

A Prospective Micro-costing Pilot Study of the Health Economic Costs of Acute Kidney Injury



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Introduction: Acute kidney injury (AKI) prevalence in the UK is estimated to be approximately 20% of all emergency admissions. Complications of AKI have a huge impact on health care costs. Most studies that have researched the economic costs of AKI have used macro-level costing using national tariffs and applying this to hospital episode statistics.

Methods: The Acute Kidney Outreach to Reduce Deterioration and Death (AKORDD) study was a pilot study that tested the provision of early specialist advice to improve outcomes for patients with AKI. As part of this prospective study, we undertook a health economics substudy that involved micro-costing to help more accurately define the total cost per patient.

Results: We found that the total cost of providing an AKI alert system and an outreach service (intervention group) was lower than current practice (control group) for patients with AKI. Overall, an episode of AKI that required inpatient care costs approximately £5000 over 12 months, which is somewhat higher than previous UK estimates. Although it was feasible to collect the required complex dataset needed to conduct a health economics analysis of an outreach service, significant amounts of time and resources needed to be dedicated to this endeavor.

Conclusion: We showed that it is possible to demonstrate a clearer, more detailed picture of the prolonged economic costs of AKI for a health care system, as part of a substudy of a larger trial. A larger scale, randomized controlled trial of AKI outreach is needed, with a prospective full economic evaluation conducted alongside the trial.

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KEYWORDS: acute kidney injury; costs; economic

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See Commentary on Page 1255

AKI prevalence in the UK is estimated to be >20% of emergency admissions,¹ and complications of AKI are now well-established as having a huge impact on health care costs. The cost implications for the National Health Service (NHS) include increased hospital stay, intensive care unit (ICU) admissions, post-discharge costs, and an increased risk of longer term health problems. Likewise, the cost of dialysis also adds to the economic burden. In 2005, Chertow *et al.* found a robust association between AKI and both increased hospital costs and length of hospital stay.² The more severe the case of AKI, the higher the impact.

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Prevention of approximately 30% of AKI cases was estimated to save the NHS between £130 and £186 million per year.³ Obviously, extended hospital stay has an undesirable effect. One audit found that preventing a modest 10% of AKI cases could save hospitals 3000 bed days per year.⁴ Previous literature focused on the cost of different renal replacement modalities in the highly selected minority of patients who require these therapies.^{5,6}

There have been studies that indirectly estimated the costs of relatively unselected AKI patients admitted to hospital. Fischer *et al.* studied >2000 patients admitted to Massachusetts Hospitals with uncomplicated AKI who did not require critical care at the turn of the millennium, as identified by the *International Classification of Disease-9th Revision*.⁷ Direct hospital costs were estimated from hospital charges for the AKI admission. Ten percent of patients required dialysis, which increased costs by 63%. Median direct hospital costs were \$2600 per admission.⁷ Kolhe *et al.* in the UK

estimated the cost of AKI in 576 inpatients, as coded by the *International Classification of Disease-10th Revision*, of a total of approximately 140,000 admissions in 2008.⁸ Approximately 5% of patients needed renal replacement therapy. Using an averaging and relative value methodology to predict AKI costs, they estimated a cost of approximately £3750 per admission. The total annual cost of AKI admissions to the English NHS was estimated to be approximately £3 billion. Studies based on coded AKI diagnoses have a potential weakness, in that coding is known to miss many patients with AKI.^{9,10}

A recent study researched the economic impact of AKI to the NHS using data that was recorded in the Hospital Episodes Statistics (HES).³ Kerr *et al.* estimated the cost of AKI in the English NHS in 2010 using HES data in patients admitted and coded to an AKI-related Healthcare Resource Group (HRG) (HRG code: LA07).³ For these admissions, the authors attributed the entire cost of the admission to AKI and used the tariff price to estimate the unit cost. Using the national tariff (costing) for this HRG, they found that >23,000 admissions had cost approximately £75 million, at a cost of £3250 per patient. This cost did not include critical care, post-discharge care, or excess bed days in patients with AKI who were coded to other HRGs, which resulted in an under-recording of AKI resource usage in their estimates. A Markov model was used; it estimated the annual cost associated with AKI-related inpatient care in England was £1.02 billion, and the lifetime cost of postdischarge care for people who had AKI as inpatients in 2010 to 2011 was estimated at £179 million.³

The AKORDD project is a pilot study of using an outreach service for patients with AKI.¹¹ We conducted a health economics substudy, which aimed to more accurately define the total cost per patient, with or without the use of an AKI outreach team, over 12 months, which began an AKI alert. This study showed the feasibility of conducting a cost-effectiveness analysis of the AKI outreach team versus standard care, and was the first to conduct a direct micro-costing of AKI for each individual patient.

METHODS

The AKORDD study took place in 2 hospitals: Heartlands Hospital (intervention) and Good Hope Hospital (control group). The study used a before-and-after design, piloting the outreach service to patients with AKI. For the Before study phase (2 months), patients at both hospitals received standard care and for the After study phase (5 months), patients at Good Hope Hospital continued to receive standard care, whereas patients at Heartlands Hospital received the intervention

(outreach via telephone). Patients were recruited once they had an electronic alert indicating that they had AKI. The outreach service offered rapid assessment, treatment, and advice for patients who developed AKI to reduce their risk of death, dialysis, and other complications. The team functioned during working hours, 5 d/wk, offering advice to clinicians looking after AKI patients. Depending on the stage of AKI, the level of intervention from the outreach team differed. For example, for relatively mild AKI (stage 1), patients received a telephone call from a member of the team, whereas if AKI was quite serious (stage 3), patients received telephone calls from a consultant plus a consultant visit. The trial, as a pilot study, was powered to estimate the rate of the combined endpoint (any of these: AKI stage deterioration, dialysis, or death) for a future cluster randomized trial. The health economic substudy was designed to test methods of economic assessment in AKI. Overall study design is detailed elsewhere.¹¹

Recruitment

For the health economics substudy, we aimed to recruit a sample of 50 patients during the After phase (25 patients from each hospital from the main study population). Data were collected during the 12-month period starting from recruitment. Two 1-week recruitment windows (in July and October 2015) were opened simultaneously at each hospital. The actual starting point for each patient for health economics analysis was the time of the AKI alert, excluding costs before the onset of AKI. Only patients admitted to the control or intervention hospital were recruited; patients with AKI who remained in the community were not eligible for recruitment. The health economics substudy was approved by the Research Ethics Committee of the National Research Ethics Service in 2014 (NRES Committee East Midlands—Nottingham 1, reference 14/EM/0184). A consort diagram for the After phase will be published later.

Resource Use Data Collection and Unit Costs

The cost analysis adopted an NHS and personal social services perspective. Resource use items that were directly linked to the index AKI episode and its sequela and/or complications were estimated over the 12 months of follow-up for each patient recruited. Thus, an admission or outpatient appointment for an unrelated condition (e.g., a comorbidity exacerbation or surgical procedure) were excluded from the analysis. These admissions and visits were attributed unblinded by the chief investigator to keep the workload manageable. We collected resource use and unit cost data for the following items:

- The AKI outreach team, which included costs of implementing and running the service (including staff costs). The core outreach team consisted of an experienced renal consultant (MT), a renal research fellow (TA), and a critical care nurse trained in AKI care. The team was responsible for delivering the interventions, with or without ward visits, triggered by the AKI alert.
- The index hospital stay from the time of the AKI alert (see the preceding) to discharge, including any ICU admissions, general ward admissions, and consultant ward rounds conducted by the “home team” (the team primarily responsible for the patients care at that time).
- Subsequent related hospital stay(s), which were estimated as for the index hospital stay.
- Subsequent related outpatient clinic visits, which included consultant or nurse-led, first or follow-up clinic visits.
- Dialysis, which included hemodialysis or peritoneal dialysis (PD; including assisted automated PD).
- All tests or investigations, which included all blood or other laboratory tests, all imaging, endoscopies, and other diagnostic procedures (including electrocardiograms).
- Supportive procedures, which included i.v. cannulation, urinary catheterization, and blood transfusion.
- I.v. fluids.
- Medications while in hospital and supplied by the hospital when patients were discharged (28 days provided). Inpatient medications usage included recording all administered doses of a given drug at a given dose, excluding all doses prescribed but not administered, and separately recording any doses at a new or changed dose regime. This allowed calculation of the exact cost of a specified number of doses of a drug at a given dosage.

Data were available via electronic patient records and the pathology laboratory system for most of the previously listed resource use items. Prescribing data were taken from the JAC electronic prescribing system (JAC Computer Services Ltd, Basildon, UK). We also consulted the renal information technology system (Proton, Clinical Computing Ltd, Ipswich, UK) for data regarding dialysis. When necessary, we also reviewed the paper notes to extract any additional information. These were reviewed chiefly for information from departments such as emergency medicine and critical care, which did not use electronic patient records.

In addition to hospital resource use data, we also collected data via a patient self-reported questionnaire. This was a practical means of collecting nonsecondary care data that included general practitioner (GP) visits

at surgery, home, or via telephone; practice nurse visits at surgery; and any community health services, such as a community nurse, allied health professional, or walk-in center visits. In addition, this questionnaire also included any nonprescribed (over the counter) medications that the patients might have also purchased. These questionnaires were sent to the patients by mail for self-completion or they were filled in by the research fellow or nurse asking the questions over the telephone. Four questionnaires were administered for each patient at the following time points: 3, 6, 9, and 12 months to take into account resource use for the 3 months before the questionnaire date. Thus, the 3-month questionnaires asked about resource use incurred from the time of the alert (baseline) to 3 months.

Unit costs for the key resource use items were based on the 2015 to 2016 financial year (Table 1)^{12–15} and are presented in pounds sterling. Staff costs were obtained from the Unit Costs of Health and Social Care^{12,13} and the Pay and Conditions Circular.¹⁴ Inpatient stays, outpatient visits and dialysis costs were obtained from the NHS reference costs.¹⁵ Costs of medications and i.v. fluids were obtained from the British National Formulary,¹⁶ and tests and investigations were obtained from published sources (e.g., NHS reference costs, NHS Trusts websites, and National Institute of

Table 1. Key resource use items and unit costs

Resource use item and mean time (min)	Cost (£)	References
AKI team		
Renal consultant (60.0)	135.59	12–14
Renal research fellow (60.0)	59.38	12–14
Critical care nurse (60.0)	46.47	12–14
GP costs		
At surgery (9.2)	36.00	12, 13
At home (11.4)	45.00	12, 13
On telephone (7.1)	28.00	12, 13
Practice nurse at surgery (13.0)	9.32	12, 13
Community costs		
Community nurse (17.5)	14.58	12, 13
Community allied health professional (30.0)	20.00	12, 13
Walk-in-centre (13.2)	38.87	12, 13
Bed-day costs		
General ward (non-elective AKI without interventions) ^a	400.72	15
High dependency unit (requiring support for at least 1 organ)	671.00	15
Clinic visits		
Consultant-led first clinic	193.01	15
Consultant-led follow-up clinic	153.01	15
Dialysis costs		
Hemodialysis for AKI (1 session approx. 4 h)	153.00	15
Assisted automated peritoneal dialysis (1/d)	49.55	Heartlands Hospital

AKI, acute kidney injury; GP, general practitioner.

^aGeneral ward cost was based on a nonelective stay without interventions to avoid double counting because interventions were accounted for separately.

Health Care and Excellence guidelines).^{15,17–19} The tests and investigations costs are presented in [Supplementary Table S1](#). The unit costs were then attached to each resource item to calculate a total cost per patient.

Outcome Data Collection

Health-related quality of life was assessed using the standardized EuroQol 5 dimensions 5 levels (EQ-5D-5L) questionnaire, which consists of 2 parts: the descriptive part and the visual analogue scale (VAS). The descriptive system consists of 5 attributes of health (mobility, self-care, usual activities, pain and/or discomfort, and anxiety and/or depression).²⁰ Each attribute has 5 levels (no, slight, moderate, severe, and extreme problems or unable to), generating a total of 3125 possible health states. Preferences for the scoring function were measured using the mapping algorithm for the crosswalk value set from EQ-5D-5L to EQ-5D-3L.²¹ The scores lie on a value scale from 0.0 (dead) to 1.0 (perfect health). The EQ-5D VAS records the respondents' self-rated health status on a 0 to 100 scale, in which 0 is the worst state you can imagine and 100 is the best state you can imagine. The EQ-5D-5L questionnaire was administered to patients in the same sitting as the resource use questionnaire. The EQ-5D-5L was administered at baseline as soon as the patient was well enough to respond to questions after the alert. The EQ-5D-5L results were used to calculate utility scores for each time period and generate quality-adjusted life years (QALYs). QALYs simply measure the area under the curve when the amount of time (e.g., 1 year) spent in a health state(s) on the horizontal axis is weighted by the utility score(s) given to the health state(s) on the vertical axis. QALYs were calculated by simply calculating the area under their utility curve, assuming a linear change in utility from baseline to 1 year.

Missing Data

Multiple imputation was used to estimate the missing EQ-5D data and resource use data as reported in the questionnaires. Multiple imputation is a Monte Carlo simulation technique in which each case of missing data is replaced by a set of plausible estimates. The technique uses information on the relationship between variables as part of the estimation process to produce overall mean estimates for the missing data. Information on patient age, sex, residence, ethnicity, AKI alert stage, and baseline EQ-5D-5L scores were included to predict missing values.^{22,23} Missing data were imputed for the EQ-5D-5L for each attribute at each level that was missing and for nonsecondary care resource use data for each resource use that was missing. The

missing data were imputed using the statistical packages NORM.²⁴

Data Presentation and Statistical Analysis

Microsoft Excel (Microsoft, Redmond, WA) and Stata version 14²⁵ were used. Results are presented for costs, utility scores, and QALYs for all cases with and without imputed data for the 2 hospitals. Statistical tests (t-test and F-test based on the bootstrap method; see the following) were used to explore the difference in costs and utility values between the 2 hospitals. All tests were 2-sided, and a *P* value of ≤ 0.05 was considered statistically significant.

Because the distributions of cost data were skewed, bias-adjusted nonparametric bootstrapping was performed with 10,000 iterations to generate confidence limits around the mean values. Bootstrapping is a simulation technique that takes repeated samples of data, with replacement and in the absence of any other data from the population, and provides a guide to its distribution.²⁶

RESULTS

In total, 48 patients consented and were recruited for the health economics substudy: 20 patients for the intervention hospital and 28 patients for the control hospital. At the intervention hospital, 2 patients were too sick for consent, and 3 declined. At the control hospital, 11 patients were too sick to provide consent, 1 died before approach, and 6 declined involvement in the substudy. [Table 2](#) summarizes the baseline

Table 2. Baseline characteristics

Characteristics	Heartlands Hospital (n = 20)	Good Hope Hospital (n = 28)	Statistical test
Age, yr	65.0 ± 18.9	66.5 ± 12.9	t = 0.319, P = 0.751
Sex: male	14 (70.0)	12 (42.9)	$\chi^2 = 3.461$, P = 0.063
Ethnicity			
British	17 (85.0)	24 (85.7)	Fisher's exact test: P = 0.329
Pakistani	3 (15.0)	1 (3.6)	
African	0 (0.0)	1 (3.6)	
Other	0 (0.0)	2 (7.1)	
Residence			
Independent home	19 (95.0)	28 (100.0)	$\chi^2 = 3.972$, P = 0.264
Nursing home	1 (5.0)	0 (0.0)	
AKI alert stage – impairment of kidney function			
1. Mild	14 (70.0)	19 (67.9)	Fisher's exact test: P = 0.322
2. Moderate	3 (15.0)	8 (28.6)	
3. Severe	3 (15.0)	1 (3.6)	
EQ-5D-5L			
Utility score	0.473 ± 0.299	0.293 ± 0.402	t = -1.69, P = 0.100
VAS	49.25 ± 21.84	44.60 ± 20.95	t = -0.738, P = 0.464

AKI, acute kidney injury; EQ-5D-5L, EuroQol 5 dimensions 5 levels; VAS, visual analog scale. Data are n (%) or mean ± SD.

Table 3. EQ-5D and resource use questionnaire completion

Questionnaire completion	Heartlands Hospital	Good Hope Hospital
Expected completion rates	<i>n</i> = 20	<i>n</i> = 28
Baseline only	9 (45.0)	6 (27.3)
Baseline–12 mo	11 (55.0)	22 (78.6)
Actual completion rates	<i>n</i> = 11	<i>n</i> = 22
Baseline	11 (100.0)	22 (100.0)
3 mo	11 (100.0)	18 (81.8)
6 mo	7 (63.6)	13 (59.1)
9 mo	5 (45.5)	14 (63.6)
12 mo	7 (63.6)	15 (68.2)
Baseline–12 mo	4 (36.4)	9 (45.5)

EQ-5D, EuroQol 5 dimensions.
Data are *n* (%).

characteristics. The mean age was similar for both hospitals; there were slightly more men in the intervention hospital ($P = 0.065$); most patients in the intervention hospital resided in independent homes; and most patients had a mild impairment of kidney function, which was not statistically significant between the 2 hospitals ($P = 0.322$). The intervention hospital at baseline had slightly better EQ-5D-5L utility and VAS scores than the control hospital, although this was not statistically significant.

Eleven patients in Heartlands Hospital and 22 patients in Good Hope Hospital completed the 3- to 12-month questionnaires. Only 4 patients in the intervention hospital and 9 patients in the control hospital completed questionnaires for all time points (Table 3).

Table 4 shows the results of the EQ-5D-5L utility scores (tariffs). The intervention hospital had slightly better utility scores than the control hospital for all time periods for the completed cases (with no imputed data), and these differences were not statistically significant. Over time (from baseline to 12 months), these differences in utility scores were statistically significant for all cases that included the imputed data ($F = 8.63$; $P = 0.001$) and for completed cases only with no imputed data ($F = 6.70$; $P < 0.001$).

Table 5 shows the overall QALY gain for the 12-month period. For all cases that included imputed data, there was an overall QALY gain of 0.066 for the intervention hospital compared with the control hospital, although this difference was not statistically significant ($P = 0.332$). For completed cases only, which included no imputed data, there was an overall QALY gain of 0.018 for the intervention hospital compared with the control hospital; this difference was not statistically significant ($P = 0.906$).

Table 6 shows the frequency of some of the key resource use items, including medications, tests, and investigations. Overall, patients in the intervention group had a lower mean length of stay in the general ward, although this was not statistically significant

compared with the control group (8.6 days vs. 9.9 days; $P = 0.712$). The intervention group also had fewer consultant ward rounds that were conducted by the home team compared with the control group (3.2 rounds vs. 4.5 rounds; $P = 0.340$).

There were slightly more GP visits to surgery by the intervention group than the control group (9.09 vs. 6.59; $P = 0.058$) (Table 7). Although the control group had more contacts with other health professionals, none of these resources were statistically significantly different between the 2 groups.

The total mean NHS costs of the initial AKI episode and any additional costs related to the initial index episode during the 12-month period was £1094 lower for the intervention group than that of the control group, although this difference was not statistically significant ($P = 0.647$). This was also reflected in the wider 95% confidence interval for the control group compared with the intervention group. One patient within the control group was driving the cost because they were the only person to have multiple ward admissions that were linked to the original AKI episode. Furthermore, this patient also had both inpatient hemodialysis sessions and automated peritoneal dialysis, which contributed to the higher cost for the control group. By removing this patient from this group, the mean \pm SD total NHS costs fell to £5232 \pm £5194, and the 95% confidence intervals were also narrower £3273 to £7191 ($t = 0.273$; $P = 0.786$).

Patients costs as outlined in the Methods section included patients recalling visits to the GP surgery or with a community nurse, or any over-the-counter medications were slightly higher for the control group than the intervention group (£359 vs. £248; $P = 0.150$) (Table 8).

DISCUSSION

Although this pilot study showed that the total cost of providing an AKI alert system and an outreach service (intervention group) was lower than current practice (control group) for patients with AKI, the results need to be interpreted with caution due to a number of inherent uncertainties, most notably, the small sample size. To the best of our knowledge, this was the first study to conduct a prospective micro-level costing of NHS resources for patients with AKI, in which patient care related to the index episode was followed up for 12 months and resource use was appropriately costed. As well as the direct micro-costing, our strengths included costs only from AKI onset and inclusion of related post-AKI care involving outpatient care or further admissions. To our knowledge, our work was also the first to demonstrate that AKI patients do incur significant

Table 4. EQ-5D-5L utility scores (tariffs)

Utility scores	Heartlands Hospital	Good Hope Hospital	Test	Heartlands Hospital	Good Hope Hospital	Test
	All cases (including cases with imputed data)			Complete cases only (no imputed data)		
Baseline						
N	20	28	t = -1.69, P = 0.100	20	28	t = -1.69, P = 0.100
Mean ± SD	0.473 ± 0.299	0.293 ± 0.402		0.473 ± 0.299	0.293 ± 0.402	
Median	0.556	0.325		0.556	0.325	
IQR	0.305 to 0.666	-0.043 to 0.671		0.305 to 0.666	-0.043 to 0.671	
3 mo						
N	11	22	t = -1.14, P = 0.259	11	18	t = -0.999, P = 0.327
Mean ± SD	0.706 ± 0.334	0.590 ± 0.240		0.706 ± 0.334	0.594 ± 0.267	
Median	0.848	0.570		0.848	0.561	
IQR	0.404 to 1.000	0.491 to 0.767		0.404 to 1.000	0.381 to 0.813	
6 mo						
N	11	22	t = 0.00, P = 0.997	7	13	t = -0.18, P = 0.861
Mean ± SD	0.660 ± 0.257	0.660 ± 0.215		0.638 ± 0.332	0.617 ± 0.235	
Median	0.648	0.657		0.740	0.541	
IQR	0.567 to 0.837	0.585 to 0.836		0.404 to 0.879	0.491 to 0.813	
9 mo						
N	11	22	t = 0.02, P = 0.982	5	14	t = -0.33, P = 0.744
Mean ± SD	0.639 ± 0.186	0.641 ± 0.220		0.706 ± 0.273	0.659 ± 0.274	
Median	0.580	0.679		0.555	0.723	
IQR	0.548 to 0.648	0.555 to 0.739		0.548 to 1.000	0.516 to 0.850	
12 mo						
N	11	22	t = -0.95, P = 0.351	7	15	t = -1.00, P = 0.328
Mean ± SD	0.743 ± 0.216	0.663 ± 0.234		0.797 ± 0.259	0.670 ± 0.284	
Median	0.716	0.679		0.796	0.698	
IQR	0.654 to 1.000	0.567 to 0.819		0.716 to 1.000	0.499 to 0.877	

EQ-5D-5L, EuroQol 5 dimensions 5 levels; IQR, interquartile range.

personal costs, in a group that is typically elderly and disadvantaged. Overall, the costs calculated by our methods were higher than 1 recent UK estimate,⁸ which suggested that the economic impact of AKI was even greater than previously thought.

However, there were limitations with this pilot study. Convincing sick patients with AKI to take part in a substudy was challenging at a time when they were acutely unwell. More severe AKI was under-represented. Even after recovery, these patients often had chronic ill health, which made it difficult to obtain follow-up EQ-5D and resource use questionnaires. Resource use and costs provided on behalf of the NHS

were conservatively estimated; that is, only the resource use and costs as a direct consequence of the initial AKI episode and any further visits related to the initial AKI episode were included. Any further inpatient admissions, outpatients visits, tests and/or investigations, or medications not directly related to the initial AKI episode within the 12-month period were excluded. Because some conditions might have been due to some other underlying cause, we also excluded any resource use and/or costs due to uncertainties that they were directly related to the initial AKI episode. Even so, our documentation of the costs of AKI were more complete than those analyses that

Table 5. Quality-adjusted life year scores

Quality-adjusted life-year scores	Heartlands Hospital	Good Hope Hospital	Test	Heartlands Hospital	Good Hope Hospital	Test
	All cases (including cases with imputed data)			Complete cases only (no imputed data)		
N	11	22	t = -0.98, P = 0.332	4	9	t = -0.12, P = 0.906
Mean ± SD	0.666 ± 0.181	0.600 ± 0.182		0.649 ± 0.262	0.631 ± 0.246	
Median	0.723	0.631		0.670	0.719	
IQR	0.469–0.818	0.454–0.751		0.424–0.874	0.441–0.808	

IQR, interquartile range.

Table 6. Frequency of key resources in hospital

Resource use items	Heartlands Hospital (n = 20)	Good Hope Hospital (n = 28)	Statistical test
General admission ward stay, d			
Mean ± SD	8.6 ± 10.6	9.9 ± 11.1	t = -0.370, P = 0.712
Median	6.5	6.5	
IQR	4.5–8.0	3.5–11.5	
Range	2.0–52.0	2.0–45.0	
Consultant ward rounds			
Mean ± SD	3.2 ± 3.1	4.5 ± 5.6	t = -0.964, P = 0.340
Median	2.5	3.0	
IQR	2.0–4.0	1.5–5.0	
Medications in hospital (6 most frequent)			
Co-amoxiclav	12 (60.0)	11 (39.3)	$\chi^2 = 4.095$, P = 0.536
Cyclizine	5 (25.0)	12 (42.9)	
Enoxaparin	15 (75.0)	27 (96.4)	
Furosemide	4 (20.0)	13 (46.4)	
Omeprazole	9 (46.0)	14 (50.0)	
Paracetamol	17 (85.0)	28 (100.0)	
Medications on discharge (5 most frequent)			
Omeprazole	7 (35.0)	10 (35.7)	$\chi^2 = 11.422$, P = 0.022
Paracetamol	7 (35.0)	14 (50.0)	
Prednisolone	0 (0.0)	17 (60.7)	
Salbutamol	1 (5.0)	12 (42.9)	
Simvastatin	3 (15.0)	8 (28.6)	
Investigations	5.0 ± 4.2	5.8 ± 7.6	t = -0.421, P = 0.676
Full blood count	6.0 ± 4.2	6.3 ± 8.2	t = -0.150, P = 0.882
Urea and electrolytes	2.0 ± 2.9	2.1 ± 4.7	t = -0.090, P = 0.929
Liver function tests	1.3 ± 1.3	1.8 ± 2.8	t = -0.731, P = 0.469
Prothrombin time, prothrombin concentration, INR			
C-reactive protein	2.1 ± 4.1	1.9 ± 3.3	t = 0.162, P = 0.872
Bone profile	1.0 ± 1.3	1.4 ± 4.1	t = -0.372, P = 0.711
Blood culture	0.5 ± 0.8	0.6 ± 0.8	t = -0.293, P = 0.771
Urine culture and sensitivity	0.7 ± 1.2	0.7 ± 0.9	t = 0.073, P = 0.942
Arterial blood gas	0.4 ± 0.7	0.1 ± 0.4	t = 1.700, P = 0.096
Immune profile	0.3 ± 0.4	0.6 ± 1.3	t = -1.027, P = 0.310
Erythrocyte sedimentation rate	0.1 ± 0.3	0.1 ± 0.3	t = 0.346, P = 0.731
Creatinine kinase	0.2 ± 0.5	0.2 ± 0.4	t = -0.225, P = 0.823
Plasma or serum glucose	0.1 ± 0.3	0.1 ± 0.4	t = -0.434, P = 0.666
Tests			
Chest x-ray	0.4 ± 0.6	0.8 ± 1.4	t = -1.294, P = 0.202
Renal ultrasound	0.5 ± 0.8	0.3 ± 0.5	t = 0.793, P = 0.432
Peripheral venous cannulation	1.4 ± 1.2	1.6 ± 1.9	t = -0.519, P = 0.606
Catheter	0.5 ± 0.8	0.3 ± 1.0	t = 0.489, P = 0.627
ECG	0.1 ± 0.2	0.1 ± 0.8	t = -0.531, P = 0.598

ECG, electrocardiogram; INR, international normalized ratio; IQR, interquartile range. Data are n (%) or mean ± SD, unless indicated otherwise.

included only direct hospital costs. The high cost in the control group was due to 1 patient with multiple admissions that were linked to the original AKI episode; this patient was also on dialysis. As expected in any costing study for AKI, cost data will be skewed by a small proportion of patients with complications.

Only the time of the AKI outreach team was included in the costing. The cost of the alert system was not added to the costs because this system was

Table 7. Frequency of key resources from the patient self-reported questionnaires (including imputed data)

Resource use items	Heartlands Hospital (n = 11)	Good Hope Hospital (n = 22)	Statistical test
GP at surgery	9.09 ± 3.11	6.59 ± 3.58	t = -1.970, P = 0.058
GP at home	0.64 ± 0.67	1.59 ± 3.59	t = 0.867, P = 0.393
GP via telephone	1.27 ± 1.19	1.77 ± 1.97	t = 0.769, P = 0.448
Nurse at surgery	2.27 ± 1.56	3.36 ± 2.56	t = 1.295, P = 0.205
Community nurse	1.82 ± 2.27	2.05 ± 3.66	t = 0.188, P = 0.852
Community allied health professional	0.00 ± 0.00	1.32 ± 3.29	t = 1.320, P = 0.197

GP, general practitioner.

Data are mean ± SD.

There were slightly more GP visits to the surgery by the intervention group than the control group (9.09 vs. 6.59; P = 0.058) (see Table 8). Although the control group had more contacts with other health professionals, none of these resources were statistically significantly different between the 2 groups.

already in place. If we had included community patients into the health economics analysis, then the cost of the alert system would have been included. No patients from the community were recruited due to research team and time limitations of this substudy.

Although the EQ-5D results for the intervention group were slightly, although not statistically significantly, better compared with the control group, this was most likely because the EQ-5D is based on a biased sample. That is, the patients recruited into the health economics substudy were more likely to be younger and were not as sick; approximately two-thirds of the patients in the substudy had a lower grade of AKI.

We could not be sure that patient costs were accurately recorded. For example, patients who might have been slightly older and not as well might have found it difficult to recall resource use (e.g., the number of visits to the GP surgery for the previous 3 months and whether the visit was linked with the index AKI episode). Accurate collection of primary care data is needed, and this needs to be linked up with GP and social care records.

We did not calculate an incremental cost-effectiveness ratio due to the small number of patients who completed the EQ-5D questionnaire for all

Table 8. Bootstrapped total National Health Service (NHS) and patient costs

NHS costs	Heartlands Hospital (n = 20)	Good Hope Hospital (n = 28)	Statistical test
Total NHS costs, £			
Mean ± SD	5661 ± 5223	6755 ± 9368	t = -0.467, P = 0.647
95% confidence interval	3371–7950	3285–10,225	
Total patient costs, £			
Mean ± SD	248 ± 233	359 ± 265	t = -1.465, P = 0.150
95% confidence interval	147–349	260–458	

relevant time points. Any ratio estimated would have had great uncertainty, and the confidence intervals would have been huge.

Conclusions

This study showed that it was feasible to collect the complex data needed to conduct a health economics analysis of using an alert and outreach service for patients with AKI in the hospital; however, significant research time would need to be dedicated for this to be undertaken. Future considerations also need to include the scale of the outreach service (i.e., how many hospitals, availability of AKI staff, and an outreach team with the right skill mix). We advocated the use of this methodology in this study by subsampling, with researchers who administered questionnaires both in hospital and in the community, and who performed blinded assessment of AKI-related events. This would give a better picture of the whole economic impact compared with an estimation of the direct hospital costs. Large-scale AKI trials that require health economic analysis should consider micro-costing in a subsample (e.g., in biomarker trials). This study could help any future definitive multicenter, randomized controlled study of AKI outreach in planning a full prospective economic evaluation. Any future interventions for AKI would help target procedures that are needed for patients and also help in reducing inpatient admissions.

DISCLOSURE

All the authors declared no competing interests.

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CONTRIBUTORS

HM, TSA, and MT were responsible for the health economics study design and management. HM conducted the analysis. HM wrote the manuscript with input from all authors, who reviewed and approved the manuscript.

SUPPLEMENTARY MATERIAL

Table S1. Detailing test and investigations costs.

Supplementary material is linked to the online version of the paper at www.kireports.org

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