	4195	5218	9413	55.4
I63	Cerebral infarction	1815	1319	3134	42.1
J18	Bronchopneumonia	7332	9352	16684	56.1
J22	Unspecified acute lower respiratory infection	1101	1265	2366	53.5
J44	Chronic obstructive pulmonary disease	2096	1679	3775	44.5
J69	Pneumonitis due to solids and liquids	1343	1251	2594	48.2
K56	Ileus	1338	752	2090	36.0
K57	Diverticular disease of intestine	696	397	1093	36.3
K70	Alcoholic liver disease	822	604	1426	42.4
K80	Cholelithiasis	1430	770	2200	35.0
K85	Pancreatitis	823	433	1256	34.5
K92	Hematemesis	703	529	1232	42.9
L03	Cellulitis and acute lymphangitis	1095	1356	2451	55.3
M16	Osteoarthritis of hip	574	433	1007	43.0
M17	Osteoarthritis of knee	706	497	1203	41.3
N13	Obstructive and reflux uropathy	1325	894	2219	40.3
N20	Calculus of kidney and ureter	1078	452	1530	29.5
N39	Other disorders of urinary system	3109	4714	7823	60.3
R10	Abdominal and pelvic pain	849	319	1168	27.3
R29	Other symptoms and signs involving the nervous and musculoskeletal systems	715	899	1614	55.7
S72	Fracture of femur	3203	2798	6001	46.6
T81	Complications of procedures. not elsewhere classified	746	303	1049	28.9

*primary diagnosis code included only if coded in N total >1000

Supplementary Table 3: Percentage of primary diagnosis codes coded in both episodes with and without the ICD-10 N17 code in HES, in AKI stage 2 and 3.

primary_diagnosis CODE	code_name	N17 Not coded	N17 Coded	Total*	% N17 Coded
A04	Enteropathogenic Escherichia coli infection	71	495	566	87.4
A09	Infectious gastroenteritis and colitis, unspecified	171	1164	1335	87.1
A41	Other sepsis	2165	11157	13322	83.7
C18	Malignant neoplasm of colon	285	439	724	60.6
C25	Malignant neoplasm of pancreas	212	362	574	63.0
C34	Malignant neoplasm of bronchus and lung	284	494	778	63.5
C61	Malignant neoplasm of prostate	186	388	574	67.6
C67	Malignant neoplasm of trigone of bladder	205	464	669	69.4
C78	Secondary malignant neoplasm of unspecified lung	233	479	712	67.3
C90	Multiple myeloma not having achieved remission	89	459	548	83.8
E10	Type 1 diabetes mellitus with ketoacidosis without coma	264	469	733	64.0
E11	Type 2 diabetes with hyperosm. w/o non-ket hypergly-hyperosm. coma	154	558	712	78.4
E87	Hyperosmolality and hypernatremia	319	698	1017	68.6
I21	Acute myocardial infarction	612	1513	2125	71.2
I25	Chronic ischemic heart disease	221	365	586	62.3
I50	Heart failure	783	3135	3918	80.0
I63	Cerebral infarction	385	764	1149	66.5
J18	Bronchopneumonia	1922	6871	8793	78.1
J22	Unspecified acute lower respiratory infection	223	620	843	73.5
J44	Chronic obstructive pulmonary disease	363	857	1220	70.2
J69	Pneumonitis due to solids and liquids	401	991	1392	71.2
J96	Respiratory failure	147	446	593	75.2
K55	Vascular disorders of intestine	235	382	617	61.9
K56	Ileus	441	806	1247	64.6
K70	Alcoholic liver disease	416	1321	1737	76.1
K80	Cholelithiasis	246	435	681	63.9
K85	Pancreatitis	220	517	737	70.1
K92	Hematemesis	183	402	585	68.7
L03	Cellulitis and acute lymphangitis	173	984	1157	85.0
N13	Obstructive and reflux uropathy	361	1267	1628	77.8
N18	Chronic kidney disease	671	223	894	24.9
N39	Other disorders of urinary system	606	3084	3690	83.6
R33	Retention of urine	252	548	800	68.5
S72	Fracture of femur	529	1168	1697	68.8

*primary diagnosis code included only if coded in N total >500

Data Availability

The data underlying the results presented in this paper are available from the UKRR through the UKRR's data application process – see https://renal.org/audit-research/how-access-data/ukrr-data. For any data access queries, contact ukrr-research@renalregistry.nhs.uk.

Conflict of Interest Statement

The authors have no competing interests to declare.

Authors' Contributions

Dr Manuela Savino	First author (conception of the work, data interpretation, writing draft of the manuscript, critical revision before submission, corresponding author)
Dr Lucy Plumb	Co-author (data interpretation and critical revision before submission)
Dr Anna Casula	Co-author (data analyses and interpretation, drafting of Methods, critical revision before submission)
Dr Katharine Evans	Co-author (writing draft of the manuscript and critical revision before submission)
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