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ORIGINAL ARTICLE

A whole system approach to improving mortality associated with acute kidney injury

T. Chandrasekar[1], A. Sharma[2], L. Tennent[3], C. Wong[1], P. Chamberlain[4] and K.A. Abraham[1]

From the [1]Nephrology Directorate, Aintree University Hospital, Liverpool L9 7AL, UK, [2]Nephrology Directorate, Royal Liverpool University Hospital, Liverpool L7 8XP, UK, [3]Administrative Services, Liverpool Heart and Chest Hospital, Liverpool L14 3PE, UK and [4]Innovation and Strategy, South Sefton CCG, Liverpool L20 3DL, UK

Address correspondence to Dr K.A. Abraham, Nephrology Directorate, Bluebell House, Aintree University Hospital, Liverpool L9 7AL, UK. email: abraham.abraham@aintree.nhs.uk

Summary

Background: Acute kidney injury (AKI) is in the main managed by non-nephrologists, many who feel challenged by or lack awareness of the complexity that the renal element adds to their patients' care. National reports have raised major concerns about the quality of care and have predicted that mortality reductions of 30% are achievable with good medical practice.
Aim: This quality improvement project evaluated whether a whole system approach could improve outcomes for patients with AKI.
Design and methods: Quality improvement methodology was used to understand hospital patterns, processes and professional knowledge. Change concepts were developed which included management of patients at risk, staff education and awareness program, development of a patient specific electronic alert to prompt diagnosis, easy to remember care bundle (ABCDE-IT), dedicated outreach team and patient and family empowerment leaflet.
Results: Statistical process control analysis was used to verify outcomes over time. A shift in the in-hospital mortality rate corresponded to a relative 23.2% reduction in mortality and was sustained over the next 33 months ($P < 0.0001$). The favourable shift in mortality was temporally distinct from the improved AKI detection rate. This timeframe corresponded to lying below the 99.8% lower confidence limit in comparison with all English acute trusts for comparative AKI specific SHMI/HSMR mortality rates. Length of stay also reduced shortly after onset of the project by 14.1% or 2.6 day reduction ($P < 0.0001$).
Conclusion: This project demonstrated that an integrated, whole-system approach is necessary to ensure sustained improvements in AKI mortality and length of stay.

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Introduction

Acute kidney injury (AKI) is a syndrome characterized by an acute reduction in kidney function with consequent disturbances in electrolyte, fluid and acid-base homeostasis. Its definition has been standardized over recent years, and its diagnosis is now based on measuring serum creatinine, and/or urine output. It can be classified into three stages of increasing severity.[1]

Contemporary data using sensitive diagnostic criteria estimate that 13–18% of hospitalized patients are affected, and the elderly are particularly prone to AKI.[2–4] In almost two thirds of cases, AKI is present at admission having been 'community acquired', with the remainder acquiring AKI while in hospital.[5]

A large analysis of 19 982 consecutive patients reported a 6.5-fold increase in mortality, as well as 3.5 day increase in length of hospital stay, associated with AKI.[6] The increased risk of mortality remains evident over longer term follow up.[7] Furthermore, AKI is associated with a 13-fold increase in the risk of subsequently developing End Stage Renal Disease.[8] The costs to the UK National Health Service [NHS] of AKI are estimated to be between £434–620 million.[2]

In 2009, NCEPOD (National Confidential Enquiry into Patient Outcome and Death) demonstrated widespread, systematic deficiencies with only 50% of AKI patients thought to have received 'good' care.[9] In view of the frequency of AKI, and its consequences, the National Institute for Health and Care Excellence [NICE] have suggested that improving the recognition and care of AKI could result in substantial absolute improvements in mortality.[2]

The numeric basis for defining AKI lends itself to computerized alerting systems, and thereby earlier recognition. This was recently tested in a single centre study which found no improvement in clinical outcomes attributable to an electronic alerting system.[10] However another recent, albeit smaller, retrospective study demonstrated that combining the alert with early review (< 1 day) and intervention by a critical care outreach team reduced mortality by 2.4 times and the likelihood of acute dialysis by 7 times as compared to those patients reviewed a day after the AKI alert.[11] No other trials have shown an improvement in AKI mortality from a single intervention. In other spheres of medicine, it has been shown that collating and delivering evidence based clinical interventions with a high degree of reproducibility using a 'bundle' approach can improve clinical outcomes.[12,13] Consensus AKI guidelines provide recommendations including appropriate fluid resuscitation, avoidance of nephrotoxic agents, and identification and treatment of the cause of AKI.[2,14,15]

Our aim was to iteratively develop and test a whole system approach incorporating a novel bundle for use in AKI with a view to delivering a 30% reduction in in-hospital AKI mortality over 12 months.

Materials and methods

Context

The STOP-AKI project was triggered following a mortality analysis at the trust and joint collaboration with Institute of Healthcare Improvement in Boston, USA. A significant patient event also re-focused attention on AKI which coincided with the condition becoming of greater importance in the national spotlight. The MUSIQ score pre-project was 108/160 highlighting that the project could be successful but with contextual challenges.[16] These were identified as a lack of quality improvement [QI] knowledge within the team and organization, QI support, relevant data systems, and desire of staff outside the renal department to focus on this area.

The team went through remote training in QI, sought to influence business intelligence reporting and met at a weekly huddle. The team consisted of nephrology doctors of varying grades and recruited an improvement advisor. Project preparation strategies included mapping stakeholders, patient journeys and current care processes. Specific system diagnostics included pareto analysis of AKI e-alerts across wards, and 3 years of data to analyse the differentials of mortality rates for critical care, non-nephrology and nephrology areas.

It was found that 48% of all alerts were in assessment areas, Nephrology, Cardiology and Gastroenterology. This informed the prioritization of the scale-up plan. There was no correlation between monthly AKI mortality and overall trust mortality suggesting specific as opposed to generic drivers at work.

The team process-mapped three different patient journeys in detail including a patient who died unexpectedly, a patient who survived but required dialysis and a patient who was deemed to be well managed. This identified themes including lack of awareness of non-nephrology staff, delays in diagnosis, lack of AKI specific monitoring and variable application of interventions.

A driver diagram (Figure 1) and standard quality improvement charter were developed as a means of guiding the project. These identified key areas for intervention.

Interventions

AKI risk assessment and in-hospital prevention

An AKI risk assessment tool had been implemented prior to the project and was extended to cover the entire hospital. At risk patients triggered a review of medications with nephrotoxic potential and were more closely monitored for oliguria, hypotension and AKI.

Guidelines for the risk assessment of peri-operative AKI were introduced. In those patients deemed at risk of AKI, interventions included optimization of medications with nephrotoxic potential such as aminoglycosides and those that affect renal perfusion during circulatory stress such as angiotensin converting enzyme (ACE) inhibitors or angiotensin receptor blockers, closer blood pressure and fluid management including urinary output measurements, daily senior review, daily monitoring of renal function and avoidance of a standardized enhanced discharge pathway.

The contrast nephropathy guidelines as well as the hyperkalaemia and pulmonary oedema guidelines were strengthened to improve compliance.

Early identification using automated AKI e-alerts

We developed and implemented an automated e-alert based on the rise in creatinine. An algorithm was developed in line with the AKIN criteria and embedded within the Laboratory Information Management System (LIMS) as early as 2011. At this point, the AKI alert was manually inputted but was subsequently automated. Our AKI e-alerts were revised during the National Audit Aug 2012–Feb 2013 and split into AKI 3 and AKI (a combination of AKI-1 and AKI-2). The algorithm was aligned to the specifics set by NHS England by April 2015.[17] The alerts appeared live on the hospital's result reporting system and were telephoned through to the ward or GP by the duty biochemist. The alert and stage of the AKI was also picked up live on the database used by our outreach specialist nursing team.

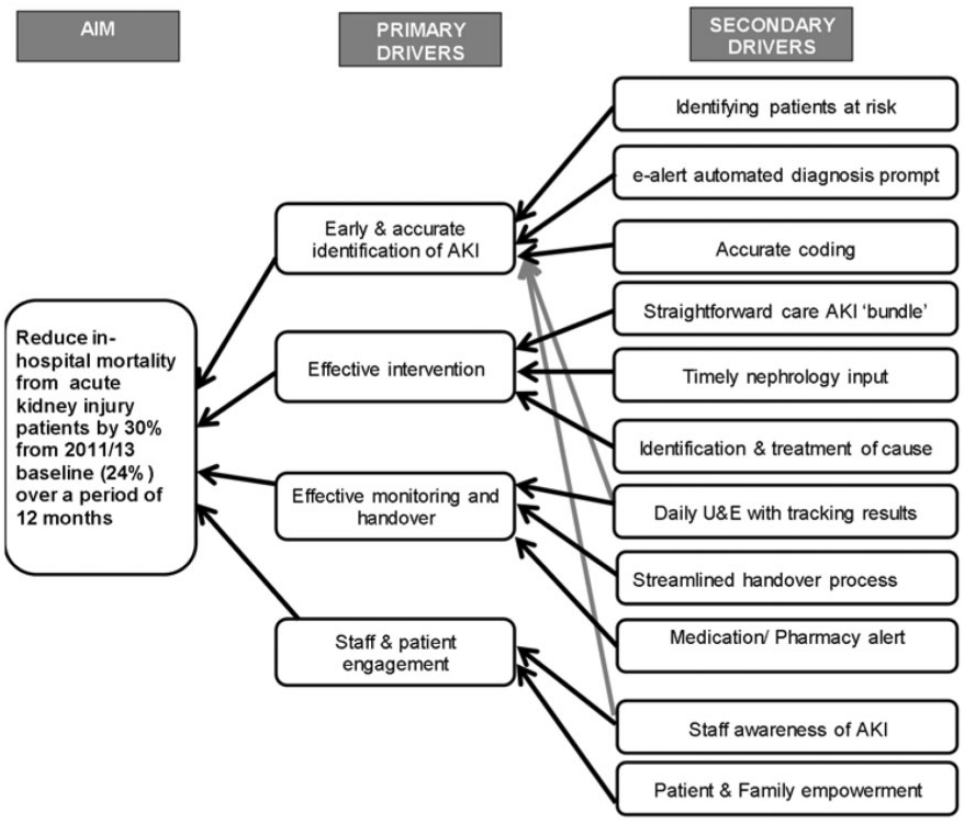

Figure 1. Driver diagram demonstrating key drivers and relationships.

AKI intervention bundle

The 'ABCDE-IT' care bundle (Table 1) incorporated a small number of critical evidence based interventions in line with national guidance and principles outlined by the Institute for Health Improvement.[12]

ABCDE-IT was developed using three development and five real-world plan-do-study act cycles.[18] The bundle sought to simplify assessment and management building on the premise that (a) most AKI cases are dealt with by non-nephrologists and (b) many non-nephrologists lack confidence in dealing with AKI.[19] The three main elements of the bundle were classification of AKI staging, linked to interventions required and referral guidelines.

The bundle was designed to not increase the work load or diminish clinical autonomy of the treating clinicians. It was initially trialed on the nephrology ward, then Accident & Emergency Department and Medical Assessment Unit, before being scaled up to all the wards in the hospital. The treatment bundle was made available on the intranet and as peel-able stickers.

Outreach support team (OST)

The OST comprised highly skilled Nurses from a Critical care background. The team was formed in February 2015 as part of avoidable mortality reduction work to focus on pneumonia, sepsis, AKI and the deteriorating patient.

A live database was created to enable the OST to screen patients who were at risk and highlight those patients with high white blood cell counts, C-reactive protein, lactate and AKI alerts. On identification the OST called the ward and reviewed the patient, alerting the clinicians to implement the appropriate care bundles and start initial management. They also arranged urgent imaging and facilitated discussion with critical care and a nephrologist if required.

Staff engagement

The team developed a staff engagement package, posters, led seminars for key staff groups and set up formal and informal awareness events in the hospital. Again, PDSA cycles were used to test early understanding and impact before more widespread dissemination.

Patient and family empowerment

A leaflet was produced which was aimed to be patient centred. This was tested incrementally with junior staff and lay people for readability, length, understanding and impact. Through this mechanism the team found it was helpful to personalize the leaflet, enable patients to use it as a clinical tracker of progress and ensure there was a copy for family members to reflect on behalf of patients.

Analysis

Data were sourced from the Trust's Patient Administration System, Medway Sigma. All analysis was spell level. Metrics included both the number of deaths that occurred in hospital and out of hospital, within 30 days post discharge. The mortality indicators presented are crude rates and not risk adjusted.

All outcome measures were analysed using ratified Bayesian statistical process control applying the Healthcare (IHI) rules

Table 1. Summary of core aspects of the ABCDE-IT In-hospital Bundle

Identify AKI: Date and time _____

Stage		↑ serum creatinine from baseline (μmol/l)	When to refer to Nephrology*
1	☐	> 1.5x OR rise of > 26 μmol/l within 48 h	K > 5.7, pH < 7.2, pulmon oedema, blood/prot on dip, suspect autoimmune disease or glomerulonephritis, HUS or TTP
2	☐	> 2.0x	As above, or if progressive
3	☐	> 3.0x OR > 354 μmol/l with acute increase	Refer ALL
			☐ Patient info leaflet
NB. If baseline creatinine not known assume AKI if creatinine >150, unless known CKD			
A		**A**cute Complications	Treat hyperkalaemia, acidosis, pulmonary oedema
B		**B**lood Pressure	Correct hypotension, fluid resuscitation, stop anti-hypertensives
C		**C**atheterize (stage 2/3)	Ongoing fluid balance chart + catheterization for severe cases
D		**D**rugs	Review and stop nephrotoxic medications
E		**E**xclude Obstruction	Examination/bladder scan/USS kidneys
I		Investigations	Daily specified bloods and urine check
			Renal & immunology screen when intrinsic pathology suspected
T		**T**reat Cause	Treat underlying cause

using QIMacros statistical software in accordance with the respective chart type. In addition, pre and post shift aggregated analysis was used to generate *P*-values using Mann–Whitney for non-parametric continuous data and chi-squared for discrete data.

AKI episodes were identified using ICD-10 coding based on the presence of the following codes coded in any position of any episode of the spell: All N17 codes (N170, N171, N172, N178, N179); A985; D596; K767; N990; O084 and O904.[19]

ICD-10 codes were used as the selection criteria in preference to e-alerts (Figure 2) as the diagnostic codes were more robust historically. Measurement using e-alerts developed over the course of the project so were not ideal to define the baseline or trends. The parameters were identified to be measured monthly at the start of the project. However, in the search for contributors to mortality reduction, the data on e-alerts was then studied to assess the severity of AKI. This analysis covered the period from December 2013 to July 2016 when there was a closer correlation with the coded diagnoses of AKI. In contrast, the data on in-patient mortality in patents with AKI 3 was far more complete and was included from January 2013. While outcome measures were tracked easily, there was a significant delay in achieving monthly process measures and initial process measures were sporadic. As such, the process measures described are only a sample of the recent more comprehensive dashboard.

Results

We have studied all 244 663 acute admissions from January 2011–July 2016. The number of patients identified with AKI during this period was 12 087 (4.9%). There were 2569 deaths observed in patients with AKI (21.3%). Since the start of the project unadjusted mortality rate in AKI patients declined by 23.2% and 25.9% for in-hospital and 30 day mortality respectively (Figure 3). This shift was sustained over 33 months.

When number of AKI cases detected was plotted against reductions in mortality, a weak inverse correlation was found, R^2 value being 0.351 (Appendix 1). From December 2013 there was a reduction in the number of patients per month with AKI 3 (Appendix 2) preceded by a reduction in their mortality (Appendix 3). Nation-wide comparative data for a corresponding period showed Aintree to lie beneath the 99.8% lower confidence limit for AKI related mortality (Figure 4). This was further supported by regional data comparing Aintree with acute trusts across the North West of England with respect to crude vs. expected rate of acute kidney injury mortality (Figure 5).

There was also an improvement in length of stay by 2.6 days for this cohort of patients (Figure 6).

During the study trust-wide all-cause raw mortality and length of stay also improved, although these changes followed the improvements in AKI outcomes (Figure 7).

Initially, the team struggled to comprehensively collect all process measures. The initial mechanism involved retrospective sampling of notes through junior doctor involvement. The Outreach Support Team proved to be key conduit to improving process. Although the outcome measures demonstrate robust improvement, process measures indicate further improvement is achievable (Table 2).

Table 2. Process measures

STOP-AKI PROCESS MEASURES (April–October 2015 Aggregate Average)	
Stop ACE inhibitors and ARBs within 24 h of 1st AKI Alert	100%
Serum creatinine test repeated within 24 h of the 1st AKI Alert	99%
Urine dipstick test within 24 h of 1st AKI Alert	79%
Written self-management information prior to discharge	75%
Ultrasound Scan of urinary tract within 24 h of 1st AKI Alert	67%
Specialist Renal or Critical Care Discussion within 12 h of 1st AKI 3 Alert	63%
Patients seen with AKI who received AKI patient and family leaflet	60%
Pharmacist Medication Review within 24 h of 1st AKI alert	51%
Patients with AKI seen by Outreach Specialist Nurse	48%
Patients seen with AKI who had the ABCDE-IT bundle documented	42%

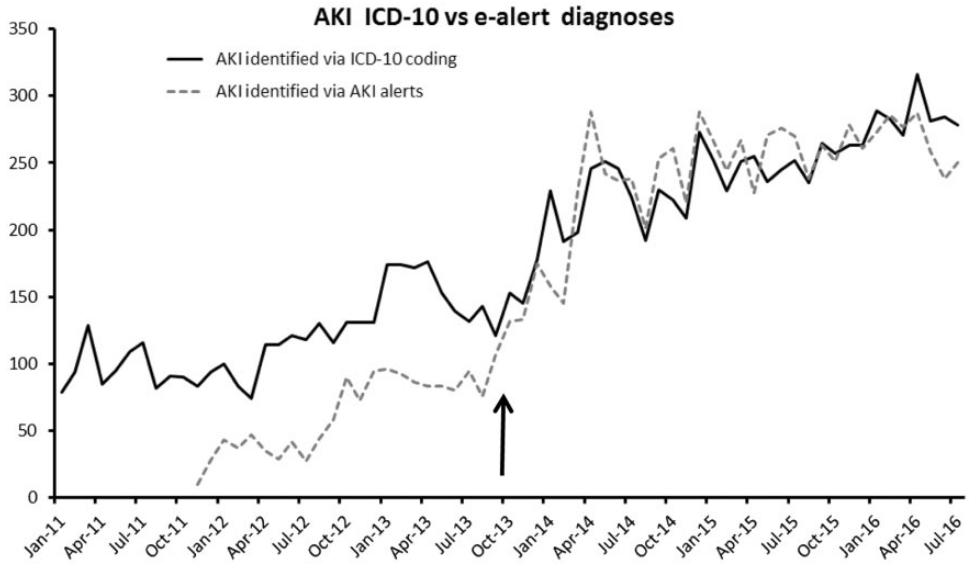

Figure 2. Number of AKI cases identified by ICD-10 coding compared to electronic alert rates. The arrow indicates the start of the project.

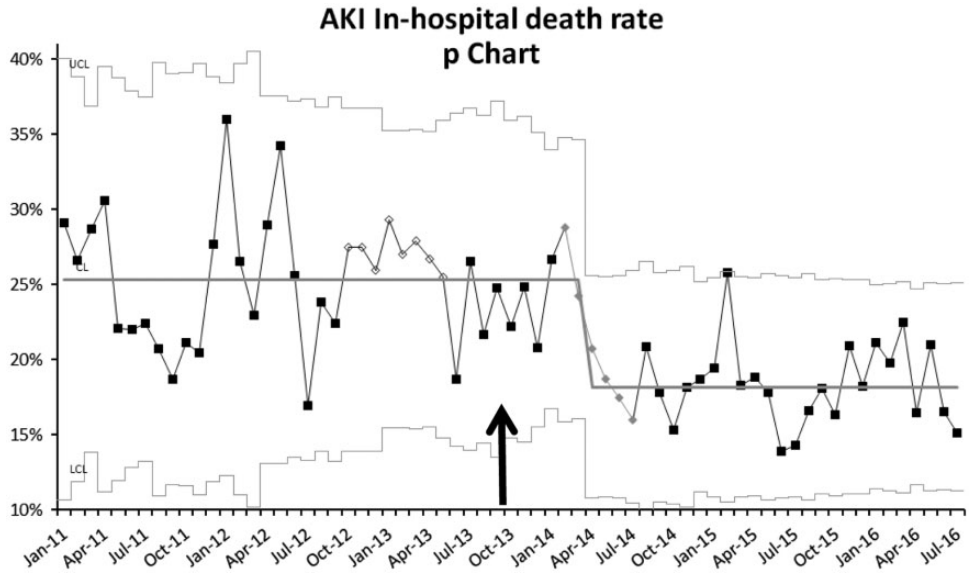

Figure 3. In-hospital acute kidney injury mortality rate (ICD-10 coding). Black squares relate to common cause variation within the respective sigma limits. Hollow diamonds relate to undesirable special cause variation and light diamonds to favourable special cause variation (IHI-healthcare rules). The shift in data in line with SPC analysis corresponds to a reduction of the mortality rate of 23.2%. Pre-post project $P < 0.0001$ derived from Chi squared analysis. The arrow indicates the start of the project.

Discussion

As shown in Figure 2, with an electronic alerting system, there was an increase in AKI recognition. Over time there was an increase in agreement between AKI coded diagnoses and recognition by electronic alert suggesting that both methods of case ascertainment are valid. The data have been analysed and are comparable with both methods, but we chose coded diagnosis as it provided more reliable historic data. Furthermore, this assertion is supported by an analysis published in 2013 indicating that diagnostic coding for AKI is accurate.[20]

This study shows that an integrated, whole-system approach is necessary to improve AKI outcomes. These interventions delivered a 23.2% reduction in in-hospital mortality, a 25.9% reduction in 30 day AKI mortality and a 2.6 day improvement in length of stay, all of which were sustained over a follow up period of 33 months. The components of our intervention included management of patients at risk, automated electronic alert, ABCDE-IT management bundle, a dedicated outreach team as early responders and timely, appropriate escalation/referral to the nephrology or critical care team added onto earlier steps that included rapid responses to referrals and where required, repeat reviews by the renal teams. This was

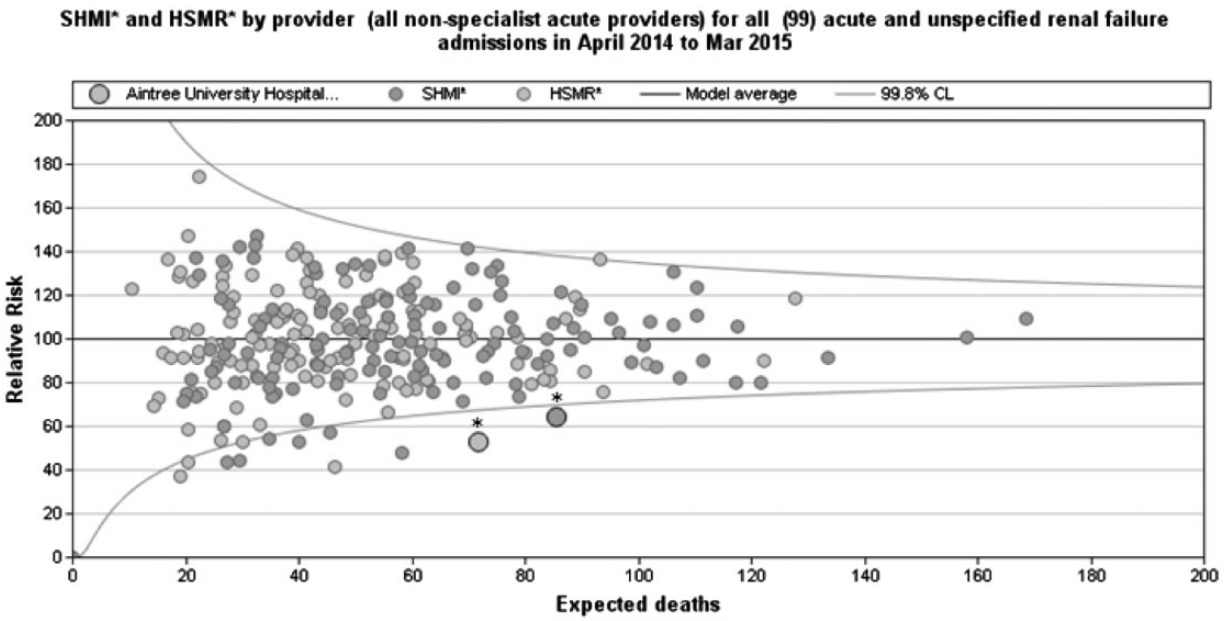

Figure 4. Funnel plot showing how Aintree University Hospital compares to other Acute Hospital Trusts in the English NHS for acute and unspecified renal failure on national standardized and risk adjusted mortality indices (Summary Hospital-level Mortality Indicator and Hospital Standardized Mortality Ratio) for period April 2014–March 2015. Large dots represent Aintree University Hospital (*). Dark dots represent providers' SHMI and light dots represent HSMR.
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Index: The SHMI for group 99 'Acute and unspecified renal failure', is 64.39 (below expected) for the most recent SHMI period (Apr 2014–March 2015). HSMR for the same period is 53.02. Aintree University Hospital is one of only four trusts with both mortality indices outside the lower 99.8% confidence limit for this diagnosis group. The average is standardized to 100 each year.
Analysis is based on SHMI Diagnosis group 99, 'Acute and unspecified renal failure', which contains the following codes: N170, N171, N172, N178, N179, N19X. SHMI methodology identifies pathways based on the diagnosis coded in the primary position of the first episode, unless this is an R code (signs and symptoms code), in which case it looks to the primary position of the 2nd episode.

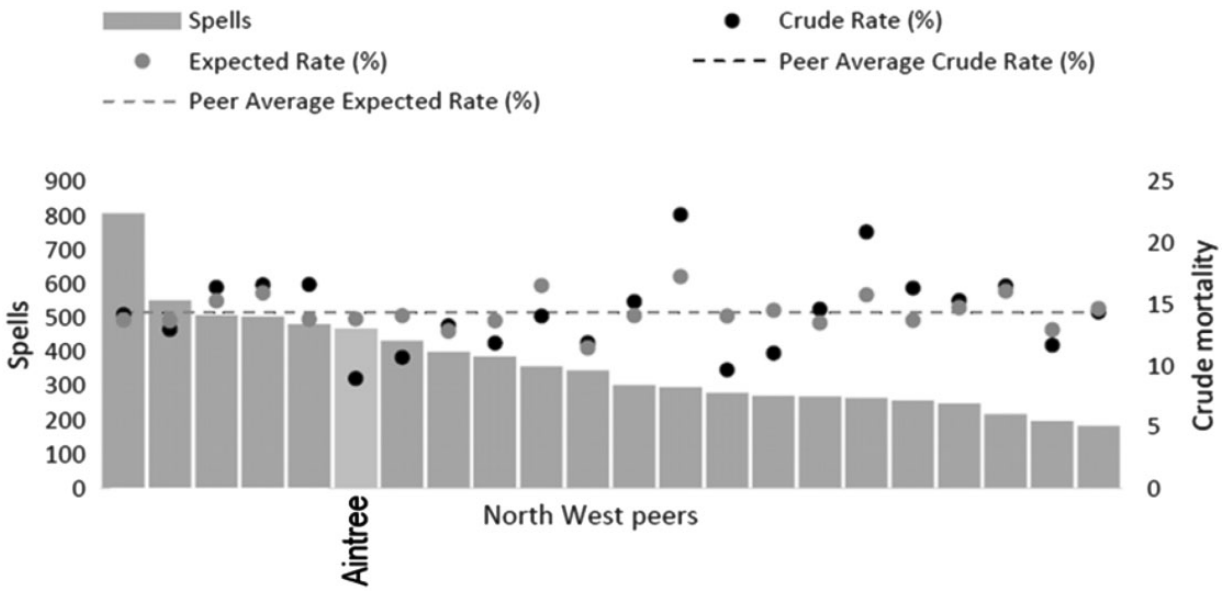

Figure 5. NW England peer comparison for in hospital Acute Renal Failure deaths (November 2014–October 2015) (ICD-10). Analysis is based on N17 codes. (This information is published with kind permission of Dr Foster. The information was generated by Mortality Comparator tool in December 2015, which is a proprietary software product of Dr Foster, and Dr Foster reserves all rights to Mortality Comparator. No further copying or reproduction of this information is permitted without consent from Dr Foster.)

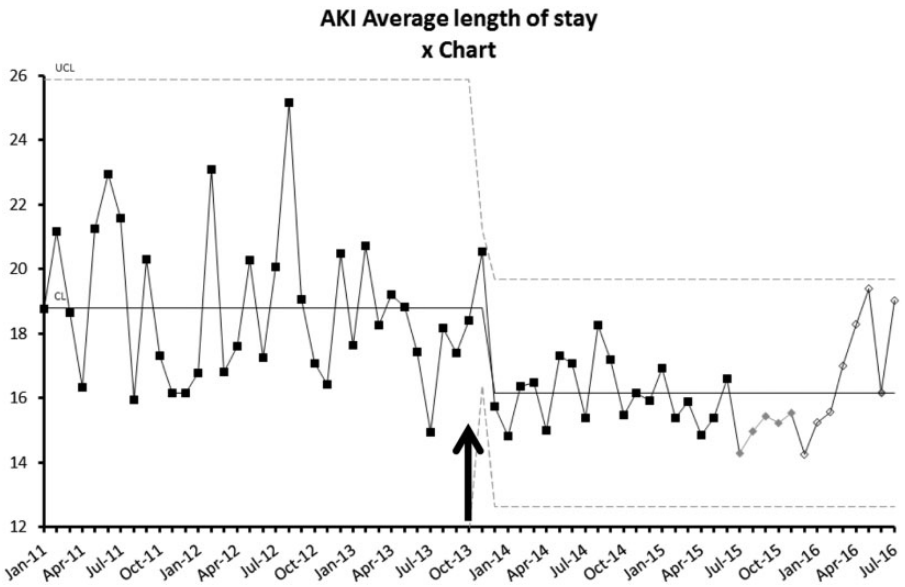

Figure 6. Average length of stay in days for acute kidney injury patients (ICD-10). Black squares relate to common cause variation within the respective sigma limits. Hollow diamonds relate to undesirable special cause variation and light diamonds to favourable special cause variation (IHI-healthcare). The shift in data in line with SPC analysis corresponds to a reduction of the length of stay of 14.1% or 2.6 days. Pre-post project $P < 0.0001$ derived from Mann Whitney non-parametric analysis. The arrow indicates the start of the project.

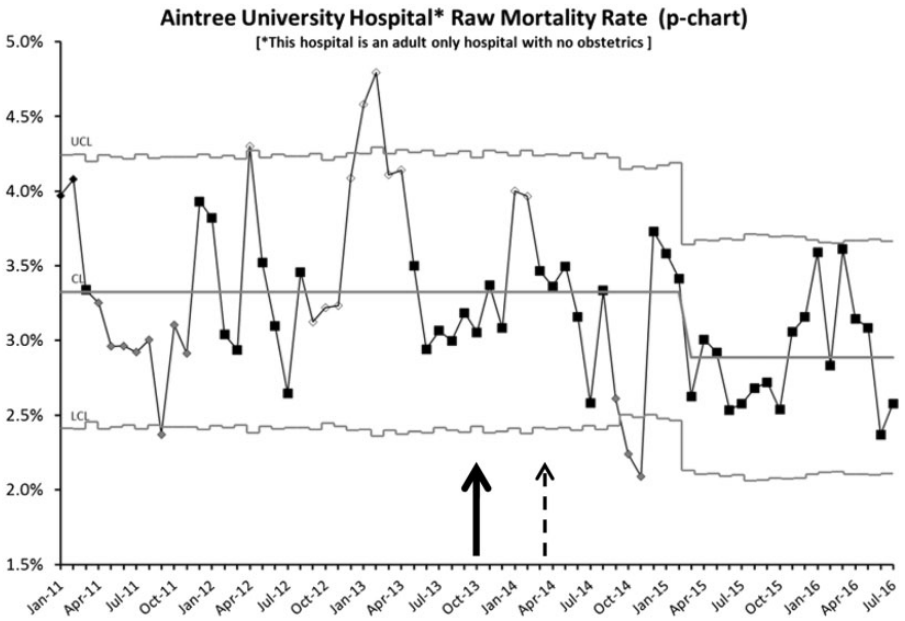

Figure 7. Hospital wide all cause mortality. Black squares relate to common cause variation within the respective sigma limits. Hollow diamonds relate to undesirable special cause variation and light diamonds to favourable special cause variation (IHI-healthcare rules). The solid arrow indicates the start of the AKI project. The broken arrow indicates the point at which AKI mortality reduced significantly.

underpinned by a robust infrastructure for education, cyclical measurement and quality improvement methodology. These improvements in mortality were further corroborated by the national comparison to all other acute NHS trusts in England using standard mortality indices for AKI. Aintree University Hospital was only one of four trusts beneath the 99.8% lower confidence limit of observed deaths over expected deaths for the period corresponding to the improvement. In other words, observed AKI mortality at Aintree was 64.4% of expected using Summary Hospital Mortality Indicator (SHMI) and 53.0% of expected mortality using Hospital Standardized Mortality Ratio (HSMR). This was backed up by more recent data covering November 2014 to October 2015 comparing crude and expected AKI mortality at Aintree with 21 other acute trusts in the North West of England. Compared to North West peers Aintree University Hospital had both the

lowest crude rate of mortality and relative risk for patients diagnosed with acute renal failure.

Despite the correlation between national and local data, the question remains whether the improvements in outcomes were solely due to better detection of milder degrees of AKI. As staff education and raising awareness were key elements of the improvement strategy that linked early detection with intervention, separating out their individual impacts has proved difficult and may require prospective studies such as AKORDD.[21] To dissect the matter further in our data, increases in case recognition had started well before the initiation of the project whereas clinical outcomes improved only after (Figures 2 and 3). Indeed, prior to the project initiation in October 2013, despite increasing case recognition, there was a sustained increase in mortality, particularly between October 2012 and June 2013. Therefore, it is unlikely that changes in case mix alone accounted for the improved outcomes. Correlation studies demonstrated a weak inverse relationship in the monthly intersects between number of patients with AKI and mortality rates, with an R^2 value of 0.351(Appendix 1). The analysis suggests that improved detection did contribute to reduced mortality. That is to be expected, both because more cases of milder forms of AKI were detected with their associated better prognosis, but also because earlier intervention corrects the factors that initiate AKI and worsen its severity resulting in reductions in the number of patients who develop AKI 3 (Appendix 2). Furthermore, the correlation calculation suggests that changes other than detection were responsible for 64.9% of the improvement in mortality. In contrast to the increase in overall number of patients detected with AKI and its probable contribution to improved patient outcomes, the reduction in AKI 3 mortality (Appendix 3) alongside reduction in numbers of patients with AKI 3 underlines the gains we have witnessed. More importantly, the fact that reductions in AKI mortality preceded and contributed to reductions in all-cause mortality (Figure 7) suggests that the benefits were real. The reductions in mortality make it immaterial whether it was improved AKI detection that better identified deteriorating patients or our intervention guidelines that improved their care, or as is more likely, a combination of the two.

Our study followed patients for 30 days post discharge. Long term effects of their AKI episodes were not studied. Neither were the long term effects of suspending medications because of AKI or restarting them. The data on recommencement of suspended medications during each patient's admission and 30 day follow up was not collected and is a limitation of our study. While certain categories like non-steroidal anti-inflammatory drugs have reasonable alternatives, other medicines such as ACE–inhibitors offer significant benefits that in selected patients cannot be replicated by substitutes. Whether to restart such medications is determined by the original indication and the extent of renal recovery.[22] The optimum time frame to recommence them is an important aspect of AKI follow up care that clinicians tailor to the individual patient.

At present there remains no specific treatment for AKI. AKI is frequently managed poorly and the challenge has been to raise standards of basic care for patients with AKI.[9] It has been hypothesized that improving early recognition of AKI would underpin timely tailored clinical intervention and improve patient outcomes. A single centre RCT evaluated whether the provision of a text based AKI alert to the unit pharmacist and treating team could improve outcomes from AKI when compared with usual care alone.[10] This study was negative, with no demonstrable improvement in creatinine change, need for dialysis or death at 7 days. Their data suggests that an alerting system alone is insufficient to modify processes of care, eliminate variation or improve patient outcomes. In contrast, our previous study highlighted that early identification and management of AKI cases including timely referral to the nephrology team can help to prevent progression of the severity of AKI and its consequences.[23]

Work outside the area of AKI has also suggested that alerts must be coupled with clinical decision support systems to deliver favourable changes in patterns of care and clinical outcome.[24] Bundles have become popular over the last decade following early success with sepsis and ventilator associated pneumonia.[12] The impact of AKI care bundles on processes of care has been assessed within a variety of settings.[25–27] Some aspects of patient care improved while others did not. These studies suggest that the application of a care bundle can improve care processes. However, these studies were not designed or powered to provide robust data on patient outcomes such as mortality and length of stay.

The impact on mortality has been examined in two recent retrospective UK studies. The outcome of 306 AKI episodes where a care bundle was completed within 24 h of AKI alert was compared with 2194 AKI episodes where the care bundle was delayed or not completed.[28] Early bundle completion was associated with a reduction in in-hospital case fatality from 23.1% to 18%. These data are encouraging, but the number of patients that received the care bundle within 24 h was small, and it is possible that confounding factors may explain why this subset of patients were treated promptly with the care bundle and had a better outcome. The Whittington group analysed 994 AKI alerts from 831 different patients and found that patients who were reviewed by the critical care outreach team $\geq$ 24 h after the AKI alert had a 2.4-fold increase in mortality and were 7 times more likely to require renal replacement therapy than those seen on the day of the alert.[11] However, in a more recent publication, Kohle *et al.*'s extension of their earlier work demonstrated the value of an AKI care bundle.[29] Completion of the care bundle within 24 h was associated with less progression of AKI and lower mortality risk. Our findings on the efficacy of a care bundle mirror their conclusions.

The strength of our study lies in the volume of longitudinal data collected relating to AKI associated mortality and length of stay, coupled with the application of quality improvement methodology to test and scale up interventions in a 'real-life' setting. This work was undertaken in the context of a broader attempt to reduce avoidable mortality in our hospital. There was a reduction in hospital wide unadjusted mortality and length of stay. However, improvements in AKI outcomes and length of stay occurred first and were far greater than the contributions of the other components of the hospital's avoidable mortality reduction drive. Therefore, it is likely that the improvements in AKI mortality and length of stay contributed to the improvement in all cause mortality and length of stay, rather than simply reflecting the effect of improved trust-wide generic factors.

The execution of this work met several challenges. Financial resources were scarce. All the work on developing the tools, setting up the systems and disseminating the education required to effectively use them were undertaken without resource allocation. Getting AKI included into the avoidable mortality work stream and with it, access to the OST was an important step. The key to this inclusion was the proof presented to the Trust management of the mortality and increased length of stay associated with AKI and its quite frequent incidence. The development and day to day running of the OST did and does require

funding. This has worked out to £20 031 per month, but is used to target deteriorating patients not just those with AKI. Another challenge was that the project team had no prior experience of quality improvement work, with the exception of PC. Furthermore, time and resource constraints limited the volume of data collected with respect to process measures, and therefore it is not possible to analyse the degree of adherence to the care bundle, and the association of the various components and clinical outcomes. Additionally, this was not a randomized controlled trial and therefore it remains possible that confounding factors may explain the observations reported. The external validity of the data is limited by the single centre nature of this study. However, the temporal relationship between the intervention and the observed improvement in clinical outcome coupled with the longitudinal collection of data from a high volume of cases is persuasive and is supported by the national and regional comparative data. Moreover, the care delivered to these patients represents 'real-life' clinical practice in a busy acute NHS hospital.

The Aintree experience has contributed to the formulation of regional guidelines (at http://www.nwcscnsenate.nhs.uk/files/8114/6183/5661/Network_Manual_V2_6_April_2016.pdf or Appendix 4) that have been adapted and adopted by regional hospitals. A regional AKI app has been released and can be accessed at http://www.akicare.co.uk/landing/index.cfm. Our whole-system approach now needs to be tested in hospitals without in-house nephrology teams where we have previously demonstrated increased mortality.[19] This may prove the only practical means to improving the care and outcomes of all patients with AKI, regardless of where and how they present.

Conclusion

All previous trials of single interventions to reduce the mortality from AKI have been negative. We have demonstrated that a holistic, multi-faceted approach to timely AKI case recognition and care delivery including the use of a care bundle can deliver significant, sustained improvements in AKI mortality and length of stay.

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Author contributions

Dr T Chandrasekar: Study design, data collection, data interpretation, writing. Dr A Sharma: Literature search, study design, data collection, data interpretation, writing. Ms L Tennent: Data collection, data analysis, data interpretation. Dr C Wong: Literature search, data interpretation, writing. Dr P Chamberlain: Literature search, study design, data collection, data analysis, data interpretation, writing. Dr K A Abraham: Literature search, study design, data collection, data analysis, data interpretation, writing.

Conflict of interest: None declared.

Ethics committee approval

This work was undertaken in the context of a hospital-wide strategy to address areas of avoidable mortality. Ethical approval was not necessary in the pursuit of this work.

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