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Incidence, care quality and outcomes of patients with acute kidney injury in admitted hospital care

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Summary

Background/Introduction: Acute kidney injury (AKI) is common in acute hospital admission and associated with worse patient outcomes.
Aim: To measure incidence, care quality and outcome of AKI in admitted hospital care.
Design: Forty-six of 168 acute NHS healthcare trusts in UK caring for 2 million acute hospital admissions per annum collected information on adults identified with AKI stage 3 (3-fold rise in serum creatinine or creatinine >354 μmol/l) through routine biochemical testing over a 5-month period in 2012.
Methods: Information was collected on patient and care characteristics. Primary outcomes were survival and recovery of kidney function at 1 month.
Results: A total of 15 647 patients were identified with biochemical AKI stage 3. Case note reviews were available for 7726 patients. In 80%, biochemical AKI stage 3 was confirmed clinically. Among this group, median age was 75 years, median length of stay was 12 days and the overall mortality within 1 month was 38%. Significant factors in a multivariable model predicting survival included age and some causes of AKI. Dipstick urinalysis, medication review, discussion with a nephrologist and acceptance for transfer to a renal unit were also associated with higher survival, but not early review by a senior doctor, acceptance for transfer to critical care or requirement for renal replacement therapy. Eighteen percent of people did not have their kidney function checked 1 month after the episode had resolved.
Discussion/Conclusions: This large study of in-hospital AKI supports the efficacy of biochemical detection of AKI in common usage. AKI mortality remains substantial, length of stay comparable with single-centre studies, and much of the variation is poorly explained (model Cox and Snell $R^2 = 0.131$) from current predictors.

Background

Acute kidney injury (AKI) is the rapid decrease in kidney function over days or weeks. It is common amongst acute admissions to hospital with ~5–20% of acutely admitted patients experiencing an episode of AKI during the course of their illness.[1,2] It is commonly associated with episodes of acute inter-current illness and is more likely in those with chronic kidney disease (CKD) or diabetes.[3] Although seldom the sole cause of a patients' death, AKI is associated with significant mortality.[4]

Consensus has been reached on a classification for severity of AKI[5] that has been useful in demonstrating that both mortality and length of stay increase progressively up to the most severe stage 3 AKI.[2] Despite this care of AKI in the UK has been

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assessed as sub-optimal, with the review of care in national selection of patients coded as dying with AKI during 2009 concluding that AKI could have been avoided in 14%, and that care was adequate in only 50% of cases.[6]

Aim

The study reported here was designed to explore the outcomes of patients with the most severe stage of AKI (AKI3) across a sample of acute hospital trusts in UK. We examined the impact of a range of national and international recommendations for good AKI care such as timely senior medical review, medication review and discussion with a nephrologist on patient outcome.

Design

Cohort study of patients identified with AKI3 during 5-month period 1 August 2012 to 31 December 2012.

Methods

All 168 acute NHS Trusts in UK were invited (by letter to all medical directors) to take part in an audit comparing AKI incidence and assessing care quality and outcome for quality improvement purposes. Data were received from 46 organizations. This study is the further analysis of the non-identifiable information collected. Published guidance and correspondence with the UK Health Research Authority confirmed that ethical approval was not required for this study.

Each trust used an automated system to identify adult patients (aged $\geq$ 18 years) with suspected AKI stage 3 using the hospital pathology system each month between 1 August 2012 and 31 December 2012 (5 months). Case selection criteria were based on the Kidney Disease: Improving Global Outcomes (KDIGO) guidance[5] and required an increase in serum creatinine measured during admission 3-fold from baseline or an absolute rise in creatinine >354 μmol/l. In this study, the baseline value was defined as the closest single creatinine to the date of admission in the preceding 12 months (from an inpatient or outpatient location). Patients with no creatinine results in the preceding 12 months and with an admission creatinine >354 μmol/L were considered to have AKI in this study. Organizations already identifying patients with AKI using alternative criteria (for instance, using a different assessment of baseline, or imputing a baseline if none was available) were allowed to submit data using their existing algorithm to allow comparison in positive predictive value (PPV, the probability that an individual identified by the algorithm had AKI3 on clinical review) between methods. Sites excluded patients with advanced CKD including those with end-stage renal disease (ESRD) where possible using a locally determined methodology.

Coded, non-identifiable data on patients identified with AKI3 by biochemical criteria were sent to the East Midlands Public Health Observatory (EMPHO) who returned to trusts each month a randomized list of 40 cases to review the notes. Notes were reviewed against a standard pro-forma based on national and international care guidelines and standards,[6–8] supported by specific coding guidance and included clinical validation of the presence of AKI stage 3. The notes review was conducted by a senior hospital doctor (general physician or nephrologist) supported by an administrator. Patient and kidney outcome at 1 month was collected, and data were returned to EMPHO for analysis. All the analysis of patient care and outcome are based on the subset of patients with a case note review.

Statistical analysis

Primary outcome was survival 1 month after AKI3 trigger. Secondary outcome was level of kidney function at 1 month compared with baseline level. Factors initially considered plausible influences on survival at 1 month were patient characteristics, geographical and temporal factors, care process attainment, discussion with a nephrologist, patient receiving renal replacement therapy (RRT) and cause of the AKI. A logistic regression model was used to determine the statistical significant of factors, but all factors considered clinically plausible were left in the final model regardless of their statistical significance to aid interpretation. Analysis was conducted using IBM SPSS Statistics version 22.

Results

Data were received from 46 trusts that treated 1 960 900 acute hospital admissions during 2012–13 (36.8% of the 5.3 million acute hospital admissions in UK each year[9]). Twenty-eight of the 46 (61%) had a main renal unit (as defined by the UK Renal Registry) in the same trust compared with 52 renal units in UK[10] and 168 acute NHS trusts[11] (31% with main renal unit) at the time of the study.

In total, 15 647 patient biochemical records were submitted by trusts that fulfilled the biochemical criteria for AKI3, and 8133 episodes of AKI were randomly selected for case note review. Case-note review data were available from 6041 patients who fulfilled the biochemical criteria for AKI3, had a care review that confirmed AKI was clinically present, and had the principle outcome (survival at 1 month) recorded. Four hundred and seven patients were excluded because the case-note review was not completed (return rate 95%). A total of 1563 patients were excluded as after note review, they were not felt clinically to have had AKI (647 cases of CKD, 575 cases of ESRD and 334 for "other reasons"). Eighty-nine patients were excluded from the analysis as the primary outcome measure (alive at 1 month) was missing.

Characteristics of the 46 trusts who supplied data are shown in Table 1. Trusts returned case-note reviews between 57 and 210 patients, confirming between 31 and 210 cases of AKI. The proportion of patients detected by the biochemical algorithm who were confirmed to have AKI varied considerably between organizations, with only 16% PPV at worst, and 100% at best. Centres with the highest PPV were generally centres with well-established local detection algorithms. Overall, the PPV was 79.7%. The clinical validated incidence of AKI3 is expressed per thousand un-planned hospital admissions as it is recognized that the majority of cases of AKI occur in patients admitted acutely. The results are very similar if presented by total hospital admissions (data not shown). Overall, the crude rate of AKI3 detected biochemically and confirmed clinically was 12.7 per 1000 un-planned hospital admissions (median, 12.4; interquartile range, 10.0115.3).

Demographics

The median age of the group with clinically confirmed AKI3 was 75 years (range, 16–99 years), and 3404 were men (56.0%). The majority of patients were recorded as White (5,126, 93.6%), with 170 South Asian, 111 Black, 70 others and 653 (10.7%) not known.

Care processes

The proportion of patients who received each of the care processes is summarized in Table 2. Early Warning Score (EWS) was implemented to some degree in all but in one trust that

Table 1. Characteristics of the 46 acute hospital trusts who submitted data

Trust	Identified biochemical AKI3	Completed reviews	Number with AKI3	Proportion reviews with AKI3 (%)	Estimated annual number cases AKI3 per year	Annual number emergency admissions	Rate AKI3 per 1000 admissions
1	614	194	113	58.2	715	55,500	12.9
2	443	200	96	48.0	425	39,500	10.8
3	178	132	101	76.5	272	22,100	12.3
4	378	182	175	96.2	727	26,200	27.7
5	755	190	131	68.9	1,041	57,900	18.0
6	148	128	117	91.4	271	15,200	17.8
7	427	198	194	98.0	837	43,900	19.1
8	254	165	140	84.8	431	27,800	15.5
9	355	135	104	77.0	547	51,400	10.6
10	208	169	114	67.5	281	28,800	9.7
11	297	182	83	45.6	271	31,800	8.5
12	232	161	122	75.8	352	32,900	10.7
13	683	188	142	75.5	1,032	73,400	14.1
14	296	192	106	55.2	327	29,200	11.2
15	454	200	138	69.0	627	33,300	18.8
16	360	198	185	93.4	673	53,700	12.5
17	273	104	78	75.0	410	28,800	14.2
18	416	198	136	68.7	571	39,000	14.7
19	345	188	165	87.8	606	36,800	16.5
20	458	197	169	85.8	786	63,800	12.3
21	256	193	182	94.3	483	39,200	12.3
22	310	188	178	94.7	587	30,600	19.2
23	484	156	150	96.2	931	59,300	15.7
24	290	191	188	98.4	571	33,700	16.9
25	279	199	165	82.9	463	36,300	12.7
26	218	160	158	98.8	431	43,300	9.9
27	581	142	110	77.5	900	75,100	12.0
28	331	178	177	99.4	658	51,000	12.9
29	301	197	194	98.5	593	50,100	11.8
30	311	74	74	100.0	622	48,600	12.8
31	220	210	210	100.0	440	53,700	8.2
32	220	154	143	92.9	409	39,600	10.3
33	144	112	87	77.7	224	25,400	8.8
34	115	73	46	63.0	145	22,300	6.5
35	303	173	172	99.4	602	43,600	13.8
36	297	194	175	90.2	536	72,100	7.4
37	333	179	176	98.3	655	47,200	13.9
38	176	127	124	97.6	344	42,500	8.1
39	315	197	170	86.3	544	88,100	6.2
40	431	168	110	65.5	564	34,200	16.5
41	336	200	137	68.5	460	51,500	8.9
42	436	191	40	20.9	183	17,400	10.5
43	675	193	31	16.1	217	54,300	4.0
44	69	57	57	100.0	138	34,900	4.0
45	340	150	142	94.7	644	34,600	18.6
46	302	136	125	91.9	555	44,200	12.6
Total	15 647	7693	6130	79.7	24 936	1 963 900	12.7

reported no use of the EWS in any of their patients reviewed. A percentage of 35.7 patients were discussed with a renal unit, and 8.7% accepted for transfer, whereas 20.1% of patients transferred to intensive treatment unit (ITU). Eighty-three people transferred to both settings. Overall, 12.9% required RRT, but although 17.4% of those aged 18–30 years required RRT, only 9.0% of those aged 75 years and over required RRT ($\chi^2 = 7.007$, $P = 0.008$).

There was a positive association between dipstick testing and both senior review and discussion with a nephrologist. A percentage of 67.2 patients who had been discussed with a nephrologist had a urine dipstick test, whereas this occurred in only 48.8% of those who were not discussed ($\chi^2 = 179.649$, $P < 0.001$). With senior review 57.0% had a urine dipstick compared with 45.2% of those who did not have a senior review ($\chi^2 = 39.110$, $P < 0.001$).

Outcomes

Median length of stay for the whole group with AKI was 12 days. Those who were alive at 1 month had a longer median length of stay (14 days) than those who had died (8 days) (Wilcoxon rank sum $P < 0.001$). The variation in outcome by trust is shown in Table 3.

A total of 3729 people were alive at 1 month to have an assessment of kidney function. In 19.4%, kidney function was not

Table 2. Demographics and achievement of key care processes by acute hospital trust

Trust	Median age (yrs)	% Male	% Senior review 12 h	% Urine dipstick	% EWS implemented	% Medication reviewed	% Renal discussion	% Renal transfer	% ITU transfer
1	75.0	46.0	85.0	51.3	88.5	85.0	44.2	15.9	29.2
2	76.0	61.5	74.5	62.5	82.1	94.8	56.3	11.6	36.8
3	78.0	58.4	93.1	83.2	96.0	92.1	25.7	5.9	26.7
4	77.0	46.9	81.7	49.7	93.1	82.3	40.0	2.9	23.7
5	75.0	47.3	95.4	48.1	97.7	58.9	27.9	6.9	14.0
6	80.0	53.0	65.5	49.6	85.3	92.2	33.6	9.5	18.1
7	75.0	58.2	82.5	54.1	92.3	86.6	50.5	19.1	16.0
8	77.0	53.6	90.7	87.9	100.0	97.9	67.1	0.7	10.0
9	76.0	59.6	86.3	51.0	95.0	85.3	30.1	5.8	22.8
10	76.0	57.0	93.9	33.3	30.7	77.9	34.2	5.3	30.4
11	78.0	55.8	86.1	50.6	63.3	88.6	25.3	5.1	14.1
12	72.0	56.6	100.0	96.7	98.3	100.0	54.2	26.2	32.0
13	72.0	57.0	79.4	49.3	44.0	69.5	31.9	10.6	14.2
14	77.0	67.0	97.1	75.5	100.0	98.1	34.6	7.6	21.2
15	80.5	57.2	88.8	35.5	81.7	81.0	20.0	3.1	18.2
16	76.0	54.1	93.5	45.4	77.3	94.6	16.2	0.5	13.0
17	77.0	55.1	84.6	44.9	98.7	59.0	20.5	3.8	19.5
18	75.5	56.6	100.0	77.9	0.0	100.0	84.6	41.9	20.7
19	73.0	53.9	89.5	26.1	99.2	96.7	53.2	10.2	12.6
20	75.0	65.1	90.8	55.0	81.9	91.0	49.7	13.7	26.2
21	70.5	65.9	94.0	52.7	78.6	87.4	36.8	6.0	37.9
22	75.5	52.8	86.1	61.2	86.1	74.5	35.8	12.7	12.2
23	76.5	54.0	77.6	53.3	97.3	63.9	38.1	6.1	23.1
24	78.0	54.8	83.5	64.4	88.5	84.6	44.6	14.0	4.8
25	68.5	60.0	95.2	73.3	93.3	95.2	12.7	5.5	43.6
26	74.5	56.3	77.1	27.2	77.8	84.6	25.5	3.7	17.3
27	72.0	60.0	81.8	54.5	89.1	73.6	20.9	4.5	7.3
28	74.0	60.5	70.5	49.2	89.2	60.2	29.5	11.9	15.9
29	75.0	56.7	87.1	62.9	67.0	87.6	17.0	8.2	31.4
30	81.5	56.8	69.6	74.3	97.1	78.3	27.5	12.7	13.0
31	77.0	49.0	84.0	70.0	100.0	97.0	37.9	4.7	21.9
32	76.0	55.9	86.6	45.5	63.4	72.7	61.5	7.0	21.8
33	80.0	65.5	67.8	74.7	97.7	79.3	28.7	12.6	13.8
34	81.0	56.5	90.9	45.7	93.2	47.7	13.6	6.8	18.2
35	74.0	47.7	76.7	31.4	90.2	90.8	39.9	10.4	20.9
36	74.0	54.3	97.3	42.3	76.9	88.5	39.5	2.9	12.0
37	70.0	60.2	94.6	51.7	100.0	98.2	42.1	3.6	21.3
38	83.0	54.8	72.5	40.3	67.3	86.3	18.4	3.9	10.7
39	74.0	49.7	85.2	24.1	79.4	92.9	13.5	1.8	11.2
40	78.0	56.9	60.9	21.8	81.8	89.9	10.9	0.9	13.6
41	69.0	58.4	97.7	14.6	97.8	88.6	38.2	5.2	31.5
42	79.0	62.5	85.0	47.5	90.0	85.0	27.5	12.5	25.6
43	73.0	64.5	92.9	12.9	32.1	78.6	50.0	3.6	21.4
44	73.0	50.9	90.9	57.9	96.4	100.0	29.1	5.5	37.0
45	74.0	54.9	92.0	45.8	89.0	86.0	26.1	8.6	15.1
46	75.0	53.6	88.9	57.6	0.8	96.6	48.7	12.4	13.8
Total	75.0	56.0	85.9	52.0	81.3	85.5	35.7	8.7	20.1

Data show the percentage of patients who had received each of the separate care processes or interventions.

recorded (in 92.8% of cases because it had not been checked). Of the patients alive at 1 month (excluding those with no measure of kidney function), 100 (3.3%) were receiving RRT, 1976 (65.8%) had recovered to baseline and 929 (30.9%) had recovered but to a level beneath their baseline value.

Multivariable model

Six factors (increasing age, dipstick urinalysis, medication review, discussion with a nephrologist, acceptance for transfer to a renal unit and cause of AKI) significantly influenced the probability of being alive 1 month after AKI3 alert, and these along with their effects are summarized in Table 4.

Discussion

These data represent the largest comparison of the implementation of nationally mandated care processes (recommended by National Institute for Health and Care Excellence and others), and outcomes in severe AKI in the UK.

Variation in PPV of detection algorithm

Across all the centres, the PPV was 79.7%, meaning that one in five patients identified biochemically as having AKI stage 3 did not have this on clinical review. Some centres have a much higher PPV close to 100%, whereas other centres clearly

Table 3. Patient outcomes by acute hospital trust showing the median length of stay (LOS), percentage who received RRT, and the patient outcome (alive at 1 month) and renal outcomes (requiring dialysis, back at baseline, above baseline kidney function)

				Renal outcome at 1 month		
Trust	Median LOS (d)	% Received RRT	% Alive 1 mo	% On dialysis	% Baseline	% Above baseline
1	11.0	20.4	62.8	6.0	62.7	31.3
2	10.0	31.6	66.0	4.7	53.5	41.9
3	13.0	20.8	63.4	2.3	69.8	27.9
4	11.0	11.4	68.0	1.8	40.0	58.2
5	11.5	11.6	50.4	8.3	50.0	41.7
6	9.0	12.9	66.4	10.1	36.2	53.6
7	9.0	12.9	61.3	3.3	68.9	27.8
8	14.0	5.0	61.4	0.0	74.4	25.6
9	12.0	31.1	55.9	2.0	42.0	56.0
10	12.0	20.2	64.0	1.6	75.0	23.4
11	11.0	11.4	67.9	0.0	72.5	27.5
12	17.0	9.8	60.7	6.3	60.3	33.3
13	7.0	5.0	61.4	0.0	43.8	56.3
14	12.0	14.4	63.1	0.0	82.3	17.7
15	17.0	12.6	57.2	1.4	61.1	37.5
16	16.0	9.7	66.5	0.0	71.9	28.1
17	9.0	9.1	55.8	0.0	53.8	46.2
18	14.0	24.4	71.9	21.3	62.8	16.0
19	15.5	6.0	62.7	2.1	71.6	26.3
20	13.0	19.8	60.9	8.0	55.0	37.0
21	15.0	22.0	82.4	3.6	69.6	26.8
22	12.0	14.5	62.2	3.3	76.9	19.8
23	14.0	13.6	60.4	3.1	57.8	39.1
24	11.0	6.9	58.0	1.9	68.2	29.9
25	15.0	17.0	69.1	0.0	69.4	30.6
26	15.0	13.7	56.1	0.0	65.9	34.1
27	11.0	5.7	65.1	6.7	73.3	20.0
28	7.0	11.4	53.1	3.8	75.0	21.2
29	10.0	16.0	60.3	1.5	53.8	44.6
30	10.5	4.3	49.3	0.0	65.4	34.6
31	15.0	8.6	64.8	0.9	72.6	26.5
32	9.0	12.6	59.4	3.9	71.4	24.7
33	10.0	8.0	55.2	0.0	59.1	40.9
34	10.0	18.2	25.0	10.0	40.0	50.0
35	13.0	17.2	55.8	4.9	67.1	28.0
36	14.0	12.7	60.6	5.3	48.0	46.7
37	11.0	13.6	63.3	5.8	69.9	24.3
38	7.0	8.8	36.1	0.0	12.5	87.5
39	9.0	5.3	68.8	0.0	88.1	11.9
40	15.0	6.4	61.8	0.0	69.2	30.8
41	14.0	11.9	72.8	0.0	77.4	22.6
42	10.0	12.5	57.5	0.0	84.6	15.4
43	16.0	7.1	65.5	0.0	84.6	15.4
44	12.0	18.2	65.5	3.4	79.3	17.2
45	8.5	9.4	55.4	3.2	64.5	32.3
46	15.0	10.0	68.0	1.3	63.2	35.5
Total	12.0	13.0	61.7	3.3	65.8	30.9

struggled to consistently identify individuals with AKI3. The algorithm used by the majority of centres in this study was modified from an earlier UK study[12] and was chosen pragmatically as one simple enough to be adopted by all centres. Since this study, NHS England has mandated a standard algorithm to detect biochemical AKI that has been positively assessed against historical data.[13] Like the algorithm in this study the NHS England algorithm considers a creatinine value up to 365 days before the current value, but unlike this study, it excludes patients with no baseline value, and for patients with values >7 days earlier uses a median of the previous values, rather than of a single result. Many of the centres with high PPV in this study had been developing detection methods over many years, and in particular had successfully developed methods for using a lowest or an average (mean or median) creatinine value over a different time period (3, 6 and 12 months) and in particular methods to reliably exclude patients with CKD and those on dialysis.

Table 4. Multivariable model of factors affecting probability of being alive at 1 month

Factor		OR	95% CI	*P* values
Age	1-year increase	0.97	0.96–0.97	<0.001
Gender	Female			
	Male	1.04	0.92–1.17	0.546
Urine Dipstick	Not performed			
	Performed	1.33	1.18–1.50	<0.001
Senior review within 12 hrs	Not reviewed			
	Reviewed	0.96	0.81–1.13	0.613
Medication review	Not reviewed			
	Reviewed	1.53	1.29–1.80	<0.001
Discussion with nephrologist	Not discussed			
	Discussed	1.54	1.34–1.77	<0.001
Transfer to renal unit	Not Transferred			
	Transferred	2.36	1.76–3.15	<0.001
Transfer to ITU	Not Transferred			
	Transferred	0.91	0.77–1.08	0.285
RRT required	Not required			
	Required	0.82	0.66–1.03	0.083
Cause of AKI	Hypovolaemia			
	Sepsis	0.48	0.42–0.56	<0.001
	Drug induced	1.74	1.26–2.41	<0.001
	Urinary obstruction	1.80	1.42–2.28	<0.001
	Intrinsic renal disease	0.80	0.53–1.21	0.283
	Other	0.53	0.44–0.64	<0.001
	Not stated	0.91	0.70–1.20	0.510

Variation in incidence of AKI

The trust median incidence of AKI3 was 12.4 per 1000 un-planned hospital admissions and is very similar to other single-centre series.[2] The interquartile range is also narrow with an ~1.8-fold variation in incidence within that group (10.0–15.3 per 1000 un-planned admissions). Organizations outside that range had considerable variation in incidence which may relate to differences in the detection method, or case-mix (although further studies would be required to prove this). Common population factors known to affect disease incidence and outcome such as deprivation or ethnic group have not been well studied in AKI. It seems likely that at least some of the differences represent different populations served, but it would be crucial to understand this variation before any attempt is made by policy makers to set an achievable target rate of AKI in all populations.

Care process measures

For several conditions, it is established that the delivery of key care steps is associated with better outcome. Examples include outpatient diabetes care,[14] and assessment of the acutely unwell adult.[8] The evidence for key treatment processes for patients with AKI is less good although there is some evidence that AKI alerts can drive earlier interventions and that these in turn may improve outcome.[15] Rates of review by a senior clinician within 12 hours of admission to hospital, and then adoption of a physiological measurement warning system to prompt senior re-review were high (86.0 and 81.3% of cases, respectively), and only one organization had no warning system in place. These were both key recommendations of the previous study of care provided to patients in UK identified with AKI in whom care was often judged to have been suboptimal[6].

Renal advice, renal and ITU transfer

A percentage of 35.7 patients were discussed with a nephrologist, and 8.6% were accepted for transfer to a renal unit, whereas 20.1% of patients were accepted for transfer to ITU. This includes 89 people who were accepted for transfer to both settings. Discussion with a nephrologist was associated with a 1.5-fold increase in 1-month survival, and acceptance for transfer to a renal unit with a 2.4-fold increase, in a model that included likely confounding factors such as patient age, and the final cause of AKI. Acceptance for transfer to ITU appeared to have no effect. Not all patients who transfer to either a renal unit or an ITU received RRT (42.5% and 39.1% receiving RRT, respectively), and significantly there was no difference in the likelihood of sending a patient to an ICU, or in committing a patient to RRT, in centres with and without renal units. Most but not all ITU settings would have been able to provide RRT at the time of this study, but the ability to access either ITU and renal unit beds will have varied significantly between sites and is likely to have influenced decision making.

In the multi-variable model, RRT was not significantly associated with patient outcome. It is not possible to tell from this study whether this means that RRT was being offered to appropriate individuals or whether this is a self-fulfilling strategy where the full potential of wider use of RRT to all patients could be shown to alter outcome.

Overall outcome

Overall, 38.3% of the patients clinically validated to have AKI3 died within 1 month of developing AKI3, and the median length of hospital stay for all patients with AKI3 was 12 days. Both are similar to that reported in other studies.[2] Crude -month mortality varied considerably between trusts from 17.6% to 75.0%. These data are not adjusted for age or case-mix, which might explain some of the variation, as might differences in access to case-notes in those who were still alive or died in some organizations. It is also recognized that trusts organizational characteristics might affect outcomes, with the presence of a renal units, or even more so a renal transplant unit being associated with better hospital outcome previously.[16] Although not included in our final model that was limited to individual and not ecological factors, the presence of a renal centre in multivariable analysis was not associated with a difference in 1-month mortality in this study.

Recovery of kidney function was the norm, with only 1.7% of the original cohort (3.3% those alive at 1 month) continuing to require RRT at 1 month. However, almost one in three of those alive (30.9%) did not recover to their baseline kidney function with a likely long-term effect on their health[17,18] and also cost to the health service.[19]

Factors predicting survival from AKI at 1 month

Each increase in age by 1 year was associated with a 4% increased risk of being dead at 1 month. Sepsis and cause "other" were both associated with a worse outcome than hypovolaemia alone, whereas nephrotoxic drugs or urinary tract obstruction as the causes conferred a better outcome. "Other" is likely to represent patients with multiple causes.

Acceptance for transfer to a renal unit is associated with a 2.4-fold greater odds of survival. It cannot exclude a clinically likely selection bias in transfer to renal units, and it is not explained simply by access to RRT as this did not itself have any association with outcome. Neither ITU transfer (also subject to

selection bias) nor senior review within 12 hours appears to provide benefit. The latter is disappointing as intuitively this would appear to be a good candidate for improving outcomes.

It is not entirely clear about the explanation behind the observation that having a urine dipstick tested is associated with a better survival. A possible explanation is found in the association between dipstick testing and both senior review and discussion with a nephrologist. It could be speculated that the urine dipstick test reflects attention to detail by the attending physician supported by discussion with a nephrologist.

Overall, the model explains only 13.1% (Cox and Snell R^2 =0.131) of the variation in patient survival, and majority of the effect is explained by patient age. It has previously been shown that mortality in patients who developed AKI after cardiac surgery is affected by pre-existing conditions (congestive heart failure, pre-operative creatinine level) and illness severity (requiring ventilation or balloon pump).[20] It is a limitation of this study that we cannot account for such factors. Therefore, it must be acknowledged that the majority of the variation is likely to be in unmeasured differences in patient characteristics, disease process or care.

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