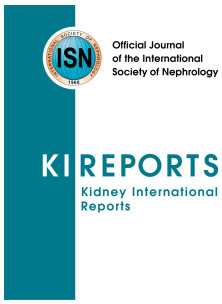

A prospective micro-costing pilot study of the health economic costs of acute kidney injury

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A prospective micro-costing pilot study of the health economic costs of acute kidney injury

Running title: Economic costs of acute kidney injury

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Abstract

Introduction

Acute Kidney Injury (AKI) prevalence in the UK is estimated to be about 20% of all emergency admissions. Complications of AKI have a huge impact on healthcare costs. Most studies that have looked at the economic costs of AKI have used macro level costing by 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 testing the provision of early specialist advice to improve outcomes for patients with AKI. As part of this prospective study, we undertook a health economics sub-study which 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 requiring inpatient care costs about £5,000 over 12 months, somewhat higher than previous UK estimates. Even though it is feasible to collect the required complex dataset needed to conduct a health economics analysis of an outreach service, significant amount of time and resources need to be dedicated.

Conclusion

We have shown that it is possible to demonstrate a clearer, more detailed picture of the prolonged economic costs of AKI for a healthcare system, as part of a sub-study of a larger trial. A larger scale randomised controlled trial of AKI outreach is needed with a prospective full economic evaluation conducted alongside the trial.

BACKGROUND

Acute Kidney Injury (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 healthcare costs. The cost implications for the National Health Service (NHS) include increased hospital stay, intensive care unit (ICU) admissions, post-discharge costs, and also an increased risk of longer-term health problems. Likewise, the cost of dialysis also adds to the economic burden. In 2005, Chertow and colleagues concluded 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.

Prevention of approximately 30% of AKI cases was estimated to save the NHS between £130m to £186m per year.(3) Obviously, extended hospital stay will have an undesirable effect. One audit found that preventing a modest 10% of AKI cases could save the hospital 3,000 bed days per year.(4) The literature has tended to focus on the cost of different renal replacement modalities in the highly selected minority of patients that require these therapies.(5, 6)

There have been studies indirectly estimating the costs of relatively unselected AKI patients admitted to hospital. Fischer et al studied over 2,000 patients admitted to Massachusetts Hospitals with uncomplicated AKI (not requiring critical care) at the turn of the millennium, identified by ICD-9.(7) Direct hospital costs were estimated from hospital charges for the AKI admission. 10% of patients required dialysis, which increased costs by 63%. Median direct hospital costs were $2,600 per admission.(7) Kolhe et al in the UK estimated the cost of AKI in 576 inpatients coded by ICD-10 as having AKI in their centre, out of a total of about 140,000 admissions in 2008.(8) About 5% of patients needed renal replacement therapy. Using an averaging and relative value methodology to predict AKI costs, they estimated a cost of about £3,750 per admission. The total annual cost of AKI admissions to the English NHS was estimated to be about £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 looked into the economic impact of AKI to the NHS using data which 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 over 23,000 admissions had cost about £75 million, a cost of £3,250 per patient. This cost did not include critical care, post-discharge care or excess bed days in patients with AKI that was coded to other HRGs, resulting in an under-recording of AKI resource usage in their estimates. A Markov model was used: estimated the annual cost associated with AKI-related inpatient care in England was £1.02 billion and the lifetime cost of post-discharge care for people who have had AKI as inpatients in 2010–11 was estimated at £179 million.(3)

The Acute Kidney Outreach to Reduce Deterioration and Death (AKORDD) project is a pilot study of the use of the Outreach service for patients with AKI.(11) We conducted a health economics sub-study, which aimed to more accurately define the total cost per patient, with or without the use of an AKI Outreach team, over 12 months from an AKI alert. This paper shows the feasibility of conducting a cost-effectiveness analysis of the AKI Outreach team versus standard care, and is the first to conduct a direct micro-costing of AKI for each individual patient.

METHODS

The AKORDD study took place in two hospitals: Heartlands Hospital (intervention) and Good Hope Hospital (control). The study used a Before and After design, piloting the Outreach service to patients with AKI. For the Before study phase (2 months), both hospitals received standard care and for the After study phase (5 months), Good Hope hospital continued to receive standard care, whereas, Heartlands hospital received the intervention (Outreach via telephone). Patients were recruited once they had an

electronic alert indicating that they have AKI. The Outreach service offered rapid assessment, treatment and advice for patients who develop AKI to reduce their risk of death, dialysis and other complications. The team functioned during working hours, 5 days/week, 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) there was telephone call with a member of the team, whilst if AKI was quite serious (stage 3) there was a telephone call with 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 randomised trial. The health economic sub-study was designed to test methods of economic assessment in AKI. Overall study design is detailed elsewhere.(11)

Recruitment

For the health economics sub-study we aimed to recruit a sample of 50 patients during the After phase: 25 patients from each hospital from the main study population and data was collected during the 12-month period starting from recruitment. Two one-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 prior to 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 sub-study 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 is published elsewhere.(12)

Resource use data collection and unit costs

The cost analysis adopted an NHS and personal social services perspective. Resource use items which were directly linked to the index AKI episode and its sequela/complications were costed over the 12 months of follow-up for each patient recruited. Thus an admission or outpatient appointment for an

unrelated condition (such as 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:

- 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. 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 above) to discharge, including any intensive care unit 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) – costed as for the index hospital stay
- Subsequent related outpatient clinic visits – consultant or nurse-led, first or follow-up clinics;
- Dialysis – haemodialysis or peritoneal dialysis (PD - including assisted automated PD);
- All tests or investigations, including all blood or other laboratory tests, all imaging, endoscopies, and other diagnostic procedures (including electrocardiograms);
- Supportive procedures including intravenous cannulation, urinary catheterisation and blood transfusion;
- Intravenous fluids; and
- Medications whilst 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.

For most of the resource use items listed above the data was available via electronic patient records and the pathology laboratory system. Prescribing data was taken from the JAC® electronic prescribing

system (JAC Computer Services Ltd). We also consulted the renal information technology system (Proton®, Clinical Computing Ltd) for data regarding dialysis. Where 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 do 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 non-secondary care data which included general practitioner 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 centre visits. In addition, this questionnaire also included any non-prescribed (over the counter) medications which the patients may have also purchased. These questionnaires were sent to the patients by post for self-completion or they were filled in by the research fellow or nurse asking the questions over the telephone. For each patient, four questionnaires were administered at the following time points: 3, 6, 9 and 12 months to take into account resource use for the 3 months prior to 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 2015/2016 financial year (see Table 1) and are presented in pounds sterling. Staff costs were obtained from the Unit Costs of Health and Social Care (13, 14) and the Pay and Conditions Circular(15); inpatient stays, outpatient visits and dialysis costs from the NHS reference costs(16); costs of medications and intravenous fluids from the British National Formulary (17); tests and investigations from published sources such as NHS reference costs, NHS Trusts websites and National Institute of Health Care and Excellence (NICE) guidelines.(16, 18-20) The tests and investigations costs are presented in Supplementary Table 1. 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 standardised EQ-5D-5L questionnaire which consists of two parts: the descriptive part and the visual analogue scale (VAS). The descriptive system compromises 5 attributes of health (mobility, self-care, usual activities, pain/discomfort and anxiety/depression).(21) Each attribute has five levels (no; slight; moderate; severe; extreme problems/unable to), generating a total of 3,125 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.(22) 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 0-100 scale where 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 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 where the amount of time (e.g. one 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 the simply calculating the area under their utility curve, assuming a linear change in utility from baseline to one 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 where each missing data case 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 the patients age, sex, residence, ethnicity, AKI alert stage and baseline EQ-5D-5L scores, where included to predict missing values.(23, 24) Missing data was imputed for the EQ-5D-5L for each attribute for each level that was missing and for non-secondary care resource use data for each resource use that was missing. The missing data was imputed using the statistical packages NORM.(25)

Data presentation and statistical analysis

Microsoft Excel® and Stata version 14(26) were used. Results are presented for costs, utility scores and QALYs for all cases with and without imputed data for the two hospitals. Statistical tests (t-test and F-test based on the bootstrap method – see below) were used to explore the difference in costs and utility values between the two hospitals. All tests were two sided and a p value of ≤ 0.05 was considered to be statistically significant.

As the distributions of cost data were skewed, bias adjusted non-parametric bootstrapping were performed with 10,000 iterations in order 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, gives a guide to its distribution.(27)

RESULTS

In total, 48 patients consented and were recruited for the health economics sub-study: 20 patients for the Intervention Hospital and 28 patients for the Control Hospital. At the intervention hospital, 2 were too sick for consent, and 3 declined. At the control hospital, 11 were too sick to provide consent, 1 died before approach, 6 declined involvement in the sub-study. Table 2 summarises the baseline characteristics. The mean age was similar for both hospitals; there were slightly more males in the intervention hospital (p = 0.065); majority of patients for the intervention hospital resided in independent homes; and the majority of patients had a mild impairment of kidney function, which was not statistically significant between the two 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 months questionnaires. Only 4 patients in the intervention hospital and 9 patients in the control hospital completed questionnaires for all time points (see Table 3 for more information).

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 which 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, which included imputed data there was an overall QALY gain of 0.066 for the intervention hospital compared to the control hospital, although this difference was not statistically significant ($p = 0.332$) and for completed cases only which included no imputed data there was an overall QALY gain of 0.018 for the intervention hospital compared to the control hospital, again 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 not statistically significantly so, compared to the control group (8.6 vs. 9.9 days, $p = 0.712$). The intervention group also had fewer consultant ward rounds which were conducted by the home team compared to the control group (3.2 vs. 4.5 rounds, $p = 0.340$).

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 7. Whereas the control group had more contacts with other health professionals, none of these resources where statistically significantly different between the two groups.

The total mean NHS costs of the initial AKI episode and any additional costs relating to the initial index episode during the 12 month period was £1,094 lower for the intervention group than 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 as they were the only person to have multiple ward admissions which was linked to the original AKI episode. Furthermore, this person also had both inpatient heaomodialysis sessions and automated peritoneal dialysis which contributed to the higher cost for the control group. Removing this patient from this group, the mean (SD) total NHS costs falls to £5,232 (£5,194) and 95% confidence intervals were also narrower £3,273 to £7,191 (t test = 0.273, p = 0.786).

Patients costs as outlined earlier in the methods section included patients recalling visits to the GP surgery or with a community nurse, or any over counter medications was slightly higher for the control group than the intervention group (£359 vs. £248, p = 0.150) (see 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 from this study 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 is the first study that has conducted a prospective micro-level costing of NHS resources for patients with AKI, where patient care relating to that index episode has been followed up for 12 months and the resource use appropriately costed. As well as the direct micro-costing, our strengths include costing only from AKI onset, and inclusion of related post AKI care involving outpatient care or further admissions. To our knowledge our work is also the first to demonstrate that AKI patients do incur significant personal costs, in a group which is typically elderly and disadvantaged. Overall, the costs calculated by our methods are higher

than one recent UK estimate(8), suggesting that the economic impact of AKI is even greater than previously thought.

However, there are limitations with this pilot study. Consenting of sick patients with AKI to take part in a sub-study is challenging at a time when they are acutely unwell. More severe AKI will be under-represented. Even after recovery they often have 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 have been included. Any further inpatient admissions, outpatients visits, tests/investigations or medications within that 12 month period after the AKI alert which were not directly related to that initial AKI episode were excluded. We excluded any resource use/costs that we couldn't be sure that they were directly related to the initial AKI episode, as it may have been due to some other underlying cause. Even so, our documentation of the costs of AKI will be more complete than those analyses that included only direct hospital costs. The high cost in the control group was due to one patient having multiple admissions which were linked to the original AKI episode and also this patient was 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, as this system was already in place. If we had included community patients into the health economics analysis then the cost of the alert system would have to be included. For this sub-study no patients from the community were recruited due to research team and time limitations.

Even though the EQ-5D results for the intervention group were slightly, although not statistically significantly better compared to the control group, this is most likely because the EQ-5D is based on a biased sample. That is, the patients recruited into the health economics sub-study were more likely to

be younger and they were not as sick; about two-thirds of the patients in the sub-study had a lower grade of AKI.

We can't be sure that patient costs have been accurately recorded. For example, patients who may be slightly older and not as well, may find it difficult to recall resource use. For example, the number of visits to the GP surgery for the previous three months and whether this 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 have not calculated an incremental cost-effectiveness ratio due to the very small numbers who completed the EQ-5D questionnaire for all relevant time points. Any ratio estimated would be with great uncertainty and the confidence intervals would have been huge.

CONCLUSION

This study has shown that it is feasible to collect the complex data needed to conduct a health economics analysis of the use of an alert and an Outreach service for patients with AKI in the hospital; however, significant research time would need to be dedicated in order 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 advocate the use of the methodology in this paper by subsampling, with researchers administering questionnaires both in hospital and community; and have blinded assessment of AKI related events. This would give a better picture of the whole economic impact compared with just estimation of the direct hospital costs. Large scale AKI trials requiring health economic analysis should consider micro-costing in a subsample, for example in biomarker trials. This study can help any future definitive multi-centre randomised controlled study of AKI outreach in planning the full prospective economic evaluation. Any future interventions for AKI will help target procedures which are needed for patients and also help in reducing inpatient admissions.

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Contributors

HM, TSA and MT were responsible for 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.

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Competing interests

The authors have no competing interests to declare.

Table 1: Key resource use items and unit costs

Resource use item and mean time (in minutes)	Cost (£)	Source
AKI team		
- Renal consultant (60.0)	£135.59	(13-15)
- Renal research fellow (60.0)	£59.38	(13-15)
- Critical care nurse (60.0)	£46.47	(13-15)
General practitioner (GP) costs		
- GP at surgery (9.2)	£36.00	(13, 14)
- GP at home (11.4)	£45.00	(13, 14)
- GP on telephone (7.1)	£28.00	(13, 14)
- Practice nurse at surgery (13.0)	£9.32	(13, 14)
Community costs		
- Community nurse (17.5)	£14.58	(13, 14)
- Community allied health professional (30.0)	£20.00	(13, 14)
- Walk-in-centre (13.2)	£38.87	(13, 14)
Bed-day costs		
- General ward (non-elective AKI without interventions)*	£400.72	(16)
- High dependency unit (requiring support for at least 1 organ)	£671.00	(16)
Clinic visits		
- Consultant-led first clinic	£193.01	(16)
- Consultant-led follow-up clinic	£153.01	(16)
Dialysis costs		
Haemodialysis for AKI (1 session approx. 4 hours)	£153.00	(16)
Assisted automated peritoneal dialysis (1 a day)	£49.55	Heartlands Hospital

* General ward cost was based on a non-elective stay without interventions to avoid double counting as interventions were costed separately

Table 2: Baseline characteristics

	Heartlands Hospital (n = 20)	Good Hope Hospital (n = 28)	Statistical test
Mean age in years (SD)	65.0 (18.9)	66.5 (12.9)	t = 0.319, p = 0.751
Sex: Male (%)	14 (70.0%)	12 (42.9%)	χ^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			χ^2 = 3.972, p = 0.264
Independent home	19 (95.0%)	28 (100.0%)	
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 Mean (SD)			
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

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

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

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

	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,	20	28	t =-1.69,
Mean (SD)	0.473 (0.299)	0.293 (0.402)	p = 0.100	0.473 (0.299)	0.293 (0.402)	p = 0.100
Median	0.556	0.325		0.556	0.325	
Interquartile range	0.305 to 0.666	-0.043 to 0.671		0.305 to 0.666	-0.043 to 0.671	
3 months						
N	11	22	t = -1.14,	11	18	t =-0.999,
Mean (SD)	0.706 (0.334)	0.590 (0.240)	p = 0.259	0.706 (0.334)	0.594 (0.267)	p = 0.327
Median	0.848	0.570		0.848	0.561	
Interquartile range	0.404 to 1.000	0.491 to 0.767		0.404 to 1.000	0.381 to 0.813	
6 months						
N	11	22	t = 0.00,	7	13	t =-0.18,
Mean (SD)	0.660 (0.257)	0.660 (0.215)	p = 0.997	0.638 (0.332)	0.617 (0.235)	p = 0.861
Median	0.648	0.657		0.740	0.541	
Interquartile range	0.567 to 0.837	0.585 to 0.836		0.404 to 0.879	0.491 to 0.813	
9 months						
N	11	22	t = 0.02,	5	14	t =-0.33,
Mean (SD)	0.639 (0.186)	0.641 (0.220)	p = 0.982	0.706 (0.273)	0.659 (0.274)	p = 0.744
Median	0.580	0.679		0.555	0.723	
Interquartile range	0.548 to 0.648	0.555 to 0.739		0.548 to 1.000	0.516 to 0.850	
12 months						
N	11	22	t = -0.95,	7	15	t =-1.00,
Mean (SD)	0.743 (0.216)	0.663 (0.234)	p = 0.351	0.797 (0.259)	0.670 (0.284)	p = 0.328
Median	0.716	0.679		0.796	0.698	
Interquartile range	0.654 to 1.000	0.567 to 0.819		0.716 to 1.000	0.499 to 0.877	

Table 5: Quality-adjusted life year (QALYs) 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		4	9	
Mean (SD)	0.666 (0.181)	0.600 (0.182)	t = -0.98,	0.649 (0.262)	0.631 (0.246)	t = -0.12,
Median	0.723	0.631	p = 0.332	0.670	0.719	p = 0.906
Interquartile range	0.469 to 0.818	0.454 to 0.751		0.424 to 0.874	0.441 to 0.808	

Table 6: Frequency of key resources in hospital

	Heartlands Hospital (n = 20)	Good Hope Hospital (n = 28)	Statistical test
General admission ward stay in days			
Mean (SD)	8.6 (10.6)	9.9 (11.1)	t = -0.370, p = 0.712
Median	6.5	6.5	
Interquartile range	4.5 to 8.0	3.5 to 11.5	
Range	2.0 to 52.0	2.0 to 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	
Interquartile range	2.0 to 4.0	1.5 to 5.0	
Medications in hospital (6 most frequent) N (%)			
Co-amoxiclav	12 (60.0%)	11 (39.3%)	χ^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) N (%)			
Omeprazole	7 (35.0%)	10 (35.7%)	χ^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			
Mean (SD)			
Full blood count	5.0 (4.2)	5.8 (7.6)	t = -0.421, p = 0.676
Urea and electrolytes	6.0 (4.2)	6.3 (8.2)	t = -0.150, p = 0.882
Liver function tests	2.0 (2.9)	2.1 (4.7)	t = -0.090, p = 0.929
Prothrombin time, prothrombin concentration, international normalised ratio	1.3 (1.3)	1.8 (2.8)	t = -0.731, p = 0.469
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			
Mean (SD)			
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

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

Mean (SD)	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

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. Whereas the control group had more contacts with other health professionals, none of these resources where statistically significantly different between the two groups.

Table 8: Bootstrapped total NHS and patient costs

	Heartlands Hospital (n = 20)	Good Hope Hospital (n = 28)	Statistical test
Total NHS costs			
Mean (SD)	£5,661 (£5,223)	£6,755 (£9,368)	t = -0.467, p = 0.647
95% confidence interval	£3,371 to £7,950	£3,285 to £10,225	
Total patient costs			
Mean (SD)	£248 (£233)	£359 (£265)	t = -1.465, p = 0.150
95% confidence interval	£147 to £349	£260 to £458	

Supplementary Material

Supplementary Table 1: detailing test and investigations costs. Supplementary information is available at *KI Reports* website.

References

1. Bedford M, Stevens PE, Wheeler TW, Farmer CK. What is the real impact of acute kidney injury? BMC nephrology. 2014;15(1):95.
2. Chertow GM, Burdick E, Honour M, Bonventre JV, Bates DW. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients. Journal of the American Society of Nephrology. 2005;16(11):3365-70.
3. Kerr M, Bedford M, Matthews B, O'donoghue D. The economic impact of acute kidney injury in England. Nephrology Dialysis Transplantation. 2014;29(7):1362-8.
4. Challiner R, Ritchie JP, Fullwood C, Loughnan P, Hutchison AJ. Incidence and consequence of acute kidney injury in unselected emergency admissions to a large acute UK hospital trust. BMC nephrology. 2014;15(1):84.
5. Laukkanen A, Emaus L, Pettilä V, Kaukonen K-M. Five-year cost-utility analysis of acute renal replacement therapy: a societal perspective. Intensive care medicine. 2013;39(3):406-13.
6. Srisawat N, Lawsin L, Uchino S, Bellomo R, Kellum JA. Cost of acute renal replacement therapy in the intensive care unit: results from The Beginning and Ending Supportive Therapy for the Kidney (BEST Kidney) study. Critical Care. 2010;14(2):R46.
7. Fischer MJ, Brimhall BB, Lezotte DC, Glazner JE, Parikh CR. Uncomplicated acute renal failure and hospital resource utilization: a retrospective multicenter analysis. American journal of kidney diseases. 2005;46(6):1049-57.
8. Kolhe NV, Eldehni MT, Selby NM, McIntyre CW. The reimbursement and cost of acute kidney injury: a UK hospital perspective. Nephron Clinical practice. 2014;126(1):51-6.
9. Ahmed A, Vairavan S, Akhoundi A, Wilson G, Chiofolo C, Chbat N, et al. Development and validation of electronic surveillance tool for acute kidney injury: A retrospective analysis. Journal of critical care. 2015;30(5):988-93.
10. Laing C, Renfrew J, Matthews B, Cockrill J, Brooke A, L B. Recording, coding and commissioning of acute kidney injury (AKI) activity 2012 [Available from: http://webarchive.nationalarchives.gov.uk/20130818114340/http://www.kidneycare.nhs.uk/our_work_programmes/patient_safety/acute_kidney_injury/tools_to_help_you/.
11. Abdelaziz TS, Lindenmeyer A, Baharani J, Mistry H, Sitch A, Temple RM, et al. Acute Kidney Outreach to Reduce Deterioration and Death (AKORDD) trial: the protocol for a large pilot study. BMJ open. 2016;6(8):e012253.
12. Thomas ME, Abdel Aziz T, Sitch A, Temple RM, Baharani J, GD P. The Acute Kidney Outreach to Reduce Deterioration and Death trial (AKORDD): the outcome of a large pilot Before and After study. In preparation.
13. Curtis L, Burns A. Unit Costs of Health and Social Care Kent: Personal Social Services Research Unit; 2015.
14. Curtis L, Burns A. Unit Costs of Health and Social Care Kent: Personal Social Services Research Unit; 2016.
15. NHS Employers. Pay and Conditions Circular (Medical & Dental) Department of Health, editor. London,2016 August.
16. Department of Health. NHS reference costs 2015 to 2016: GOV.UK; 2016 [Available from: https://www.gov.uk/government/publications/nhs-reference-costs-2015-to-2016.
17. British Medical Association and Royal Pharmaceutical Society of Great Britain. British National Formulary No. 70, September 2015-March 2016. London: BMA and PRS.
18. Homerton NHS trust. Homerton NHS tariff 2014-2015 2015 [Available from: http://www.homerton.nhs.uk/media/174141/1251-private-patient-tariff-for-2014-15.pdf.
19. National Clinical Guideline Centre. Preoperative tests (update) - routine preoperative tests for elective surgery. Appendix M: Economic considerations for Delphi. National Insitute for Health and Care Excellence, editor2016 April.
20. National Insitute for Health and Care Excellence. Irritable bowel syndrome - costing report2008.
21. Brooks R, Group E. EuroQol: the current state of play. Health policy. 1996;37(1):53-72.

22. Van Hout B, Janssen M, Feng Y-S, Kohlmann T, Busschbach J, Golicki D, et al. Interim scoring for the EQ-5D-5L: mapping the EQ-5D-5L to EQ-5D-3L value sets. Value in Health. 2012;15(5):708-15.
23. Rubin DB. Multiple imputation for nonresponse in surveys: John Wiley & Sons; 2004.
24. Schafer JL. Analysis of incomplete multivariate data: CRC press; 1997.
25. Schafer JL. NORM: Multiple imputation of incomplete multivariate data under a normal model, version 2. software for Windows. 1999;95:98.
26. StataCorp L. Stata Statistics and Data Analysis Software. Special Edition Release2016.
27. Manly BF. Randomization, bootstrap and Monte Carlo methods in biology: CRC Press; 2006.