
Thesis by
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**Improving clinical
outcomes in Acute Kidney
Injury through education.**

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Acute Kidney Injury (AKI) is caused by a sudden decline in kidney function, which may be caused by numerous pathologies such as hypovolaemia or septicaemia. It has only recently been recognised that patients who develop AKI have significantly worse outcomes.

The aim of this project was to develop, deploy, and evaluate a multifaceted education package aimed at improving clinician knowledge on AKI in a real life postgraduate clinical setting.

We developed a web based learning resource on AKI that was recognised for its ease of use and quality in the 2013 BMJ Awards. In addition, specific AKI teaching sessions were developed, based on sound educational theory and delivered using interactive presentation software, which helped to increase audience engagement.

Our findings show that it is possible for a multifaceted educational intervention to have a positive impact on clinicians' self-reported confidence in managing AKI; as well as a trend towards better performance in knowledge based multiple choice questions. There was also a trend towards improved clinical outcomes including reduced mortality and shorter length of stay, though the significance of these findings is not clear.

This thesis demonstrates the need for us to develop a better understanding about AKI prognosis, especially in the community setting. The trends shown in the mortality and length of stay data could be a consequence of factors that are currently poorly understood.

The results also showed that despite increasing presence of technology in our lives, clinicians still prefer learning when it is delivered in a face-to-face setting. Much more work needs to be done in this area, so that we can better understand how to develop future postgraduate education tools that are effective and sustainable in a real world clinical setting.

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List of Abbreviations

AAU:	Acute Admissions Unit
AKI:	Acute Kidney Injury
AKIN:	Acute Kidney Injury Network
ALS:	Advanced Life Support course
ARF:	Acute Renal Failure
ATLS:	Advanced Trauma Life support course
ATN:	Acute Tubular Necrosis
CKD:	Cardio Vascular disease
CLT:	Cognitive Load Theory
CRIMP:	Care of the Critically Ill Medical Patient course
e-Learning:	Electronic Learning
eGFR:	Estimated Glomerular Filtration Rate
EL:	Experiential learning
FY:	Foundation year doctor
GMC:	General Medical Council
GR:	Grand Round
GRF:	Glomerular Filtration Rate
HIEC:	Health Innovation and Education Cluster East Midlands
IT:	Information Technology resources
JRCPTB:	Joint Royal Colleges of Physicians Training Board
KDIGO:	Kidney Disease: Improving Global Outcomes
LOS:	Length Of Stay
MAU:	Medical Assessment Unit
MCQ:	Traditionally Multiple Choice Question
MDRD:	Modification of Diet in Renal Disease
Min-Cex:	Mini-Clinical evaluation tool
NCEPOD:	National Confidential Enquiry into Patient Outcomes and Death
NHS:	National Health Service
NICE:	Nation Institute for Health and Care Excellence

PBL:	Problem Based Learning
RA:	Renal Association
RDH:	Royal Derby Hospital
RIFLE:	Risk of renal dysfunction; Injury to the kidney; Failure of kidney function, Loss of kidney function and End-stage kidney disease
RRT:	Renal Replacement Therapy
SBA:	Single Best Answer format
SHISM:	Summary Hospital Mortality Index
SL:	Situated Learning
SMR:	Standardized Mortality Ratio
UHL:	University Hospitals of Leicester
VLE:	Virtual Learning Environment
WBL:	Web Based Learning resource

1. Introduction

Chapter overview:

I will start this thesis by describing the basic physiology of the kidneys, and then set the theme for the clinical problem associated with Acute Kidney Injury (AKI). Finally I will go on to explore the complex nature of postgraduate education.

Background

Acute Kidney Injury (AKI) is the term used to describe any condition that causes a sudden drop in renal/kidney function. This thesis describes a project aimed at improving outcome in patients with AKI through better education of postgraduate non-specialist clinicians.

Renal function

The majority of human adults have two kidneys, located in the retroperitoneal space in both flanks of the body, just below the diaphragm. The kidneys are supplied by blood directly from the Aorta via the renal arteries, with venous drainage back to the Vena Cava. Urine is the waste product produced by the kidneys and drained away into the bladder via the ureters. Each kidney consists of roughly 1 million filtration units, known as nephrons, which are located throughout the kidney and perform the basic vital functions of the kidneys (Floege et al., 2010) Figure 1.

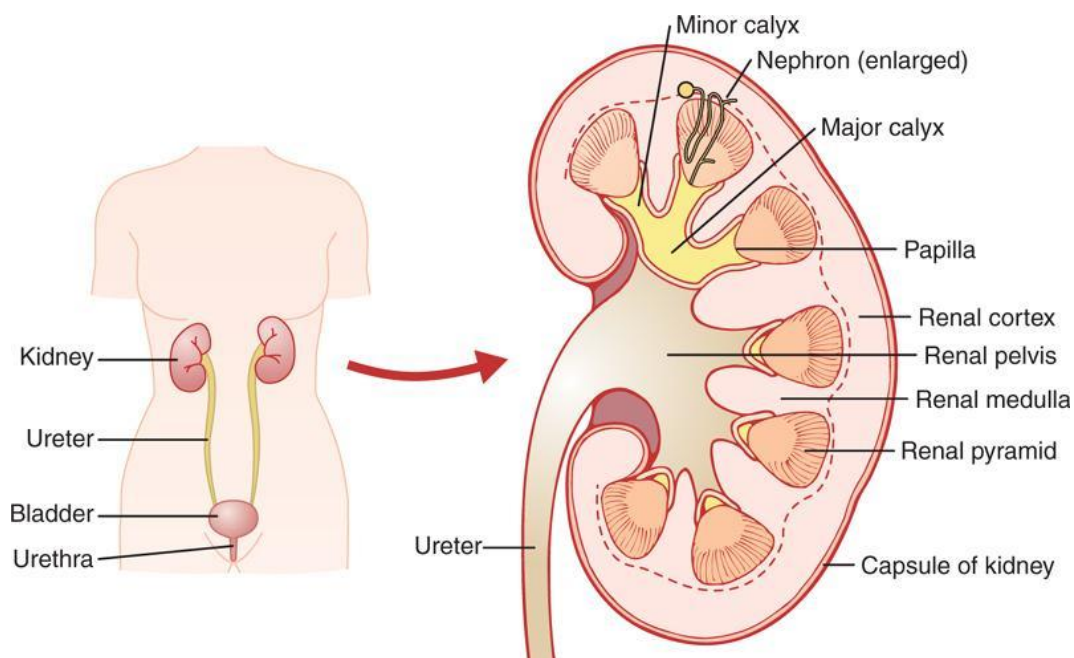


Figure 1: Basic renal anatomy. Line drawing demonstration anatomical layout and basic anatomy of the kidneys. Taken from (Hall and Guyton, 2011).

The kidneys have several key functions; the primary purpose of the kidneys is to maintain a balance of water, electrolytes, and proteins in the body. This is done through a continuous process of filtering blood to actively reabsorb and secrete key substances, as well as removal of waste products through the production of urine (Floege et al., 2010).

A failure in the function of the kidneys leads to a build-up of waste metabolites that would normally be excreted in the urine. If this occurs over a long period of time, patients are often asymptomatic until toxin levels build up to extremes. However, patients with chronic kidney disease (CKD) suffer long-term damage to various organ systems including the cardiovascular system (Rostand et al., 1991), the endocrine system (Juttmann et al., 1981), and is associated with significantly increased morbidity and mortality (Tonelli et al., 2006).

In the more acute setting, a sudden decrease in kidney function can cause dangerous changes in serum electrolyte concentrations, such as a high serum potassium (Hyperkalemia), that can lead to cardiac arrhythmia and cardiac arrest (Acker et al., 1998). A loss of kidney function will also cause an accumulation of fluid in the pulmonary system, which can lead to impaired gas exchange and life threatening hypoxia in the form of pulmonary oedema (Presberg and Effros, 1998).

AKI is therefore not a new medical condition, previously the term Acute Renal Failure (ARF) was used to describe a sudden worsening in renal function. However the term ARF was never well defined. One of the first epidemiological studies into ARF described ARF as:

“..a sudden rise in serum creatinine concentration (Scr) of more than 177 $\mu\text{mol/litre}$ in subjects with prior normal renal function”. (Liaño and Pascual, 1996).

But what time frame constituted ‘sudden’ was not defined in the paper, nor was the term ‘normal renal function’, but Liaño and Pascual were amongst the first to

report on the high mortality rate associated with patients who develop a sudden drop in renal function (Liaño and Pascual, 1996).

The function of the kidneys is traditionally defined by the volume of blood that is filtered over a predefined time period in relation to body surface area: this figure is known as the glomerular filtration rate (GFR) (Stevens et al., 2006). This value is related to age, sex and body volume, a figure of 130 ml per minute per 1.73m² surface area is widely accepted as 'normal' for a healthy human adult (Stevens et al., 2006).

However, directly measuring GFR is not an easy task. In the past, inert polysaccharides such as Inulin, which is freely filtered but not absorbed by the kidneys have been proven as the most accurate way to measure GFR (Toto, 1995). But due to cost and the complexity associated with carrying out such tests, they remain mainly confined to research studies. Clearance of radioisotope-labelled molecules have also been shown to be an accurate way to measure GFR, but this method still requires injection of foreign material into the body and exposure to radiation, and therefore have not gained popularity in routine clinical practice (Morton et al., 1997). More recently Cystatin C, an endogenous low molecular weight proteinase that is produced at a constant rate by all nucleated cells has been shown to be a more accurate way to assess GFR compared to measuring serum creatinine (Dharnidharka et al., 2002). However, measuring serum creatinine remains the most widely used and accepted way to assess kidney function and GFR in clinical practice, and is unlikely to be replaced in the immediate future (Traynor et al., 2006).

Creatinine is a metabolic by-product of creatine metabolism in skeletal muscle. It is excreted and produced at an almost constant rate, though the amount of creatinine produced is directly related to the skeletal mass/creatine load, which will vary depending on age, sex, ethnicity and general condition of the individual **Figure 2** (Wyss and Kaddurah-Daouk, 2000). A number of other factors independent from GFR also affect serum creatinine values. For example, it is known that as kidney function declines, there is a degree of active creatinine secretion and reabsorption

by the renal tubules, which varies between individuals (Perrone et al., 1992). This therefore means measuring kidney function using serum creatinine will always be subject to bias and error.

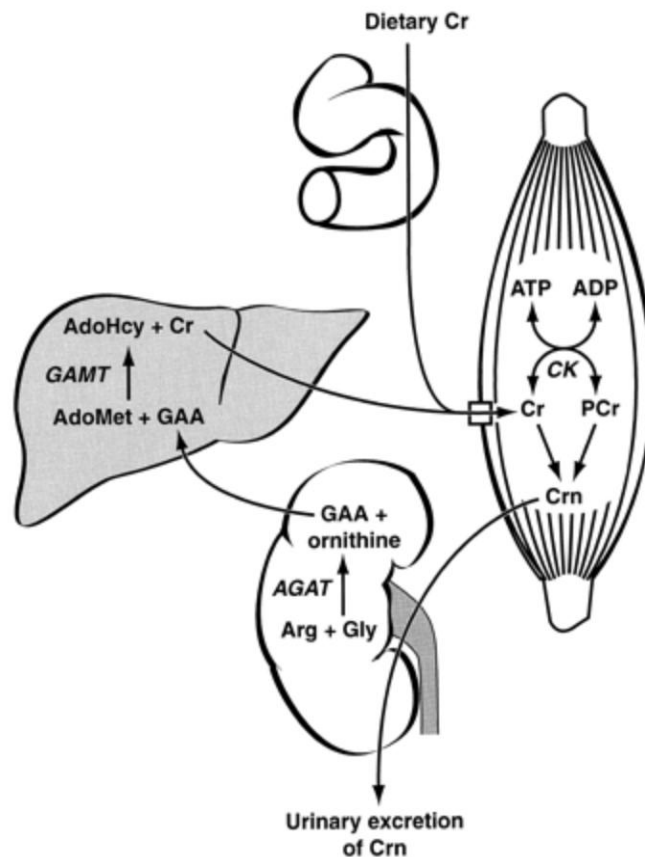


Figure 2: Overview of creatinine production. Metabolic pathway of creatinine (Crn) production from creatine (Cr) metabolism within skeletal muscle. Taken from (Wyss and Kaddurah-Daouk, 2000).

Various mathematical formulas have been developed based on reviews of large population based studies to try and correct for some of the extra-renal factors that affect serum creatinine, including age, sex, and ethnicity. The most widely used formulas are currently the Cockcroft-Gault and Modification of Diet in Renal Disease (MDRD) formulas (Stevens et al., 2006). Both provide an estimated GFR (eGFR) based on a serum creatinine value, whilst taking into account additional factors such as age and sex. These formulas have known limitations, the MDRD formula has a tendency to underestimate GFR in healthy adults and overestimate GFR in severe CKD (Stevens et al., 2007), but despite these limitations, it has become acceptable to use the MDRD formula to help identify patients with CKD

(2008). The current most widely used eGFR formula is based on the MDRD formula, and known as the CKD Epidemiology Collaboration (CKD-EPI) formula. It has been shown to be more accurate than the MDRD formula and is described below (Stevens et al., 2010).

$$\text{GFR} = 141 \times \min(\text{Scr}/\kappa, 1)^\alpha \times \max(\text{Scr}/\kappa, 1)^{-1.209} \times 0.993^{\text{Age}} \times 1.018 [\text{if female}] \times 1.159 [\text{if black}]$$

Where Scr is serum creatinine (mg/dL), κ is 0.7 for females and 0.9 for males, α is -0.329 for females and -0.411 for males, min indicates the minimum of Scr/ κ or 1, and max indicates the maximum of Scr/ κ or 1

In the next section of the thesis I will discuss how serum creatinine is used to measure acute changes in kidney function in the context of AKI.

Acute Kidney Injury

Defining AKI

As already mentioned AKI was previously known as ARF. However the term ARF was universally poorly defined. Even as recently as 2006, a review article on ARF published in the BMJ (Hilton, 2006) defined ARF as:

“Acute renal failure is characterized by a rapid fall in glomerular filtration rate, clinically manifest as an abrupt and sustained rise in urea and creatinine.”

But there was no quantification of what constitutes ‘a rapid fall’ in GFR or even how much creatinine had to rise in order for a diagnosis of ARF to be made. Recognizing this problem, in 2004 a standardized definition for AKI was proposed by the Acute Dialysis Quality Initiative group (Bellomo et al., 2004).

The definition was formed at a consensus meeting consisting of Nephrology and Intensive Care consultants. It was recognized that although using an eGFR value derived from a serum creatinine value is useful in the context of detecting CKD, in

the acute setting eGFR was likely to be inaccurate and too insensitive. Therefore, using changes in serum creatinine directly as a marker for AKI was proposed in addition to using eGFR.

The group proposed measuring delta change in creatinine value over an acute time period of 1 to 7 days for the diagnosis of AKI. A graded marker of the severity was also devised and divided into 5 stages (RIFLE); **R**isk of renal dysfunction; **I**njury to the kidney; **F**ailure of kidney function, **L**oss of kidney function and **E**nd-stage kidney disease (Bellomo et al., 2004) Error! Reference source not found..

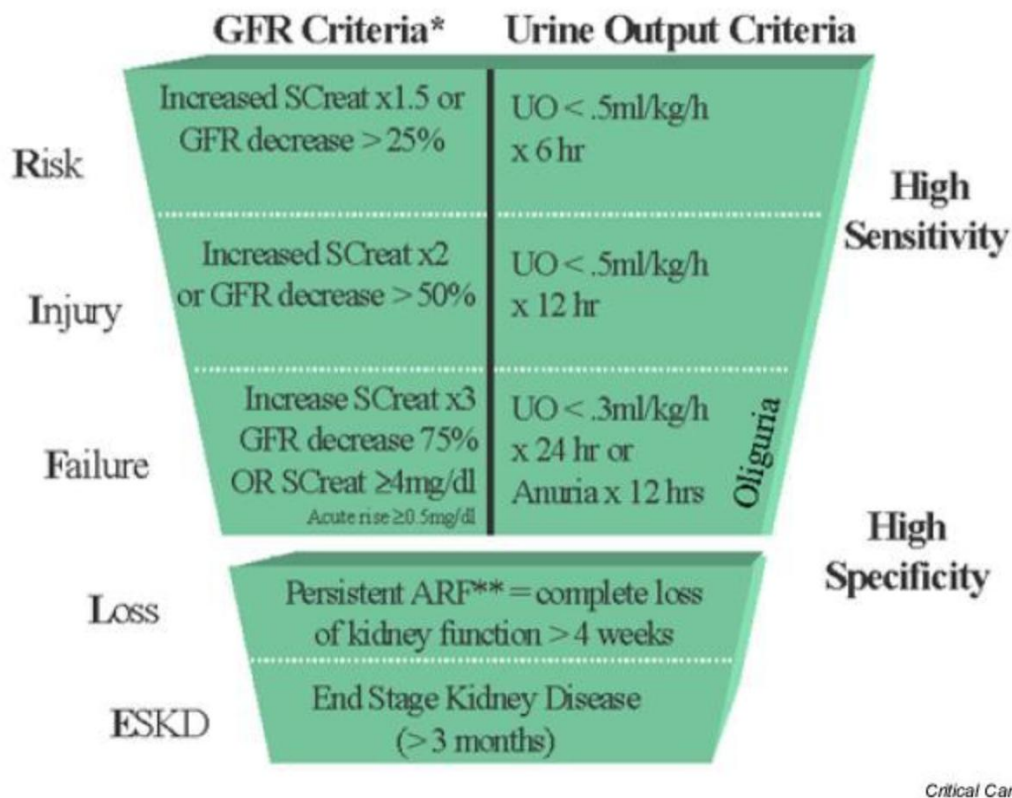


Figure 3: RIFLE AKI classification. RIFLE staging of AKI based on changes in serum creatinine, including measurement of urine output. Taken from (Bellomo et al., 2004)

The proposed RIFLE criteria also included measurement of urine output. A fall in urine output may indicate a change or worsening of renal function, but it is recognized that patients may develop AKI without a drop in urine output (Anderson et al., 1977). Though urine output measures can be accurate when carried out in an environment such as intensive care (Bouwuijsen et al., 2012),

practically urine output is often measured poorly in clinical areas outside of the intensive care environment (Reid, 2004), and therefore would prove to be too unreliable to use as a diagnostic marker in some clinical environments.

Development of the RIFLE criteria allowed clinicians worldwide to identify and track patients with AKI in a uniform way. When it was used to monitor the incidence and prognosis of patients with AKI admitted to seven different intensive care units; out of 5000 patients evaluated, 33% were found to have AKI, with more than 50% of those who had initially developed the lowest degree of AKI (R), going on to progress to a more severe form of AKI (F) (Hoste et al., 2006). It was shown that as the severity of AKI increased, so did the mortality. Patients without any AKI were found to have a mortality of 5.5%, this rose to 8.8% for patients with the lowest degree of AKI (R) and 26.3% for patients with the worst stage (F) (Hoste et al., 2006). The researchers were unable to explain why even the patients with the lowest degree of AKI (R) had a significantly higher mortality rate compared to patients who had not developed AKI. The problem of how to define an accurate 'baseline' creatinine, by which changes in serum creatinine are measured and severity of AKI established, was identified. This problem arises because not every patient admitted to hospital will have had a blood test carried out in the recent past and equally, patients with slowly progressing CKD may not have a stable 'baseline' creatinine. In the case of a patient who has no past creatinine on record, the authors generated an 'ideal' creatinine by a reversed calculation of the MDRD formula, based a GFR of 75ml/min taking into account the patient's age and gender. The difficulties associated with defining the term 'baseline' in particular for patients with CKD will be discussed later on in this chapter.

The validity of the RIFLE criteria to predict mortality has now been shown in numerous studies. A recent meta-analysis of the RIFLE criteria included 13 studies with over 71,000 patients, and found remarkable consistency between the relative risk of death in patients with AKI and those without AKI across different institutions (Ricci et al., 2007). But it was shown that the last two stages of the RIFLE criteria, Loss (L) and End stage kidney disease (E), produced results that

were not consistent. This was due to the heterogeneous nature of treatments given to patients who had lost total kidney function, since the criteria for starting renal replacement therapies is poorly defined, and often relies on the clinical condition of the individual. Overall it was shown that patients had an increase in their relative risk of death of 2.4, 4.15, 6.4 fold respectively, depending on the severity of the AKI they developed according to the R, I, and F stages of the RIFLE criteria. But it should be noted the majority of the studies into the RIFLE criteria were carried out in the intensive care setting, so the validity of the results in a non-intensive care setting is not clear.

The increase in mortality associated with even a small rise in creatinine was shown by Chertow et al (Chertow et al., 2005). Chertow defined AKI as any patient with a rise in creatinine of more than $44.2 \mu\text{mol/L}$ during their inpatient admission at a single centre. Only patients who had at least 2 serum creatinines checked during their admission were included in the study. The results showed that both adjusted and unadjusted odds ratios of death were significantly higher for patients who had a rise in their serum creatinine compared to those who did not. At the same time, a larger delta change in serum creatinine was associated with higher risk of death **Figure 4**.

Mortality associated with change in serum creatinine.

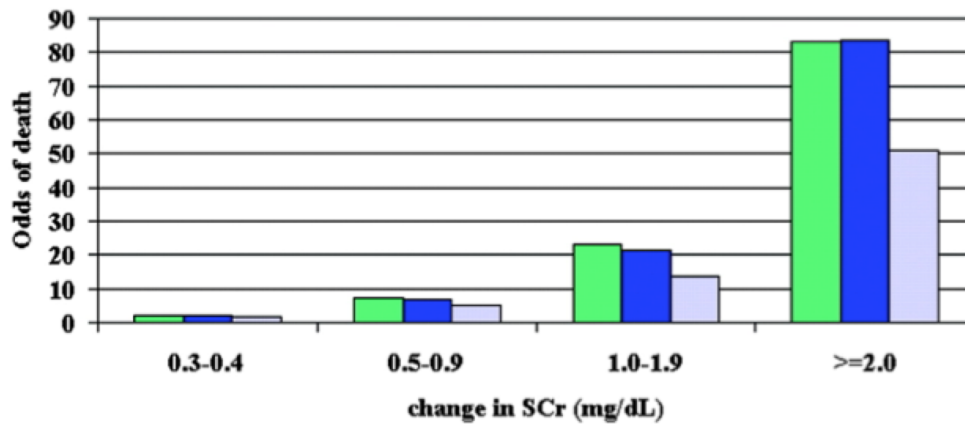


Figure 4: AKI mortality. Mortality associated with change in serum creatinine (SCr). Green bars are unadjusted, blue bars are age and gender adjusted, and grey bars are multivariable adjusted. Multivariable analyses adjusted for age, gender, diagnosis-related group (DRG) weight, chronic kidney disease (CKD) status and ICD-9-CM codes for respiratory, gastrointestinal, malignant, and infectious diseases; n = 1564/ 885/ 246/105 for change in SCr 0.3 to 0.4/ 0.5 to 0.9/ 1.0 to 1.9/ ≥2.0 mg/dl.(Chertow et al., 2005)

With growing awareness of AKI, the Acute Kidney Injury Network (AKIN) was established to help generate an international consensus on AKI management and research. The AKIN group reviewed the published literature on AKI, as well as the feedback received from using the RIFLE criteria, and proposed a new uniform criterion for diagnosing AKI. The group hoped to improve the sensitivity of the RIFLE criteria by taking into account the changes in mortality associated with even small rises in serum creatinine which might be missed on the RIFLE criteria, and introduced a shorter 48hr window in which AKI could be diagnosed, compared to the 7 day window in the RIFLE criteria.

This new criteria removed the last two stages from the RIFLE criteria and renamed the first three stages as stage 1, 2, and 3 AKI to reflect the increase in mortality associated with the first three stages of the RIFLE criteria **Table 1**. eGFR values were felt to be too insensitive and therefore removed completely from the criteria. At least 2 serum creatinine results must be available within 48hours for a

diagnosis of AKI to be established. Urine output was retained, as it was felt that in certain situations, a drop in urine output may precede any changes in serum creatinine (Mehta et al., 2007).

Stage	Serum creatinine criteria	Urine output criteria
1	Increase in serum creatinine of more than or equal to 26.4 $\mu\text{mol/L}$, or increase to more than or equal to 150% to 200% from base line.	Less than 0.5 ml/kg per hour for more than 6 hours.
2	Increase in serum creatinine of more than 200% to 300% from base line.	Less than 0.5 ml/kg per hour for more than 12 hours.
3	Increase in serum creatinine of more than 300% from base line. Or serum creatinine of more than 354 $\mu\text{mol/L}$ with an increase in serum creatinine of more than 44 $\mu\text{mol/L}$.	Less than 0.3 ml/kg per hour for 24hours.

Table 1: AKI criteria AKIN. AKIN criteria for diagnosis of AKI, based on RIFLE criteria. Adapted from (Mehta et al., 2007).

Though the changes in the diagnostic criteria may seem trivial, because of the change in the time frame needed for diagnosis between the AKIN and RIFLE criteria, in certain situations, a diagnosis of AKI could be given to a patient at significantly different time intervals.

For example, if a patient with no previous blood tests is admitted to the hospital with a creatinine for 88 $\mu\text{mol/l}$ and then their serum creatinine increases slowly by 8.8 $\mu\text{mol/L}$ every day, the patient would be flagged up as suffering from AKI on day 6 of their admission in the RIFLE criteria, due to their serum creatinine raising to more than 1.5 time above their baseline creatinine. However, following the AKIN criteria it's not until day 17 that the patient will be diagnosed with AKI, due to the fact the AKIN criteria relies on comparing changes in blood tests over a period of 48 hours. But in clinical practice, the AKIN criteria have been shown to be just as

effective as the RIFLE criteria at identifying patients with AKI. In one retrospective ITU study containing over 100,000 patients, the AKIN criteria diagnosed AKI in 36.1% of patients compared to 37.1% of patients if the RIFLE criterion was used. Mortality in both the AKIN and RIFLE groups were increased to the same degree compared to patients with no AKI (Bagshaw et al., 2008).

Further evaluation of the AKIN and RIFLE criteria suggested that a new diagnostic criteria that builds upon what is known already should be developed (Cruz et al., 2009). In 2012, the International Society of Nephrology published its own revised criteria for diagnosing AKI through the Kidney Disease: Improving Global Outcomes (KDIGO) AKI guidelines (KDIGO, 2012). The new criteria aimed to correct some of the criticism levelled at the AKIN criteria with regards to the strict 48hr rule for diagnosing AKI, but also incorporate the importance of picking up small changes in creatinine that was missing in the RIFLE criteria.

KDIGO divides the severity of the AKI into 3 grades in a similar format to the AKIN criteria **Table 2** (KDIGO, 2012).

Stage	Serum creatinine criteria	Urine output criteria
1	1.5–1.9 times baseline OR 26.5 $\mu\text{mol/l}$ increase	0.5 ml/kg/h for 6–12 hours
2	2.0–2.9 times baseline	0.5 ml/kg/h for 12 hours
3	3.0 times baseline OR Increase in serum creatinine to 353.6 $\mu\text{mol/l}$ OR Initiation of renal replacement therapy	Less than 0.3 ml/kg per hour for 24hours.

Table 2: AKI criteria KDIGO. Proposed AKI staging criteria by the KDIGO group 2012.

The KDIGO guidelines also attempted to address the problem of defining a 'baseline' creatinine in patients with no previous blood test results. The KDIGO group noted that an 'ideal' creatinine can be generated using a reverse MDRD formula, assuming a GFR of 75 ml/min as 'baseline'.

Závada et al tested the validity of this approach to defining a baseline creatinine (Závada et al., 2010). The group compared the performance of using MDRD formula to generate an ideal creatinine in 3 population cohorts without AKI and one with AKI. The generated ideal creatinine values were compared to real life mean-creatinine values of each cohort, and, as well as using the MDRD formula, two other formulas were trialed. The results showed that although the MDRD formula performed as well as the other proposed formulas for generating an ideal creatinine, there was a degree of error between the generated ideal creatinine and the actual value, with the diagnostic accuracy of lower grades of AKI being most affected. The group concluded that where available, actual measures in serum creatinine should be used as the baseline creatinine (Závada et al., 2010).

This problem is even more apparent in the CKD population. At present there is no consensus on how a baseline creatinine for a patient with CKD should be produced. Siew et al asked two consultant nephrologists to review the blood tests of 400 patients who had been admitted with AKI (Siew et al., 2012). The consultants were asked to produce what they thought the patient's 'baseline' creatinine was before admission using their clinical judgment and were allowed to review all available results for the patient. Overall the consultants were in agreement on 88% of patients reviewed. Three automated methods for generating a baseline creatinine were picked, one method simply picked the most recent outpatient result, a second method was to generate a value based on the mean outpatient result from the last 12 months, and finally the nadir outpatient result within the last 12 months. It was found that the correlation between the physicians' derived creatinine and automated results varied between 0.8 and 0.91 depending on which automated method was used.

However only 81% of the patients in the study had results available within the last year prior to admission. The correlation of values became worse if results from the last 3 years were included in the calculations for the automated methods, but expanding the result range from 1 year to 3 years meant that 93% of the patients in the study could have an automated result generated. In all cases, the automated methods generated higher creatinine results than the adjudicated value, suggesting the possibility of under-diagnosing AKI in the initial stages if an automated method was used to establish a baseline creatinine. Overall, the authors concluded that the mean outpatient average creatinine over past year was the most accurate way to produce an automated creatinine, with a correlation of 0.9.

Clearly, the exact definition of AKI is still fluid. It should be noted that even the latest KDIGO AKI diagnostic criteria is rated as 'Un-Graded' evidence by the authors, indicating the clinical uncertainty that still exists around the topic. In addition, many of the current studies that have been reported took place in either the renal or intensive care setting. Therefore how valid the current AKI diagnostic criteria are in a non-intensive care setting is still unclear, especially when you consider the large number of patients in the community whom may only have one blood test every few years.

The uncertainty about how to define an accurate 'baseline' is a problem that remains to be solved, but despite these concerns, most clinicians are in agreement that some kind of system is needed to identify patients with AKI (Haase et al., 2011). Using the MDRD formula to generate an ideal creatinine seems like the most pragmatic way forwards at present.

Having a set and established international consensus on the definition of AKI is vital in order to allow for productive research into the topic. But at the same time, what is already known about the huge mortality and morbidity associated with AKI demands action to be taken now to try and improve outcomes, as work continues to refine the exact diagnostic criteria (Haase et al., 2011).

Being able to diagnose AKI is only the first step towards improving outcomes; in

the next section of the thesis I will discuss the pathophysiology of AKI.

Aetiology of AKI

Like many other syndromes, AKI by itself is not a diagnosis of pathology. However, unlike a syndrome such as Acute Coronary Syndrome, which is almost always caused by atherosclerosis of coronary artery vessels leading to the formation of an atheromatous plaque (Epstein et al., 1992), the underlying pathology that causes AKI is numerous.

The aetiology of AKI can be broadly divided into three main divisions. Disorders that affect renal blood flow/perfusion (pre-renal), disorders that affect the kidneys directly (renal), or disorders due to urinary drainage (post-renal) **Figure 5**.

Disease pathologies such as pauci-immune rapidly progressive glomerulonephritis that causes direct damage to the renal tissues is rare (renal cause), and when it occurs, requires rapid involvement and treatment by Nephrologists to avoid further irreversible damage to renal tissue (Hedger et al., 2000). Post-renal causes often include undiagnosed malignancy and ureteric stones, the treatment of which are almost always by surgical methods (Norman et al., 1982). Pre-renal causes are recognised to be by far the most common cause of AKI in the secondary care setting and most often managed by non-specialists, and so will be the focus of this chapter (Bellomo et al.).

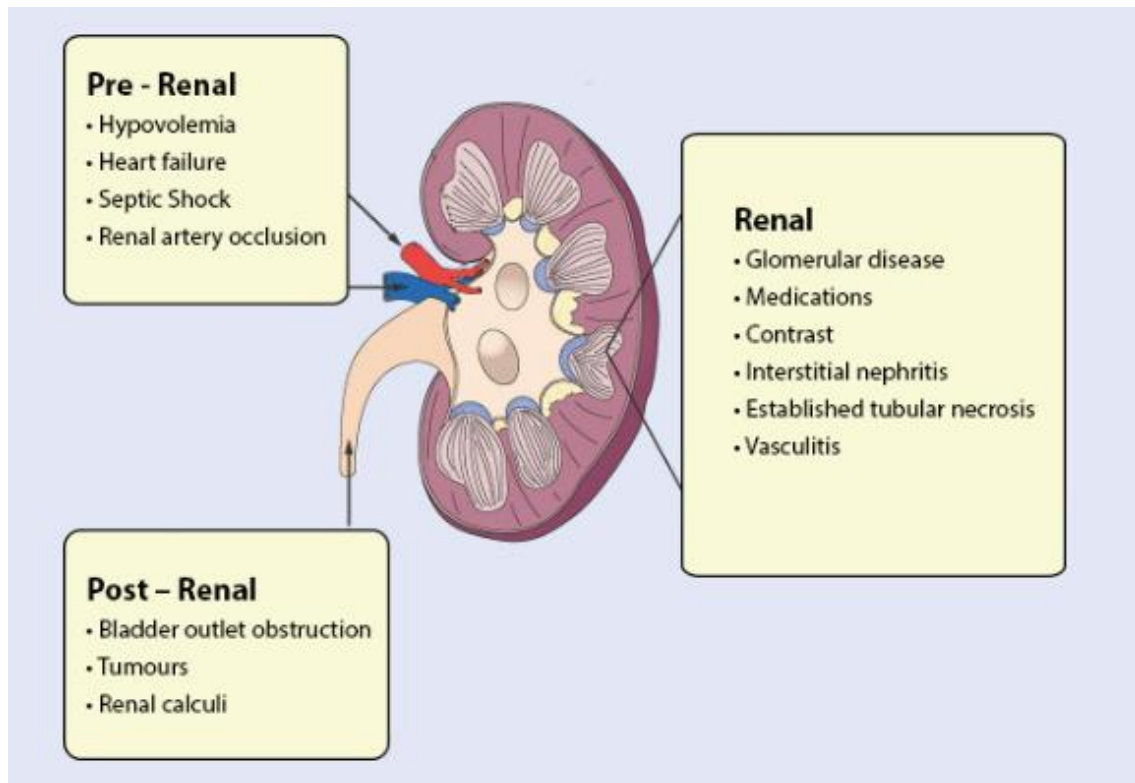


Figure 5: Common cause of AKI. Adapted from (Floege et al., 2010).

The term Acute Tubular Necrosis (ATN) is often associated with AKI due to pre-renal causes. ATN describes a characteristic histological appearance of damaged renal tubular cells, that most often occurs as a result of prolonged ischemic injury to the kidneys due to a fall in renal perfusion (Floege et al., 2010). The most common cause of prolonged ischemic injury is low blood pressure, which may be as a result of dehydration or sepsis. The exact mechanism by which ATN develops is still unclear, but it is thought that regulation of vascular tone at a tubular level plays an important part in the disease pathway (Rosen and Stillman, 2008), and may explain why medications that alter prostaglandin release (e.g., Diclofenac) or the renin-angiotensin system (e.g., Rampril) may predispose patients to developing ATN. ATN can also occur in the presence of sepsis, and even as a result of being exposed to certain antibiotics (Rose, 2003).

Some patients who develop ATN will require a short duration of renal replacement therapy (RRT) while damaged tissue regenerates (Floege et al., 2010). Here in the UK currently its estimated less than 10% of all AKI patients require renal

replacement therapy during their acute admission (Wonnacott et al., 2014). This is in contrast to a purely 'pre-renal' cause of AKI such as dehydration, causing hypotension leading to reduced renal perfusion and a fall in GFR, but no established ischaemic insult to the renal tissue. In a situation where ATN has not been established, adequate fluid resuscitation to correct hypotension should lead to an improvement in renal perfusion and GFR, without requiring RRT. But clinically, it is often difficult to ascertain if a patient has established ATN that may require RRT, or if the patient has AKI due to pre-renal hypotension, or a mixture of the two scenarios. Some clinicians argue artificially dividing patients into 'pre-renal' and 'renal' causes means that many patients with established ATN are coming under harm by being given too much intravenous fluids, as many of these patients are wrongly labelled as suffering from purely a 'pre-renal' aetiology (Belcher and Parikh, 2011). But never the less, the 'pre-renal', 'renal', 'post-renal' approach in diagnosing the underlying cause of AKI remains the most widely taught and accepted approach, and will be the method taught in the educational interventions developed for this project.

Liano et al studied the most common causes of AKI in Spain in a prospective trial involving 13 centres in Madrid (Liano and Pascual, 1996). Physicians were asked to fill in questionnaire surveys designed to establish a cause of AKI based on reviewing medical notes, investigation results and where available, renal histology. A total of over 700 cases were studied. The most common cause was ATN, as defined by a failure of renal function to return to normal after reversible factors are corrected. Pre-renal was the second most common cause, and together with ATN, this accounted for over 70% of all the cases. Overall mortality in the study was high at over 40%, and it was estimated that AKI was present in 1 in 267 admissions during the study period. Over one third of patients required dialysis and overall patients with AKI had hospital admissions three times longer than for patients without AKI. The group also noted that only 13% of patients with AKI were directly under the care of Nephrologists.

Liano's findings suggest that ATN and pre-renal factors are responsible for AKI in the majority of cases. As already described, ATN itself is most commonly caused

by prolonged/untreated hypotension and may develop if pre-renal causes are not corrected promptly. The AKIN group have therefore developed a conceptual framework on how AKI may develop as a result of predisposing risk factors such as CKD, in combination with additional external insults, with the possibility of biomarkers that may be useful in helping determine if established kidney damage such as ATN has occurred or if the patient is suffering from a pure pre-renal cause **Figure 6** (Murray et al., 2008).

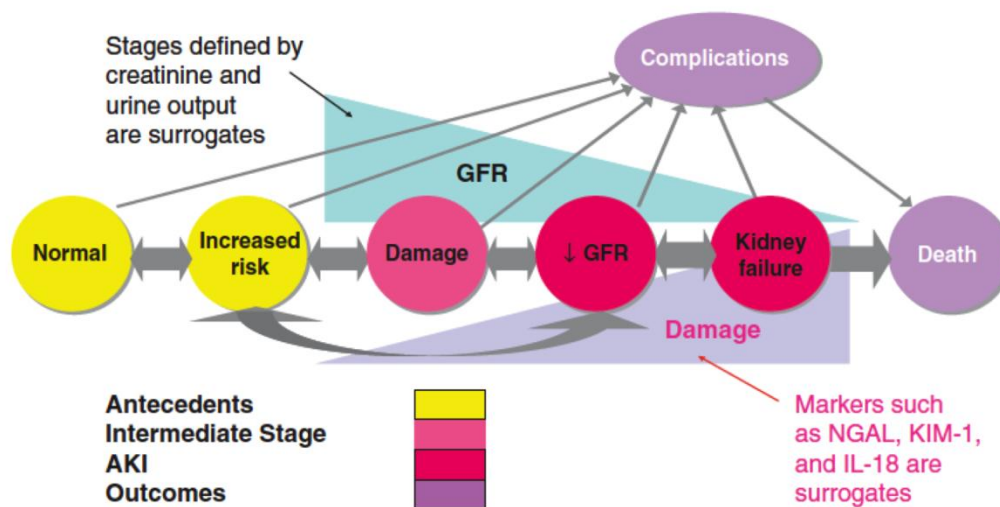


Figure 6: Conceptual model of AKI pathology. Pink circles indicate established AKI. Yellow circles indicate increased risk. Arrows show possible progression of disease if risk factors or insults are not corrected. Purple circles show complications/end results of AKI. Adapted from (Murray et al., 2008)

It could therefore be concluded that one way to improve outcomes in AKI is to stop patients from developing ATN and pre-renal AKI by reducing their risk factors, or to stop patients from progressing to ATN with prompt medical treatment of any reversible causes. To consider if this is possible I will review the current literature regarding the incidence and management of AKI here in the UK.

Incidence of AKI in the UK

As previously mentioned, Liano et al have reported high mortality and morbidity rates associated with AKI in developed countries (Liano and Pascual, 1996). However, the definition of AKI Linano used has now been superseded. More recently, Ali et al carried out a retrospective study of patients with AKI in Scotland,

using the RIFLE criteria (Ali et al., 2007). The annual incidence of AKI was calculated as 1811 per million population (pmp), overall mortality ranged from 26% to 56% at 6 months depending on AKI severity based on the RIFLE criteria. Only 25% of patients with AKI had input from Nephrologists, with 8% receiving dialysis. Average length of stay in hospital for patients with any form of AKI was much higher than for patients without AKI at 17 days.

The findings Ali et al reported are significant; previous studies had only reported incidence of around 200 pmp (Liaño and Pascual, 1996). The higher incidence of AKI reported by Ali is partly accounted for by changes in definition, but also the fact that Ali took into account patients with CKD who then went on to develop AKI. Despite the inclusion of more patients with the newer RIFLE criteria, the mortality rate associated with AKI remains worryingly high, indicating that the burden of disease is higher than previously thought. As a reference, the incidence of acute myocardial infarction in Europe is currently estimated at 1900 pmp (Widimsky et al., 2010), but unlike acute myocardial infarction, there is little established infrastructure, education or evidence at present on how to manage patients with AKI.

The high incidence of AKI is also associated with a financial cost both in the form of acute short-term therapy and long-term risk of developing CKD. Data from the Intensive Care National Audit Research Centre suggested that AKI accounted for almost 10% of all intensive care unit bed days (Kolhe et al., 2008), whilst at the same time, there is now increasing recognition that patients who develop AKI are at risk of developing CKD, as well as cardiovascular disease, with many currently receiving no follow-up care post hospital discharge (Chawla et al., 2014).

Much more work is needed to understand how AKI affects patient outcomes in the long term, but it is clear that the incidence of AKI is much higher than previously thought and that it is a condition which is relevant to all physicians in both secondary and primary care. In the next section of this chapter I will examine what we currently know about the quality of care patients with AKI receive here in the UK.

Management of patients with AKI in the UK

The National Confidential Enquiry into Patient Outcomes and Death (NCEPOD) report into the management of patients with AKI in England entitled “Adding Insult to Injury” was published in 2009 (Stewart, 2009). Hospitals were asked to submit case notes of patients who had died of AKI and an expert panel of clinicians reviewed the notes. In total the group reviewed the notes of nearly 600 patients who died of AKI in the UK between January and March 2007. The findings of the report made for worrying reading; the group felt that only 50% of patients who died of AKI had received a ‘good’ standard of care Figure 7. 14% of cases were thought to have been avoidable, with only 3% of patients with AKI had been under the direct care of a Nephrologist.

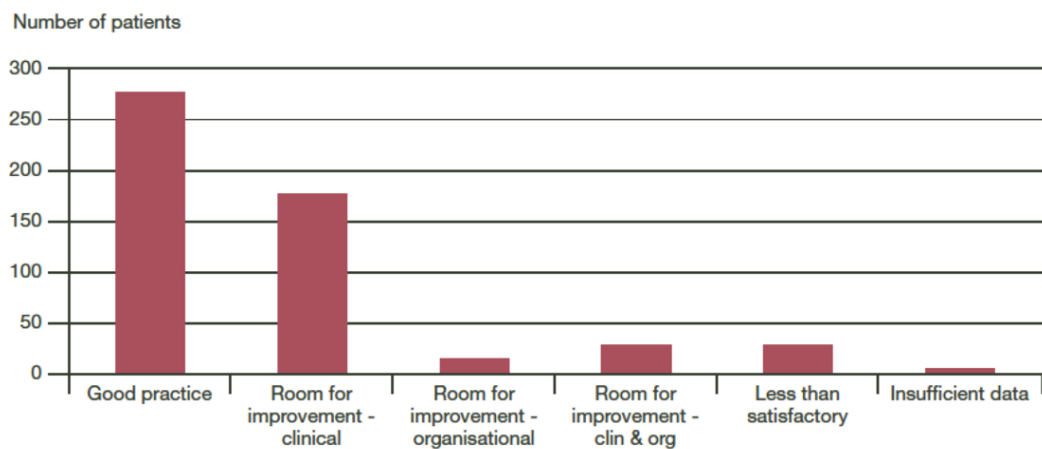


Figure 7: NCEPOD report on AKI care. Breakdown of overall quality of care based on NCEPOD advisor group opinion, Taken from (Stewart, 2009).

The report highlighted that the majority of patients with AKI are looked after by non-specialists, who may lack current training and knowledge in AKI. The NCEPOD report recognized that early management decisions made by health professionals are critical in ensuring good quality of care, which is often variable in quality. This resulted in significant shortfalls in the standard of care with delays in diagnosis,

suboptimal management in a large number of cases, with 33% of cases not adequately investigated and 29% not receiving 'adequate' management. Deficiencies in education and training were highlighted, and training in the awareness, recognition of causes, management and complications of AKI was recommended.

Overall, the NCEPOD group felt that the problems associated with delivering care to patients with AKI in the UK were more associated with a lack of clinical awareness of the condition rather than a lack of resources. Therefore better education on AKI at the undergraduate and postgraduate level, as well as more senior review and earlier input from Nephrologists may be appropriate in helping to improve care .

The NECPOD report however, provides a slightly biased view of AKI management in the UK, since all the cases reviewed were of patients who had unfortunately passed away. It may be that the care of patients who survived their AKI episode is better. Equally, the NCEPOD group arrived at their decision on 'good/adequate' quality of care based on a multidisciplinary group of advisors reviewing each case. Though the decisions made by the advisors are clearly of sound judgment and logical, currently there is little to no evidence guiding us about what the best form of treatment for AKI is. It is unclear just which investigation/intervention is most crucial in improving outcomes. But despite these concerns, the NCEPOD report provides the best snapshot of AKI care in the UK at present and identifies the need to improve practice.

Measuring outcomes

Ultimately, the aim of this project is to improve outcomes in patients with AKI. The most simplistic way of measuring outcome is with markers such as mortality or length of stay. But recently, the use of mortality figures as makers for quality of care has come under review (Lilford and Pronovost, 2010). Concerns have arisen because it is often hard to work out the exact number of 'preventable deaths' in a hospital, compared to the overall death rate. Complex statistics can be used but

depending on how data is inputted and collected, even a small amount of bias can lead to drastically different conclusions. However, before I can even consider analysing mortality figures, an AKI identification system needs to be introduced locally, since being able to identify and track patients with AKI is the first step in the data gathering process.

Even if accurate mortality statistics are collected and calculated it must be interpreted with some caution. Below are descriptions of the care given to two patients who died of AKI taken from the NCEPOD AKI report 2009 (MacLeod, 2009). The first patient died from preventable AKI due to poor care, which is the kind of practice this project is aiming to eliminate Figure 8. The second patient also died from AKI, but received all appropriate care Figure 9. In both cases, the patient died, however it is clear to see that the two patients received totally different levels of care, which only becomes clear if the process of care is reviewed. Mortality figures alone would not have discriminated between the quality of care given in these two cases.



An elderly patient was admitted with a fractured neck of femur. The patient was known to have chronic kidney disease but the electrolytes on admission showed no evidence of recent deterioration. The patient was noted to be taking aspirin and two diuretics. Hemi-arthroplasty was undertaken but post-operatively the patient developed worsening renal function consistent with pre-renal failure. Whilst this was noted and recorded, the diuretics were not discontinued and the patient was given inadequate intravenous fluid replacement. Renal function continued to deteriorate to the point where significant acidosis developed. After a prolonged hospital stay the patient ultimately died of AKI secondary to hypovolaemia precipitated by the above mismanagement.

Figure 8: Management of a patient who died from preventable AKI. Taken from (MacLeod, 2009).



An elderly patient was admitted to hospital as an emergency due to a chest infection. Significant co-morbidities existed (type II diabetes, ischaemic heart disease, previous myocardial infarction, left ventricular failure, chronic kidney disease, chronic obstructive pulmonary disease, morbid obesity). Renal function deteriorated despite good medical care. Advice was requested from a consultant nephrologist who discussed treatment options with the patient and next of kin. After several discussions, the patient decided that they did not want to undergo renal replacement therapy.

Figure 9: Management of a patient who died from AKI despite good care. Taken from (MacLeod, 2009).

Clinical audit of care is often promoted as a way for doctors to monitor and improve their clinical practice (Benjamin, 2008). The process of audit involves deciding on a set of 'minimal' standard of care expected to be delivered and then reviewing the care of patients against those standards. For this project I will use the British Renal Association (RA) recommendations as the 'minimal' standard of care expected for patients with AKI (Lewington and Kanagasundaram, 2011). An audit of care for AKI patients using the criteria set out by the RA had already been carried out in a limited number of patients before the start of the project within the trust in 2011 **Appendix A**. I therefore aim to repeat a similar clinical audit at the end of the project and compare the results.

Therefore, for this project I will aim to collect both overall mortality data and length of stay on patients with AKI, as well as data on quality of care through an inpatient audit of patient case notes.

The NCEPOD report clearly highlights that care for patients with AKI in the UK could be improved and suggests that improving the basic elements of management, such as more rapid diagnosis, may prove to be beneficial to patient outcomes. In the UK, a national consensus meeting on AKI was held at the Royal College of Physicians Edinburgh in 2012, the aim of which was to review the latest evidence on AKI and to produce national guidance on how to improve care (Feehally et al., 2013). One of the key themes that emerged following the meeting was that outcome for patients may be improved by ensuring the basic elements of care is done well. Better education and training was highlighted as important steps needed in order achieve this.

So, despite the lack of firm evidence on how to improve outcomes in patients with AKI, education has been identified as a potential tool to improve clinical care. This concept forms the basis of the project described in this thesis.

Post-graduate education

In this section of the thesis, I will explore the literature surrounding physician/adult education and how best to develop an educational intervention to try and change clinical behaviour.

Adult educational theories considered when developing the educational intervention

The learning/educational theories I considered most relevant to this project are the theories of Andragogy and Constructivism.

Andragogy

It has long been recognized that delivering learning resources through long didactic lectures is not an effective way to teach adults (Bryner, 1995). Malcom Knowles developed a learning theory specific to adult learners known as Andragogy in the 1970's (Knowles, 1973). Andragogy assumes that adult learners have specific learning needs, and in order for any adult education to be successful, the educator must be aware of these learning needs and ensure that they are fulfilled.

These include (Knowles, 1990):

- 1) **The need to know;** Adults need to understand why they are being asked to learn something before undertaking it, compared to children who learn what is dictated to them.
- 2) **The learner's self-concept;** Adults have a strong self-concept of who they are, their role in society and family, and therefore will resist anything that challenges this self-concept, consciously or subconsciously.

- 3) **The role of the learner's experience;** Adults have a great volume of experience which can be drawn up, but this experience can also hinder learning due to habit, bias, and previous misconceptions.
- 4) **Readiness to learn;** Adults are ready to learn different things at different stages of their lives, the learning objectives should be relevant to their current life situation, for example, there is no point in teaching management of complicated conditions to newly qualified doctors who require education on basic management plans.
- 5) **Orientation to learning;** Adults learn best when they can clearly sense how the learning objectives can be directly applied to real life problems.
- 6) **Motivation;** Adults are often motivated by a need to improve themselves, but this may be hindered by external factors such as time and financial constraints.

However, critics of Andragogy claim that Knowles makes an artificial distinction between the learning needs of adults and children, which is not supported by evidence. In particular, the concept that children have to be taught in a conscripted way and have no self-motivation to learn, compared to adults, who are self-motivated and learn best through self-directed learning. Indeed, some argue the opposite is true, that children naturally are curious to learn, where as adults will often have to be 'motivated' by the right incentives before they take part in additional learning (Darbyshire, 1993).

Constructivism

Another adult education theory that has to be considered in the context of this project is Constructivism. Von-Glasersfeld (Glasersfeld, 1989b) defined Constructivism as having two key epistemology principles:

" (1) Knowledge is not passively received but is actively built up by the cognizing of the subject;"

“(2) The function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality.”

In particular, the second concept is important, since how a student perceives and constructs knowledge and experiences will differ from individual to individual. Von-Galserfeld (Glaserfeld, 1989a) goes into more detail about how changes in the environment may affect learning. One example given is of a child banging spoons at the dining table, Von-Galserfeld argues that the child has “constructed” this behaviour through previous experience of playing with a rattle. Both are stick shaped objects with round heads, the only difference being that the rattle makes a noise and the spoon does not. So when a child is first presented with a spoon, his or her natural reaction is to grab it and shake/bang the spoon. Since in the mind of the child, the spoon should behave like a rattle, yet to the adult it may seem like the child wants attention. Through giving the child attention, the children will then develop/construct a new understanding about banging the spoon and associate it with attracting attention from adults. Hence, although the action itself has not changed, the meaning and consequence of the action has altered dramatically due to the changing social environment and mind set of the individuals involved.

This concept is of importance when we are considering how best to develop an educational resource that will engage with clinicians. We need to take into account the previous experiences clinicians may have had when dealing with patients suffering from AKI and produce a tool that will guide clinicians to learn and construct an appropriate course of action when faced with a patient suffering from AKI. The tools developed therefore must not just focus on ensuring that clinicians carry out the correct investigations/treatment plans, but that they develop an understanding of why they are carrying out those investigations/treatment plans, so that when they are faced with a real life case, they are able to use their knowledge to help construct the most appropriate treatment plan given the specific clinical context of the case.

However, there are also criticism levelled at using a purely constructivist theory to education, after-all, not all knowledge can be experienced or discovered directly. Scientific theories such as evolution or genetics cannot be easily discovered or experienced by students if they were to just study animals in the wild. Some form of guidance is needed in ensuring that students develop a realistic viewpoint of the world and understand that certain theories which govern the world cannot be experienced or felt directly (Matthews, 1993).

Therefore, when developing the educational tools I will also bear in mind the epistemological view of positivism (Bowling, 2009), which states that the world is logical and governed by a set of rules that can only be acquired through observing and recording of measurable variables. This will help me to ensure that the resources developed for the project will guide students in the correct direction of best AKI care, as we understand it at present.

Curriculum mapping

Constructive alignment is an important concept when designing education tools; it is vital that the assessment tools developed help to reinforce the learning objectives (Biggs, 1996). The concept of alignment means that the underlying learning outcomes influence teaching methods, curriculum design and the assessment processes. This approach helps to ensure that the assessment tools developed are appropriate given the context of the learning objectives.

The main steps in the alignment process are:

1. Defining the learning outcomes (the curriculum objectives)
2. Choosing teaching/learning activities likely to enable the students to attain these objectives
3. Assessing students' learning outcomes using methods that enable students to demonstrate the intended learning.

4. Evaluating how well the outcomes were achieved by the curriculum.

Therefore, when considering developing an educational intervention, a review of relevant curriculum is vital to ensure that the intervention developed is suitable for the target audience and fits into the overall educational agenda. Wear and Castellani described the importance of developing an undergraduate curriculum to focus in on professionalism and personal values in conjunction with objective, fact-based learning. Developing these elements of the curriculum is important in ensuring that students emerge from medical schools with a better understanding of social and ethical concerns of patients, as well as helping students to develop a habit of lifelong learning (Wear and Castellani, 2000).

Recognizing the importance of developing a curriculum that is less fact laden but more focused on personal development, the General Medical Council (GMC) has produced guidance on how junior doctor curriculums should be developed to ensure more emphasis is placed on core values that are central to the delivery of good health care (GMC, 2009b).

Some of the key points of these guidance document are listed below (GMC, 2009b):

- *Make the care of your patient your first concern*
- *Protect and promote the health of patients and the public*
- *Provide a good standard of practice and care*
- *Keep your professional knowledge and skills up-to-date*
- *Treat patients politely and considerately*
- *Act without delay if you have good reason to believe that you or a colleague may be putting patients at risk*
- *Never discriminate unfairly against patients or colleagues*

- *Never abuse your patients' trust in you or the public's trust in the profession.*

It is clear to see that without good factual knowledge or clinical skills, it would not be possible to deliver most of the aims listed above, however simply having good factual knowledge or clinical skills does not guarantee that good clinical care is being delivered.

Assessment of how doctors progress and meet the learning aims of the curriculum is also important. However, assessments based on recall of factual knowledge are only valid if the curriculum is also based on factual knowledge. Instead, the GMC puts emphasis on the importance of providing feedback and supervision of junior doctors to ensure that the curriculum aims are being met and tasks the doctors with the job of providing evidence that they are meeting these aims. The current training and assessment structure for clinicians is complex and managed in part by the Joint Royal Colleges of Physicians Training Board image of training (JRCPTB), the Foundation schools and the GMC, with much emphasis on feedback based assessments rather than pure factual recall tests **Figure 10**.

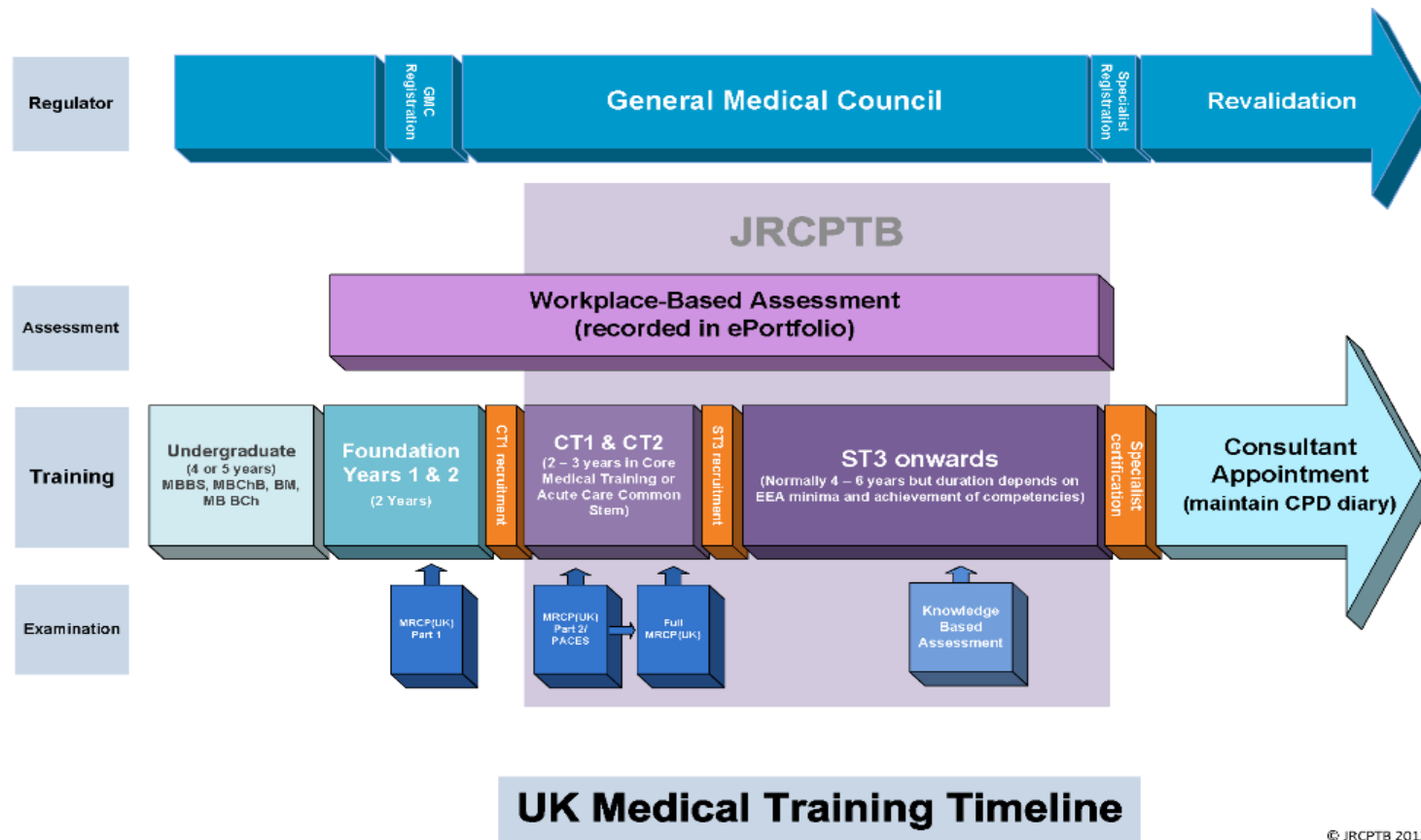


Figure 10: Current training pathway for junior doctors in the UK. Taken from JRCPTB website.

The current curriculum and syllabus for Foundation Year (FY) doctors were published in 2012 (<http://www.foundationprogramme.nhs.uk/pages/foundation-doctors/training-and-assessment/fpcurriculum2012>) (2012).

The curriculum covers patient safety and personal development. In keeping with guidance from the GMC, the curriculum focuses in on ensuring juniors doctors develop the generic skills needed to deliver good care, so no specific medical conditions are listed. Instead there is a focus on 'good clinical care' and 'recognition and management of acutely ill patients', which requires junior doctors to develop skills in identifying, investigating and managing patients with acute illness. These curriculum aims fit in well with the topic of AKI, since nearly all patients with AKI are acutely ill, but the curriculum does not contain any specific sections on more complex management issues associated with AKI, such as considering the need for dialysis or the cause of AKI.

For more senior doctors, the JRCPTB has its own curriculum which does contain specific points about recognizing, investigating and managing AKI (JRCPTB, 2012). The key learning objectives are listed below and on the whole are also relevant for majority of FY doctors. I will therefore use these points to help develop the learning objective for this project; this will ensure that the educational resources developed map to the JRCPTB national curriculum:

- Describe the common conditions that cause acute kidney injury and chronic kidney disease
- Outline the clinical approach required to distinguish chronic kidney disease from acute kidney injury, and to diagnose different common causes of these conditions
- Describe the life-threatening complications of renal failure, in particular of hyperkalaemia, and the indications for emergency renal replacement therapy
- Describe the principles of maintaining fluid balance in the oliguric or polyuric patient

- Describe the effect of renal failure on handling of drugs

Learning objective development

Developing learning objectives that are concise and useful for students is not a simple task. The most well-known approach is to use a method developed by Bloom, known as Bloom's Taxonomy (Krathwohl, 2002).

Bloom originally developed a list of 6 processes, which he felt was key in learning. These areas were defined as Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. However, Bloom felt that the original classification of knowledge was too rigid and placed too much emphasis on recall of knowledge. Bloom tackled this by revising the classification, which has led to the development of a hierarchal-based structure of different learning processes.

This new classification placed creative thinking as the top learning process, followed by the ability to evaluate, analyse, apply, understand, with the most basic learning process being factual-recall. Using this new classification system, it is clear to see that without being able to carry out factual-recall, it is impossible to develop a deeper understanding of new concepts, however, simply being able to carry out factual-recall does not guarantee higher knowledge or function **Figure 11**.

Learning objectives therefore should be designed to target higher levels of the thinking, but designers must make sure that enough material is provided to students to ensure that they can first meet the most basic learning needs, such as having basic factual information.

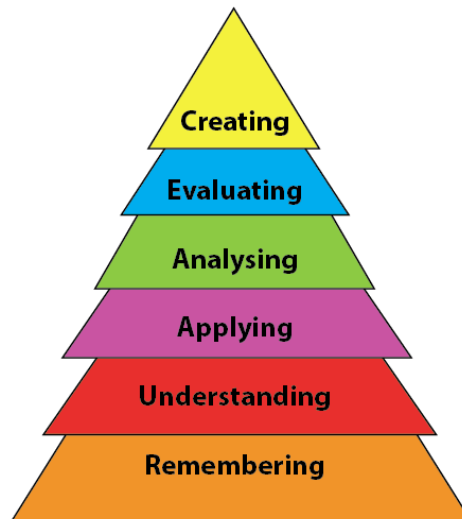


Figure 11: The dimensions required in the cognitive process as defined by Bloom. Taken from (Forehand, 2010).

Bloom also identified four specific types of knowledge: factual, conceptual, procedural, and metacognitive (Krathwohl, 2002):

- Factual knowledge is defined as basic knowledge that is required to understand terminology and details.
- Conceptual knowledge is being able to understand how individual elements may work together in a larger more complex structure.
- Procedural knowledge is an understanding of how to apply appropriate procedures / methods to solve a problem.
- Metacognitive knowledge is about being aware of one's own knowledge and limits.

These different dimensions of knowledge can be integrated with the different processes of learning on to a 6x4 table. Course designers can then map out the learning objective of a course and identify what kind of knowledge/processes the students might gain by completing a specific learning objective **Figure 12**.

The Cognitive Process Dimension						
The Knowledge Dimension	1. <i>Remember</i>	2. <i>Understand</i>	3. <i>Apply</i>	4. <i>Analyze</i>	5. <i>Evaluate</i>	6. <i>Create</i>
A. <i>Factual Knowledge</i>	Objective 1					Objective 3
B. <i>Conceptual Knowledge</i>		Objective 2			Objective 4	Objective 3
C. <i>Procedural Knowledge</i>						
D. <i>Metacognitive Knowledge</i>						

Figure 12: Bloom's taxonomy table on learning. Example of how learning objective can be mapped onto Bloom's different dimensions of processes and knowledge, to help identify weak learning objectives that do not encourage higher learning. Taken from (Krathwohl, 2002).

Writing Learning outcomes are now commonly called Intended Learning Outcomes (ILOs), and writing these is a skilled process aimed at developing the active high-level cognitive processes defined by Bloom.

Feedback

Feedback is vital in helping students develop into independent learners and is an integral part of any course (Swanwick, 2010). A commonly used method of giving feedback is Pendleton's method. There are four steps to this model: first, students are asked to described the positive points of their learning experience, the tutors then feedback their views on the positive points, the students then describe what they felt could have been done better, followed by the tutors' feedback on how things could be improved. This model of feedback is designed to encourage reflective thinking in the student and help them identify areas of deficiency and evolve a plan with the tutor on how to tackle those deficiencies (Cantillon and Sargeant, 2008). But it has been suggested that the Pendleton's rules for feedback is too rigid and many students may have become so familiar with its structure that they will focus most of their attention on the inevitably "bad points" which always follow the "good points", thus reducing the effectiveness of the feedback process (Carr, 2006a).

Regardless of how feedback is done, having a structure to the feedback process is vital and must be considered when designing any educational intervention. A

recent meta-analysis of education research into formative feedback concluded that as long as the feedback is targeted, objective, focused and clear, student learning can be improved (Shute, 2008).

Therefore, for this project, I will try to integrate the feedback process into the learning resources developed. Given that the educational interventions developed for this project will be multifaceted, it is unlikely that a single feedback method will be valid to cover all the resources developed. Therefore, feedback will be sought using individual tools developed specifically for each element of the educational intervention.

Current teaching methods utilized in postgraduate medical education

When developing any adult educational resource, numerous factors must be taken into account. These include theories on how adults learn, ensuring that the learning content is in keeping with the overall curriculum, developing learning objectives to ensure students gain the relevant type of knowledge and ensuring a method of feedback is in place.

However, it is not always easy to convert educational theories into practice and financial constraints, time pressures, and patient safety concerns all have to be considered in real life environments.

Adult learning resources

In this section of the thesis, I will consider what educational resources are currently available to doctors and consider new resources which could improve education in the clinical environment.

Traditional teaching methods

Undergraduate teaching usually takes place in a mostly formal and structured setting, with well-defined curriculums, assessment methods and normally supervised by one institution. Postgraduate teaching however, takes place in a much more challenging environment. Trainees often move between trusts, trusts have to balance delivering training opportunities with providing a clinical service, the criteria for assessments often change on a regular basis and even organizations which are responsible for monitoring education at the national level are subject to reorganization (SEVERS and CRANE, 2000, Tooke, 2013).

Traditionally, postgraduate education has taken place in several different settings:

- Formal 'grand round' (GR) presentations are common to nearly every hospital; during these presentations, trainees have the chance to present local audits or research projects to the entire hospital community. Traditionally GRs have formed the basis of hospital-based education, however in recent years, their educational value has been challenged.

In 2003 Hebert *et al* sent out questionnaires to nearly 400 hospital directors in the United States of America in an attempt to try and understand how GR were been carried out (Hebert and Wright, 2003). Questions asked included how often GR occurred, what the contents of the meetings were, if there was any audience engagement or any test for change in knowledge and the cost of holding GR meetings. Hebert found that nearly all hospitals had weekly GR meetings, but only 17% of meetings attempted to assess knowledge of the audience in any way, and only 60% of presenters were given specific instructions on what learning objectives should be covered by the GR meeting. 78% said GR meetings was also the most expensive educational event for the hospital and on average most clinicians could only attend 50% of GR meetings organized. Hebert concluded that GR meetings needed to be better organized as to improve their educational content, especially given their expense.

More recently, Van Hoof *et al* studied how grand rounds were planned and carried out in a single hospital (Van Hoof et al., 2009). Van Hoof found that whilst the organiser of the GR program was keen to include elements of assessment, interaction and integration with other educational resources, very little of these elements were ever delivered in the sessions. It is unlikely GR meetings will disappear or be replaced from the hospital setting, but their learning content and method of delivery could be improved greatly.

- Educational courses/sessions that take place away from the clinical environment are becoming ever more popular.

These sessions offer many advantages over more traditional hospital based education programs. In particular, because the training takes place in a comfortable, non-work environment, trainees are in a better mind-set to take aboard new information. The importance of having a relaxed learning environment is heavily emphasized in the theory of Andragogy (Knowles, 1973). These external sessions also give educators more freedom to carry out more flexible lesson plans and make use of new technologies.

The best examples of these sessions are the Advanced Life Support (ALS) course and Advanced Trauma Life support course (ATLS). These have been so successful, that taking part in these courses has now become mandatory in most hospitals in the UK (Carmont, 2005). So successful is the format of the ATLS/ALS courses, that my local trust (University Hospitals of Leicester) has started a dedicated education program for junior doctors based on ATLS/ALS structure known as the Care of the Critically Ill Medical Patient (CRIMP) course. The CRIMP course aims to improve education of common medical emergencies and is an ideal platform to deliver educational content on AKI.

Problem based learning/Experiential learning

So, it appears that although resources currently exist for postgraduate educators, many are not been exploited to their full potential. The most successful external courses, such as the ATLS/ALS course, makes heavy use of a concept known as 'problem based learning' (PBL).

PBL techniques have been developed based on constructivist learning theory. PBL aims to stimulate a student's interest on a certain topic; students are then encouraged to explore the topic and allowed to construct their own knowledge through discussion amongst peers, with minimal guidance from a tutor. However, there are risks with PBL; too little tutor engagement with students and incorrect

knowledge may be constructed, but too much engagement and the benefits of PBL is lost, as students lose the ability to develop their own understanding of the problem (Hendry et al., 1999). In addition, a review regarding the effectiveness of PBL educational programs in the postgraduate setting came to the conclusion there was only limited evidence that PBL is more effective than other methods of teaching, however, a lack of high quality research on the topic limited the power of the review (Smits et al., 2002).

Following on from PBL, a similar learning style is known as 'Experiential learning' (EL). EL can be described as 'learning by doing'. The learning event is structured around a real life activity that the student takes part in. The idea is that the students learn from their experience in an organized manner. Tutors closely monitor the students during the activity and then give them a chance to evaluate the activity, as well as providing feedback (Gentry, 1990). The initial activity could be staged or indeed be a 'live' situation; regardless of the setting, crucial to the success of the EL technique is the ability of the tutor to monitor, guide and provide feedback to the student, so that reflective learning can take place. In a way, the informal 'apprenticeships' style of learning that currently occurs in clinical medicine is similar to EL (Swanwick, 2005), but without the rigid guidance and feedback.

PBL/EL are not without criticism though. Critics argue that the effectiveness of PBL/EL is often over stated and not backed by evidence. Kirschner argues that the human mind relies heavily on long-term memories, which are often accessed unconsciously, and for any learning to be effective, the information must be incorporated into the long-term memory. This process is complex and involves higher cognitive engagement and close guidance in order to ensure that the correct knowledge is assimilated, a process that PBL/EL struggles to achieve, and in fact may lead to incorrect knowledge being assimilated due to lack of guidance (Kirschner et al., 2006). Regardless of the arguments surrounding PBL/EL, it offers another potential way for us to engage clinicians on the topic of AKI.

Electronic learning resources

As a result of decreasing cost of equipment, electronic communication tools such as the internet (world-wide-web) has revolutionized global communications. In the last two decades, it is estimated that computer usage worldwide has increased by over 50% annually since the late 1980s (Hilbert and López, 2011).

In theory, modern technologies allow for the creation of learning resources that have all the desirable attributes as set out by many educational theories. For example, the developers of Moodle, one of the most widely used 'Virtual Learning Environments' (VLE) platforms, place much emphasis on how the platform can be used to develop VLEs that support learning based on constructivist theory (Moodle, 2013). Over the last decade, VLEs have now become integrated into most undergraduate and higher education institutions.

Although the use of newer technologies such as VLEs are now common place in most undergraduate institutions (Browne et al., 2006), a recent survey of junior doctors in Scotland showed that none mentioned having been exposed to any new technologies to help improve their training experience in the postgraduate setting (Kendall et al., 2005).

A more recent survey on technology usage by doctors was carried out by Sanders *et al* (Sandars and Schroter, 2007). Nearly 6000 emails were sent to clinicians electronically, with a 21% response rate. Though a large percentage of responders had used technologies such as social networking applications and podcasts outside of the professional environment, less than 10% thought that they would want to use such technologies in a professional manner, in order to improve their training. Interestingly, the article showed how senior educators perceived the potential of new technologies very differently from junior doctors. Whilst junior doctors reported they used podcasts more than consultants outside of work, more consultants felt podcasts could be useful for delivering training compared to junior doctors. The reasons for the lack of engagement with newer technologies were multifactorial, including a perception that existing resources were already good

enough, a lack of good quality educational material developed using newer technologies and problems with a lack of technological infrastructure at work.

Mike Larvin recently reviewed the current provision of electronic learning (e-Learning) resources for surgical trainees in the UK (Larvin, 2009). He concluded that e-learning resources have the potential to improve the training experience of doctors. But high quality resources must be developed and these must be linked to other resources, since different trainees have different learning styles.

Spedding et al (Spedding et al., 2013) recently reported how a blended learning environment, which included a VLE, was used by postgraduate trainees working in the Accident and Emergency department. The project used the VLE to deliver educational content in a constructivist manner. A senior clinician lead case-based discussions through the VLE on a weekly basis and learning resources were made available on the VLE for trainees to explore at their own pace.

The authors concluded that (Spedding et al., 2013):

“A blended approach to e-learning in basic paediatric emergency is effective and enjoyable to trainees.”

This conclusion was based on semi-structured interviews that were carried out to gauge feedback from trainees, but these followed a very positive trend of questioning and trainees reported statements such as below when asked if they valued the way the learning resources had been delivered in the project (Spedding et al., 2013):

“Yes, certainly. Computers and technologies are there to be used. Having the backbone and structure that trainees can refer to at an easy point of access and then having further face-to-face teaching, that will be the norm”

Though feedback from the students was on the whole positive, the project required dedicated input from senior clinicians on a weekly basis. There was no direct comparison of how effective the e-Learning resources were compared to more traditional methods, so it remains unclear if the e-learning resource was any

more effective than an equivalent traditional teaching program with consultant input on a weekly basis.

So it would seem that e-Learning resources could be effective when used in combination with other forms of teaching and bring benefits to students by allowing them to access learning resources at anytime/anywhere, as well as allowing course tutors to develop learning resources which are engaging. But in order for the resource to be effective, it must be developed to a high standard and be based on sound learning theories.

Measuring the impact of educational interventions

Assessments are a vital part of ensuring learning. However, a balance must be struck to ensure that learners don't just focus on learning for the purpose of passing assessments, but instead, assessments should be seen as a chance to engage and develop learners. But in the context of clinical medicine, assessments are vital to ensure that doctors reach a set 'minimal' standard by which they are deemed to be safe to practice and will not put members of the public at risk by their actions.

Though various assessment tools have been developed over the past decades, it is recognized that there is no single best way to measure clinical competency, but regardless of the tools used, reliability and validity are important considerations.

Reliability is how accurately the test can be reproduced and classed as either inter-rater (i.e., do different raters/examiners produce the same results for the same student) or inter-case reliability (i.e., does the exam deliver the same results each time a student of the same ability takes the test). Developing standardized assessment tools or giving assessors more time and clear instructions can improve reliability.

Validity is how effective the test is in measuring what is being tested (i.e., do the results of the test correlate with the true performance/knowledge of the student). This is more difficult to achieve in clinical medicine, since many different dimensions of knowledge are required to perform certain clinical tasks, and a single test may only be able to test one part of the decision making process (Vleuten, 1996).

To help the evaluation process Donald Kirkpatrick described four key areas consider in any evaluation setting. These has become known as Kirkpatrick levels (Kirkpatrick, 2006).

These levels are described below:

1. Reaction: This is a measure of participant satisfaction with the educational program. Though this is easily done via simple questionnaires it doesn't give any indication on how the program might have changed behavior or affected performance.
2. Learning: Validating what was learnt usually requires assessment of post education knowledge. Standard assessment tools include multiple-choice questions, but knowledge doesn't always translate to better performance. It has been shown that scoring well in the United States Medical Licensing Examination exams doesn't guarantee better performance in more focused training assessments (Black et al., 2006).
3. Behavior: A well-executed education program should change the behavior of the student over time. This change in behavior should reflect the new knowledge learnt by the student, and be sustained. Measuring change in behavior is difficult and often requires close observation of a student's behavior over time.
4. Results: The ultimate aim of any education program in healthcare is to improve clinical care. Given the complex nature of patient care, it is often difficult to measure how healthcare outcomes have been effected. However this dose not mean educators shouldn't attempt to create a robust evaluation tool that can help them better understand the impact of an educational program (Hutchinson, 1999b).

Similarly Miller also developed a conceptual model to try and define how different assessment tools could be used to assess validity, known as "Miller's Pyramid". The ultimate goal of any assessment tool is to try and accurately capture knowledge at the top of the pyramid **Figure 13** (Wass et al., 2001).

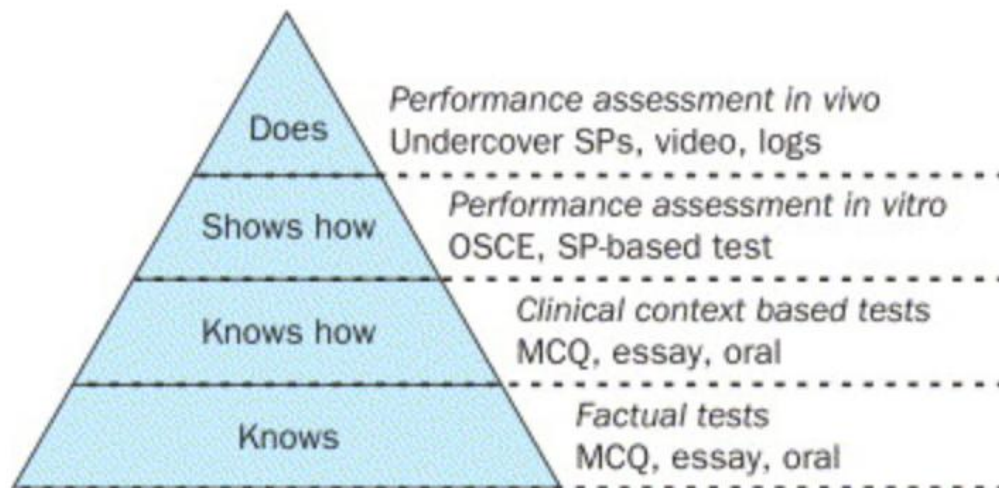


Figure 13: Miller's pyramid of competence. Example of how different assessment tools reflect/test different dimensions of knowledge. Taken from (Wass et al., 2001).

SP=simulated patients; OSCE=objective structured clinical examination; MCQ=multiple-choice questions.

In the following section of the thesis, I will now review the most relevant literature on the topic, as well as consider what assessment tools may be suitable for this project.

Surveys

Surveys present an attractive tool by which knowledge and behaviour can be assessed. It has been demonstrated that a short 21-question survey aimed at newly qualified doctors on CKD is powerful enough to discriminate levels of knowledge (Agrawal et al., 2009). Agrawal *et al* showed that the mean scores of newly qualified doctors was significantly lower than the scores of more senior doctors, and this difference was most significant in questions around risk factors, diagnosis and complications of CKD, suggesting that even a short survey may be a valid way to assess knowledge on AKI.

Surveys can also be used to assess self-perceived behaviour and knowledge of doctors; however the validity of results is not entirely clear. Curry and Purkis looked at how prescription habits of physicians changed after an educational program (Curry and Purkis, 1986). After receiving education, physicians were

asked to evaluate the course straight away, and then 2 months later, asked to evaluate how they perceived the course had changed their practice. The prescription habits of the physicians before and after the educational program were compared. It was noted that physicians did appear to change their prescription behaviour in line with their own perceived changes in practice. However, the overall sample of the group was small (n=16), and despite changes in specific aspects of prescription practice, overall analysis showed no changes to generalized prescription practice.

Young *et al* examined the relationship between self-perception of knowledge against an objective marker (Young et al., 2002). Young asked 50 qualified doctors on their perceived confidence in defining a series of specific medical terminologies. The doctors were then asked to explain the terminologies to an interviewer, who graded their response according to a pre-defined mark sheet. Young found that even those who perceived themselves to fully understand the terminologies failed to score highly against the mark sheet. However, Young concedes that the terminologies used in the study were very research specific and many doctors had a good understanding of them but simply did not use the specific phrases that were set out in the mark sheet.

These studies show the problem with simply using self-perception as guides to effective education. In addition, all surveys are prone to non-response and self-selection bias.

Templeton *et al* (Templeton et al., 1997) looked into the effect of non-response bias on survey results. Templeton approached General Practitioners (GP) who had not responded to a national postal GP survey on the topic of alcohol misuse and requested telephone surveys with them. Templeton then compared the results of the telephone survey with the national postal survey and found differences in responses between those who had completed the national postal survey and those who didn't reply to the national postal survey but did complete the telephone survey. Even though the original postal survey had a 44% response rate, Templeton demonstrated that there was still evidence of non-response bias

present. Interestingly, those who replied to the telephone survey were much more confident in dealing with alcohol misuse compared to those who complete the national postal survey the first time round, suggesting that the rate of response to a survey may be related to how relevant the survey topic is to the clinician's daily activities and their own confidence on the topic.

Surveys can also be used to help assess patient knowledge and confidence in CKD. Finkelstein *et al* surveyed the knowledge of 2000 patients with CKD in the United States of America (Finkelstein et al., 2008). Just under 700 patients replied to the survey and over 30% of the patients reported that they had no knowledge regarding any form of renal replacement therapy, despite more than 65% of patients having been under the care of a Nephrologist for more than 1 year. Patients who had seen a Nephrologist more than 4 times in one year and patients with the worst forms of CKD were more likely to report increased knowledge about their disease. The reasons for the poor perceptions on knowledge were unclear, because patient knowledge was not directly tested; it may simply be because patients didn't perceive they had the knowledge, when in fact they did. It may also be possible that patients were given information but failed to retain or understand it. This study shows the difficulties involved with interpreting results of what seems like a straightforward survey.

Never the less, surveys remain a popular tool to gather data on knowledge, and if done correctly, can produce valid results. I will try to ensure that any surveys carried out in this project have a high completion rate, in order to reduce the problem of bias.

MCQ

Traditionally, Multiple Choice Questions (MCQs) have been seen as a good way to produce reliable data, however, MCQs may not be valid in testing appropriate dimensions of knowledge, since better factual knowledge does not translate to better clinical performance. Despite these limitations, MCQs in a single best answer

format (SBA) is one of the most widely used forms of assessment in clinical medicine.

Writing MCQs can be tricky; questions should be clear, concise and where possible, linked in with a management plan. Questions written in the format of real life 'clinical cases' have a higher chance of engaging deeper thinking. The cases should be set in a realistic manner, where students are given enough background information about the case to answer the questions, but this information should include both 'negative/irrelevant' information as well as the key content, in order to allow the question to discriminate between candidates who have a sound baseline of knowledge and those who do not (Schuwirth, 1999).

One way to improve the validity of MCQs is to ensure that an 'exam blue print' of important concepts is drawn up and questions are then developed to ensure that all points of the blue print are covered. Peer-review of the questions is vital to ensure the wording and phrasing of the questions remains consistent in meaning across different peer groups. Post-hoc analysis of the questions is also important to determine the difficulty level of each question and if needed, prompt a review of certain questions (Sadaf et al., 2012).

An example of how MCQs are used in the assessment of clinicians can be seen in the way the Royal College of Radiologists implemented SBA MCQs to replace True/False MCQs as part of the assessment process towards gaining a certificate of completion of training in Radiology in 2006. It was found that the SBA MCQs had better power in predicting which candidates would pass the overall assessment compared to the previous True/False MCQs (Tan and McAleer, 2008).

So, although MCQs can be limited in the dimensions of knowledge they test, when developed appropriately, they remain a relatively efficient and reliable way to assess clinicians. For the purpose of this project, we will use the guide produced by the GMC to write a set of SBA MCQs to assess knowledge about AKI (JCIE, 2012). To improve validity, the MCQs will be reviewed by a group of senior clinicians with experience in MCQ question writing before dissemination.

Work based assessments

As alluded to earlier, the medical curriculum for junior doctors has evolved from being fact-driven to being more focused on personal development. This has also triggered a change in the way junior doctors are assessed. Rather than using a summative knowledge based exam, junior doctors are now encouraged to take charge of their learning and demonstrate their knowledge by using work based assessments (UK Foundation Programme Office, 2012). These assessments are designed to offer a chance for junior doctors to receive direct formal feedback from senior colleagues in a manner that was previously not possible (Carr, 2006a). As well as a learning opportunity, a record of these sessions can be used as 'evidence' of learning and progression through the curriculum.

It has been shown that the tools used for work based assessments, such as the 'Mini-clinical examination tool' (MiniCex) are valid in discriminating levels of knowledge, however, due to the subjective nature of the feedback given by different individuals, the reliability of the tool is harder to assess. Never the less, overall, both students and tutors find work based assessments satisfactory when they are carried out in an organized manner (Lima et al., 2007).

So, it would seem that various options exist on how to assess the effect of an educational program, though none are perfect. Different assessment tools are useful in different settings, for example, MCQs can be used to assess factual recall, but direct observation will be more appropriate when trying to assess how clinicians actually perform in clinical scenarios. Increasingly, it has been recognized that a portfolio of evidence collected through different assessment tools may be a more valid way to assess the impact of training/education than any single method alone (Cox et al., 2007). Therefore, I will use a range of different assessment tools in this project and collate the results together, in order to better understand the effect of the educational resources developed.

Current education program on AKI

The NCEPOD report showed that 30% of patients with AKI were initially seen by a doctor with less than 48 months of experience, and less than 20% were seen by a senior trainee or consultant level doctor at the time of presentation **Table 3**.

Grade of Doctor	Number of patients
FY1	101
FY2	83
SHO/ST 1-2	257
SPR/ST3 or higher	79
Consultant	11

Table 3: NCEPOD report showing the grade of doctor undertaking the initial clerking. Taken from (Stewart, 2009). FY1 = Foundation year 1, FY 2 = Foundation year 2, SHO/ST = Senior House Officer/Specialist trainee year 1-2, SPR/ST3 = Specialist registrar/ Specialist trainee year 3 +.

Therefore, it would seem logical that any educational intervention aimed at improving care for patients with AKI, should target junior clinicians as well as senior ones.

The current curriculum for FY doctors does not specifically refer to AKI, but covers the management of patients who are actually unwell. The introduction of the European Working Time Directive (EWTd) in 2009, where working hours were limited to 48hours per week, has caused concern amongst trainees and trainers. In particular, there are concerns that junior doctors are no longer gaining enough exposure to certain clinical cases, and the introduction of complex shift patterns to ensure working hours now comply with new regulations is having a detrimental impact on education/supervision (Cairns et al., 2008).

I only found 1 piece of published literature on AKI education. A recently published single centre study from Ulster used a checklist approach in conjunction with an

educational program to increase awareness of AKI in targeted clinical areas (Forde et al., 2012). The Nephrology team made regular visits to target areas to increase awareness of AKI, as well as answer questions and gain feedback about the AKI checklist. Through this intensive education program, the team was able to improve recognition of AKI. However, the project was implemented in a limited fashion and required continued input by the Nephrology team. It is therefore unclear how sustainable the project is in the longer-term. In the 1980's Rutz *et al* demonstrated that better education of clinicians on how to manage depression may be an effective way to reduce the use of tranquilizers and reduce suicide rates in the community, but 3 years post education, the improvements achieved had been eroded and outcomes returned to baseline (Rutz et al., 1992).

So, it is clear that there is a need for better provision of postgraduate clinical educational resources on AKI, which is the aim of this project. But whatever teaching resources I hope to develop for this project, it has to be sustainable in the longer term in the real world.

Summary

AKI is a serious medical condition, which is associated with significant mortality and morbidity worldwide. Though the exact diagnostic criteria for AKI are still been debated, the high mortality that is associated with AKI cannot be ignored. This means that action needs to be taken now to try and improve outcomes.

Here in the UK, it has been demonstrated that care of patients with AKI can be improved upon significantly, and although lacking evidence, current consensus suggests that ensuring basic management plans are carried out promptly, along with increased awareness may lead to better outcomes.

Education therefore may be a powerful tool in helping improve outcomes for patients with AKI. However, postgraduate educators face many challenges, including how to integrate new technologies with existing educational programs, how to develop new educational resources at a time when the NHS is facing severe financial constraints, as well as ensuring that the training needs of doctors are met without affecting clinical service delivery.

Whatever educational resources are developed, they have to be sustainable, easily implemented and have measurable outcomes.

2. Aims and Methods

Chapter overview:

In this chapter, I will provide a methodological overview of the project. A more detailed description on each individual aspect of the project can be found in their individual chapters later on in the thesis.

Aims

The aim of the project is to improve the knowledge and confidence of clinicians managing patients with AKI using a multifaceted education program.

The hypothesis posed by my project is as follows:

Education of doctors using a multifaceted education package on Acute Kidney Injury is effective at improving knowledge and confidence on the topic, as well as clinical outcomes.

The project needs several developmental stages in order to test this hypothesis:

- Deployment of an electronic identification system for patients with AKI in relevant clinical areas to allow a database of AKI patients to be developed.
- Assessment of baseline knowledge and confidence of doctors on the topic of AKI in the local area.
- Development and implementation of a theoretically driven education package based on recognized educational theories and supported by clear learning outcomes and objectives.
- Evaluation of the effectiveness of educational package using both qualitative and quantitative data.

Audience

The project took place at University Hospitals of Leicester (UHL) and Royal Derby Hospital (RDH), which serve a combined population of over 1.5 million. There is a

large number of medical staff based within these hospitals with approximately 320 FY doctors (less than 48 months of training) across both sites, and an additional 260 core/specialist grade trainees.

As a result of the large number of trainees and the large geographical area, the educational intervention was delivered by members of the project team within their base trust at UHL and RDH, details of the team members are provided in the next section.

The project was designed to run during one academic year (August 2011- August 2012) to ensure that doctors exposed to the education remained within the region at time of project evaluation.

We recognized that delivery of clinical care is often fragmented and that no one particular clinician would be solely responsible for the patient's care through their journey in hospital (Trebbles et al., 2010b). Therefore, we targeted all clinicians who have contact with patients, with a focus on FY doctors and other training grade doctors.

We were also aware that shift work and clinical rotations might mean that not all clinicians could be reached by the interventions planned; therefore we aimed to disseminate the interventions across a staggered time period and different geographical locations, in order to gain as much exposure to the target audience as possible. The educational intervention developed for the project aimed to overcome these barriers; in particular, development of a web based learning resource (WBL).

Project management/Funding:

Regular project steering group meetings were held during the entire project period to ensure good communication and uniformity in the way the educational resources were delivered and evaluation data collected. Meetings were arranged on a quarterly basis from June 2011 through to the completion of the project in August 2012.

5 different members of the project team outlined below carried out the work reported in this thesis:

Dr. Nick Selby (NS)	Consultant Nephrologist	Royal Derby Hospital (RDH)
Professor Sue Carr (SC)	Consultant Nephrologist	University Hospitals of Leicester (UHL)
Dr Rachel Westacott (RW)	Consultant Nephrologist	University of Leicester / University Hospitals of Leicester (UHL)
Dr Richard Baines (RB)	Locum Consultant Nephrologist	University Hospitals of Leicester (UHL)
Dr Gang Xu (GX)	Renal SpR and Education Fellow	University Hospitals of Leicester (UHL)

I (GX) was responsible for developing the project outline, development and delivery of the educational interventions, data gathering, data analysis, as well as carrying out the final evaluation of the overall project. Appropriate acknowledgements have been made throughout the thesis to other relevant members of the project team, where I did not make a significant contribution to the data reported.

Health Innovation and Education Cluster East Midlands (HIEC) provided financial support for the project. The HIEC group however had no influence on the design, implementation, results analysis or writing of the project.

Ethical considerations

Authorization to carry out this project was granted by the chief executive of the trusts **Appendix B**, and supervision provided by senior clinicians within the trusts. The project was carried out as a quality improvement (QI) exercise at UHL and RDH. The proposed project posed no threat to patients and fulfilled the criteria for QI as outlined by in the Healthcare Quality Improvement Partnership guidance, therefore formal ethics approval was not required (Dixon).

Educational interventions

The overall plan for the project is shown in Figure 14.

Because the project was carried out in a real clinical setting, we divided the academic year into three phases to allow for data analysis. Though we have defined a pre- and post-intervention phase, in reality, the educational intervention continued till the end of the project period Figure 15.

The separate project elements are listed below:

- Identification of patients with AKI and establishing baseline audit clinical measures and clinical outcomes.
 - **Pre-intervention phase**
- Measurement of educational knowledge pre-intervention.
- Development of the educational intervention tools.
 - **Intervention phase**
- Dissemination of the educational intervention.
 - **Post-Intervention phase**
- Measurement of educational knowledge post-intervention.
- Measurement of clinical outcome post-intervention.

Due to the complex nature of the project development and deployment, each educational intervention will be described briefly in this chapter, and then in more detail in their own separate chapters (**Chapters 3,4,5**).

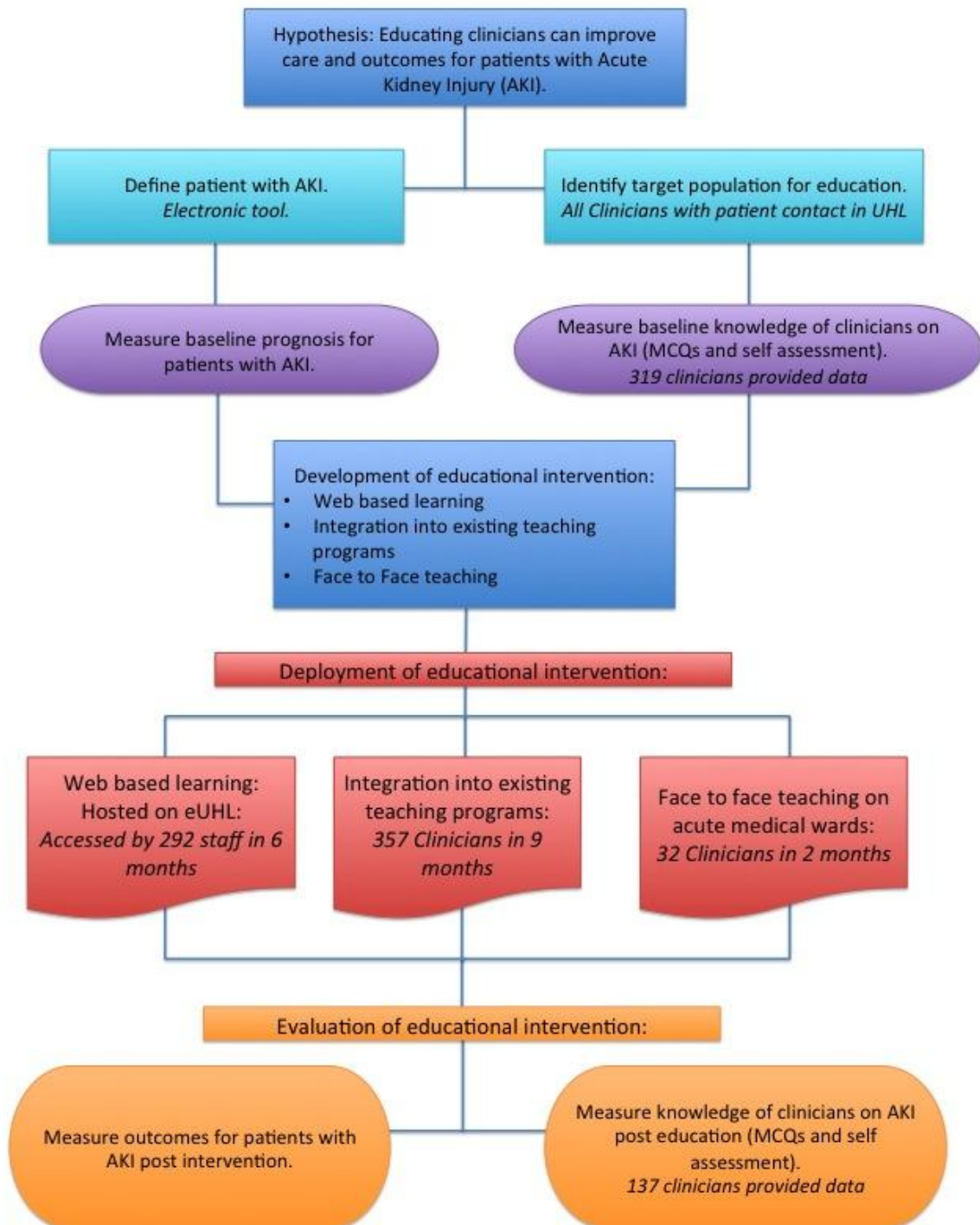


Figure 14: Flow Diagram showing the overall project plan.

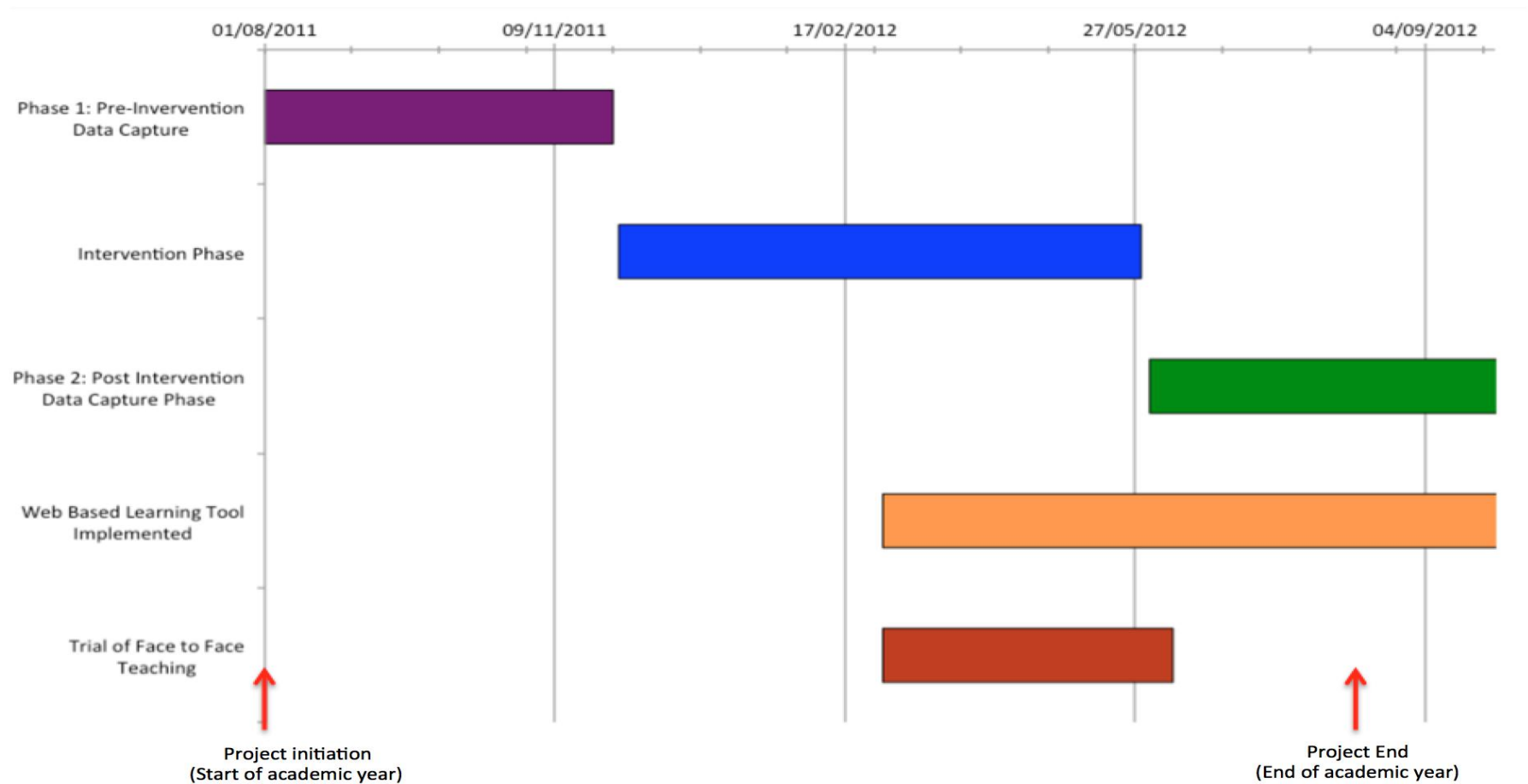


Figure 15: Schematic of project time line. Phase 1 of the project is defined as the Pre-intervention phase (August to December 2011); Phase 2 of the project is defined as the Intervention phase (December 2011 to June 2012); Phase 3 of the project is defined as Post intervention phase (June to July 2012).

Web based learning (WBL) resource

Development of the web based learning resource was carried out jointly between the project team at UHL (RW, GX, SC) and the Department of Clinical Educational team at UHL. Mrs Joanne Kirtley and James Trew provided the technical support and programming needed for the module. The resource was deployed at the end of March 2012, and remains available to UHL staff.

The details of the how the resource was developed and deployed is described **Chapter 3** of the thesis.

Integration of AKI teaching into existing education resources

Specific AKI education sessions were developed to integrate into existing education programs that already existed in UHL and RDH. In total, 21 teaching sessions on AKI were delivered between August 2011 and August 2012 in UHL and RDH. At least 505 clinicians took part in the sessions. The number of clinicians in each session varied between 4 and 48. Members of the project team delivered the sessions, all of who were experienced educators. The format of the sessions was pre-defined, with clear learning objectives and a lesson plan. Each session lasted between 45 minute and 1 hour. Clinicians had a choice not to attend sessions.

The methodology regarding the development of these sessions are covered in **Chapter 4** of the thesis.

Development of face-to-face teaching

The concept of using face-to-face interactions to increase engagement and provide feedback to junior doctors was trialled in this project. A member of the project team (GX or RW/RB) visited the medical assessment area at UHL every day for a trial period of 4 weeks during the project. The idea of the sessions were to provide

clinicians with an experiential learning experience, which would help them to solidify their knowledge on AKI, and to use work based assessments as a way to provide structured feedback to the students.

The findings of the face-to-face trial are discussed in more detail **Chapter 5** of the thesis.

Evaluation tools: Clinical

Deployment of electronic alert system/database

In order to evaluate the effectiveness of the project, first, a robust system needs to be developed so that patients with AKI can be identified and tracked.

Though the exact diagnostic criteria for AKI is likely to alter as our understanding of the disease improves, it is likely that the current guidelines that rely on measuring a delta change in serum creatinine and urine output, will remain unchanged. Dr Nick Selby (NS), a Nephrologist working at RDH has already developed a validated electronic alert tool that is compatible with the biochemistry computer system within UHL (Selby et al., 2012). It was agreed that this system would provide an acceptable level of accuracy with regards to diagnosing patients with AKI, and was implemented at the Leicester Royal Infirmary (LRI), the largest of three acute hospitals in UHL.

Each patient who had a serum creatinine carried out at the LRI had their result automatically compared to a theoretical baseline result creatinine generated using the reverse MDRD formula, assuming a GFR of 75ml/min. All results were then staged as either AKI stage 1, 2 or 3, using modified AKIN/KDIGO AKI guidelines. The diagnostic criterion used in the algorithm is outlined in **Figure 16**.

Each day the electronic alert system generated an automated list of patients whose creatinine suggested that they might have AKI. This list was then verified by the biochemistry team at UHL, who removed patient receiving chronic haemodialysis from the list, as well as ensuring that the label and staging of AKI was suitable given the biochemical picture presented. The final list of verified patients with AKI was then stored in a central database ready for processing **Figure 17**.

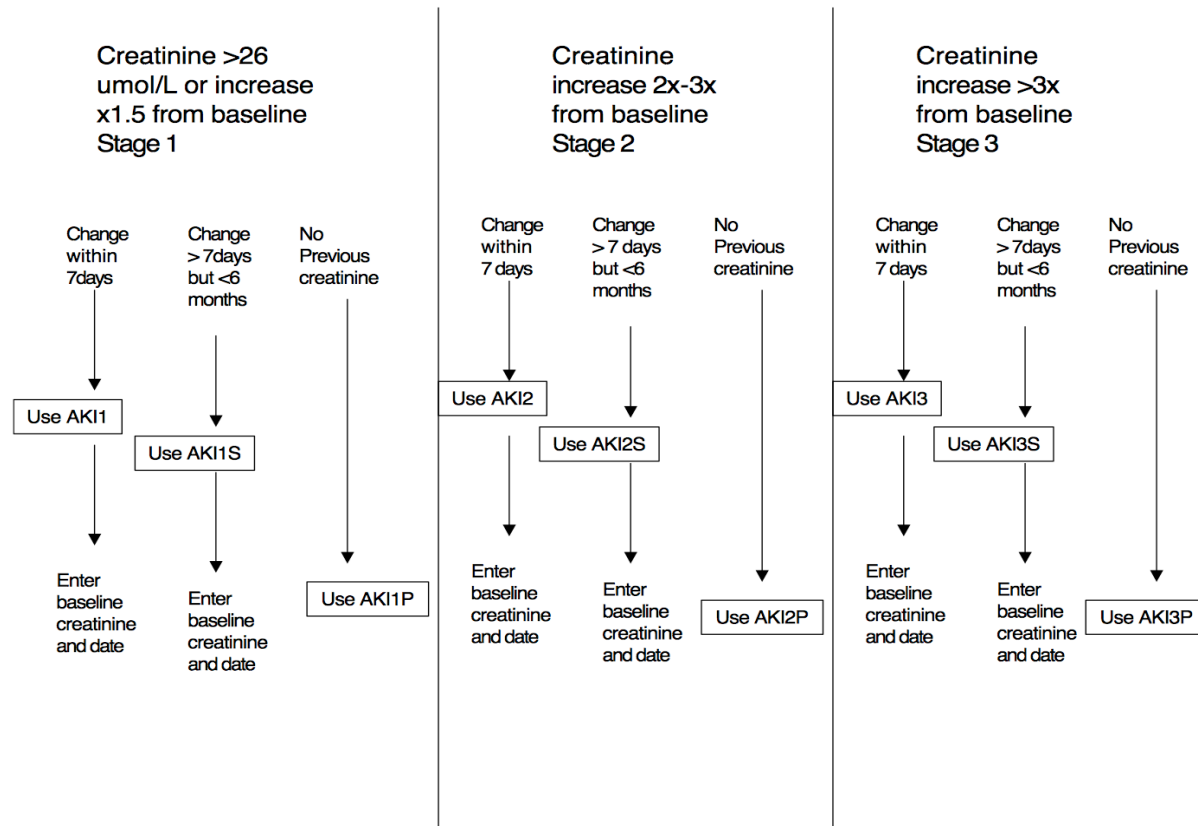


Figure 16: Diagnostic criteria for electronic AKI identification system. Based on KDIGO AKI guidelines.

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File Edit View Insert Format Tools Data Window Help

Type a question for help

A1

AKI results Stage 3

System Number	Surname	Forename	Date Of Birth	Location	Receive Date	Specimen Number	Test Code	Test Result	Current Status
1508/1941	ITU LRI		11/05/2012			CP139663S	AKDUM	3	11/05/2012
11/01/1930	Ward 22 LRI		10/05/2012			CP138005M	AKDUM	3	11/05/2012
11/01/1930	Ward 22 LRI		11/05/2012			CP139884A	AKDUM	3	11/05/2012
1508/1944	Accident and Em		10/05/2012			CP138549S	AKDUM	3	11/05/2012
11/2/1934	Emergency Decisi		11/05/2012			CP139841K	AKDUM	3	11/05/2012
11/2/1934	ITU LRI		11/05/2012			CP139959J	AKDUM	3	11/05/2012
11/01/1920	Ward 38 LRI		10/05/2012			CP138758A	AKDUM	3	11/05/2012
11/01/1920	Ward 38 LRI		11/05/2012			CP138298Q	AKDUM	3	11/05/2012
1508/1924	Ward 31 LRI		11/05/2012			CP138246C	AKDUM	3	11/05/2012
20/1/1928	Ward 37 LRI		10/05/2012			CP138761S	AKDUM	3	11/05/2012
15/12/1921	LRI WD Fielding J		10/05/2012			CP137227Z	AKDUM	3	11/05/2012
15/12/1921	LRI WD Fielding J		11/05/2012			CP139832B	AKDUM	3	11/05/2012
14/05/1925	AMU 15 Bal L5		11/05/2012			CP139784M	AKDUM	3	11/05/2012
19/04/1972	Accident and Em		11/05/2012			CP139684K	AKDUM	3	11/05/2012
14/01/1928	LRI WD 16 AMU B		10/05/2012			CP138658M	AKDUM	3	11/05/2012
20/3/1927	AMU 15 Bal L5		11/05/2012			CP139782T	AKDUM	3	11/05/2012
11/01/1943	Haematology OPC		09/05/2012			CP135742Y	AKDUM	3	10/05/2012
11/01/1930	Ward 22 LRI		09/05/2012			CP134178T	AKDUM	3	10/05/2012
4/03/1926	LRI WD 16 AMU B		09/05/2012			CP135963V	AKDUM	3	10/05/2012
4/03/1926	LRI WD 16 AMU B		10/05/2012			CP138776Q	AKDUM	3	10/05/2012
14/04/1971	LRI WD 30 HDU		09/05/2012			CP134305B	AKDUM	3	10/05/2012
11/04/1924	Accident and Em		09/05/2012			CP135866Z	AKDUM	3	10/05/2012
7/01/1944	Haematology OPC		09/05/2012			CP137025G	AKDUM	3	10/05/2012
15/12/1921	LRI WD Fielding J		10/05/2012			CP134388W	AKDUM	3	10/05/2012
14/05/1925	Accident and Em		10/05/2012			CP134448T	AKDUM	3	10/05/2012
1508/1925	AMU 15 Bal L5		09/05/2012			CP135707M	AKDUM	3	10/05/2012
1506/1939	Kinmonth Unit LRI		09/05/2012			CP136634W	AKDUM	3	10/05/2012
20/3/1927	AMU 15 Bal L5		09/05/2012			CP135974J	AKDUM	3	10/05/2012
20/3/1927	AMU 15 Bal L5		10/05/2012			CP134451N	AKDUM	3	10/05/2012
11/01/1930	Ward 22 LRI		08/05/2012			CP134570N	AKDUM	3	09/05/2012

Stage 3 Stage 2 Stage 1 No AKI

Figure 17: Daily electronic report of patients with AKI.

Dr Gang Xu

MD, Thesis, 2015

The system does have limitations; it does not include patients who had developed AKI based on their urine output, the system still required a manual operator to verify the list, and patients who had multiple creatinines carried out in one day were counted multiple times. However, despite these limitations the system did provide the basis for tracking patients with AKI in UHL for the first time, and was implemented in conjunction with deployment of the educational interventions.

Only data from patients who developed AKI at the largest hospital in UHL (Leicester Royal Infirmary) was captured. I was responsible for clinical data capture and analysis at UHL, while in RDH, NS was responsible for data capture and analysis. Given this thesis is primarily reporting on the work carried out by myself, the clinical data reported in this thesis is from UHL, unless otherwise specified.

The first database of AKI patients was compiled in February 2012 by the biochemistry team at UHL. The data set was then manually checked for accuracy by GX throughout the project period. For the project period, a database of AKI patients was produced from February 2012 till the end of July 2012.

The database was anonymised by GX, but the NHS hospital number preserved. This ID was then processed by the clinical audit department at UHL to obtain clinical outcome data, which included:

- Hospital ID
- Sex
- Date of Birth
- Date of admission
- Date of discharge
- Date of death (if applicable)
- Staging of AKI
- Ward/location origin of blood test

Patients who developed AKI on more than one occasion during a single hospital stay only had their most serious/worst incidence of AKI analysed.

Clinical audit of patient care

A clinical audit of patients who had suffered from AKI was carried out at the end of the project, using templates provide by a national body (NHS Kidney care). The audit was carried out by the UHL audit department, under guidance from GX. Due to the large number of patients with AKI in the project, there were not enough resources available to audit every patient with AKI. Therefore, randomly selected sets of clinical notes were audited. In total, 30 sets of clinical notes were audited after the intervention in July 2012. The results of the audit were compared with results of a previous audit on AKI care carried out in March 2011 **Appendix A**.

Only the definition of the below two audit criteria remained unchanged between the two audits:

- Renal ultrasound within 24hours of admission
- Documented evidence of urine analysis

All patients audited had AKI stage 3, as defined by the criteria set out in the project. Any cases with incomplete data were excluded from the audit analysis.

Evaluation tools: Education

Due to the nature of postgraduate training, no formal uniform summative assessments exists for the broad range of different clinicians who are involved in the caring for patients with AKI. Equally, it was beyond the scope of this project to devise a formal summative assessment on the topic. Instead, we have chosen to assess clinical competence using knowledge based MCQs and self-assessment questions. By triangulating the results of different assessment tools we aimed to increase the validity of our findings to try and demonstrate the impact of the educational intervention (Hutchinson, 1999a).

Baseline survey on educational knowledge

Baseline surveys on educational knowledge were carried out during the 'pre-intervention' phase of the project.

The survey consisted of two stages (Full survey in **Appendix C**):

1. Self-assessment survey on AKI knowledge/confidence

Clinicians were first asked to complete MCQ questions including demographics data on their clinical experience and previous exposure to AKI education.

Clinicians were then asked to complete a survey containing 4 self-assessment questions on their own clinical behaviour when looking after patients with AKI. The questions were presented in the format of a Likert scale with clinicians given the choice options presented in visual form.

Each of the 4 questions asked the clinician to rate their confidence/clinical behaviour on one specific aspect of AKI management:

Questions 1,2,3

“If a patient under your care develops AKI how often would you consider it diagnosed?”

“If a patient under your care develops AKI how often would you initiate a basic management plan?”

“If a patient under your care develops AKI how often would you initiate further investigations?”

The options for the clinicians for these questions were:

Always

Almost Always

Often

Not very often

Rarely

Never

To enable more objective processing of results, the responses from the Likert scale were then coded into binomial responses, in keeping with recommended clinician behaviour according to national guidance on patients with AKI. This allowed us to analyse the results using Chi Squared tests. The answers for Always and Almost always were recoded ‘satisfactory practice’, and all other response coded as ‘could improve’.

Questions 4

“Are you confident in making a diagnosis of AKI most of the time?”

The options for the clinicians for this question was:

Yes

No

2. A series of 15 single best answer MCQs was designed to test knowledge on AKI. The MCQs were written using guidance from the GMC (JCIE, 2012). The MCQs were reviewed by all members of the project team to ensure they were of adequate quality before being finalised and included in the survey. SC and RW have previous experience of writing MCQ questions on behalf of the Royal College of Physicians Specialty Writing groups, for postgraduate MRCP part 1 and Specialty Certificate Exams.

The MCQs were designed to test the following domains of knowledge on AKI:

- Diagnosis – 4 Questions
- Clinical Findings/Investigations – 4 Questions.
- Clinical Management - 3 Questions
- Medications Management – 4 Questions.

The questions were written to reflect the important aspects of clinical care associated with AKI and where possible, set in relevant clinician context. To improve reliability, the MCQs were disseminated using Turning Point software (Turning Technologies, DA Hilversum).

Turning Point software allows the presenter of the MCQ survey to interact with the audience in a direct face-to-face manner, as well as allowing for live data collection and instant feedback of survey results to the audience (2012) **Figure 18**. Each member of the audience is provided with a wireless data pad (size of credit card) and when prompted, can register their answer to a question quickly and easily. This ensures excellent reliability in terms of data gathering and allows for accurate processing of results, with minimal chance of human error, in a quick and efficient manner **Figure 19**.

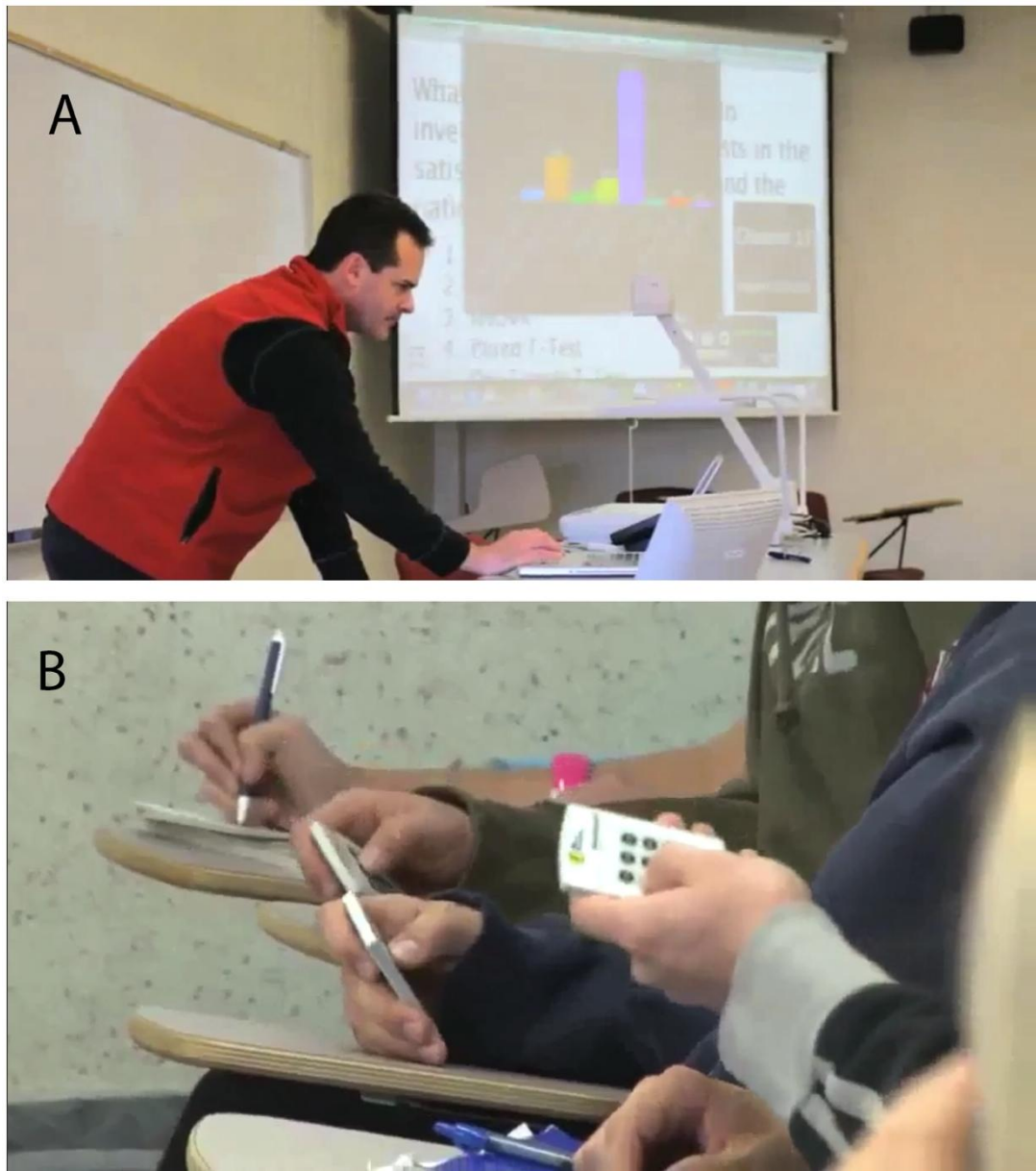


Figure 18: Turning Point in use. Example of live survey results being displayed in real time using Turning Point software (A). Survey participants are able to interact with the survey using ergonomically designed key pads (B) Taken from Turning Technologies promotional video (2012).

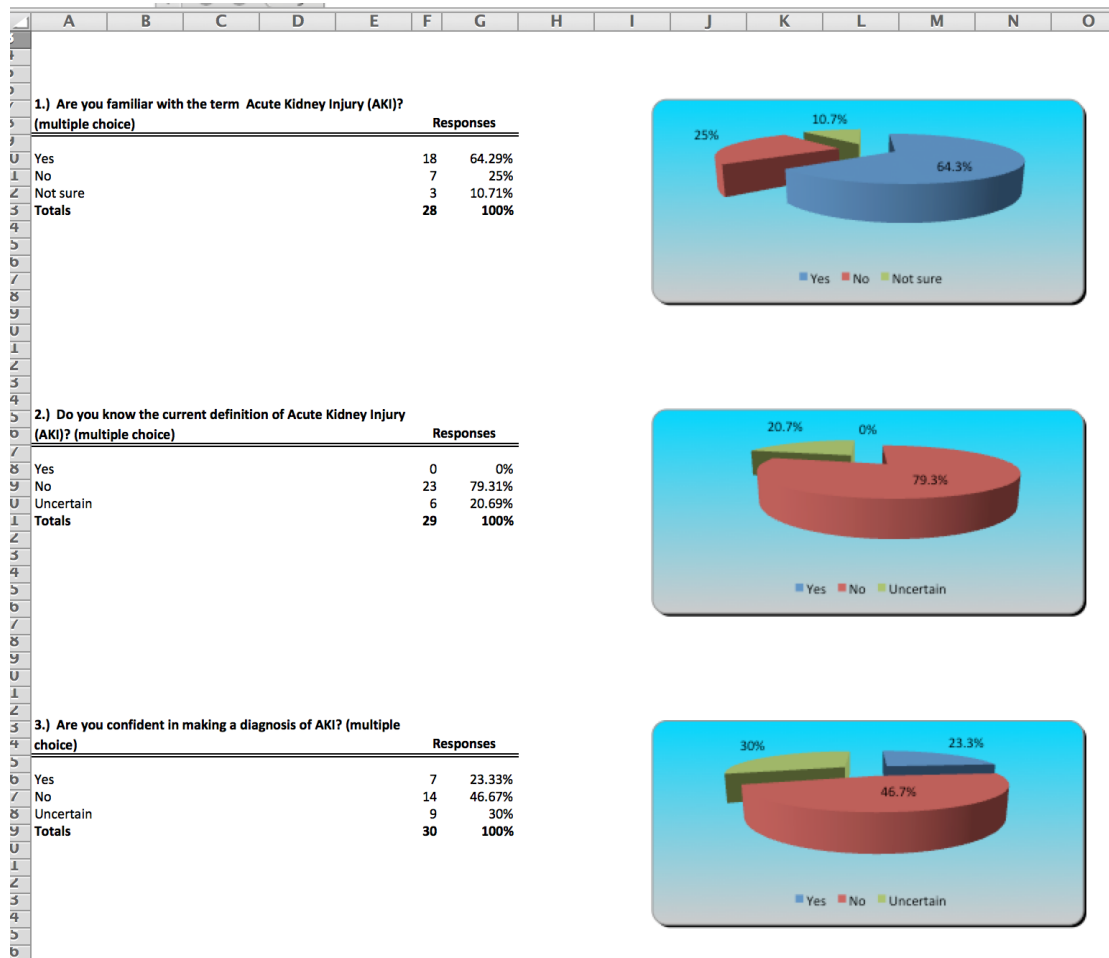


Figure 19: Survey data captured automatically and electronically using Turning Point software.

Because the Turning Point software allowed us to visualize instantly the confidence and knowledge of the audience on AKI, we could quickly adapt and tailor the subsequent educational session to the needs of the audience. This enabled us to maximize the educational benefit of the sessions delivered.

All the MCQ sessions were delivered to clinicians as part of the existing educational program provided by the trusts. The surveys were carried out as part of the educational session on AKI. The sessions were not compulsory and no formal record of attendance was kept. At the beginning of the session, we made clinicians aware that the data they provided was being used as part of a quality improvement project, and they could choose not to take part in the MCQ surveys if they wished. Those clinicians who chose not to provide demographic data on their clinical experience were excluded from data analysis. All data collection was anonymous.

The baseline surveys took place between August and December 2011, to coincide with the start of the academic year.

Post-intervention survey on educational knowledge

A repeat survey took place between June and August 2012 towards the end of the educational intervention.

This survey was carried out in the same format, using Turning Point software, but in addition, we asked if the clinicians had used the Web Based Learning resource on AKI.

The MCQs on knowledge in the repeat survey were altered, but the main question theme/stem remained the same, to ensure the same dimensions of knowledge were tested. The same number of questions was used in the final repeat survey. The full survey can be found in **Appendix D**.

Data analysis

For the survey data, an individual's entire responses were excluded from data analysis if no data about their clinical experience was provided. Where there was a non-response to a MCQ question on knowledge, the response was graded as 'incorrect' in the final analysis.

Results from the pre- and post-intervention questionnaires were compared. As the data was anonymised, an individual doctor's improvement between the two samples could not be assessed. This precluded the number of doctors who completed both questionnaires from being determined.

The data was analysed using a SPSS version 16 (IBM Software, NewYork). Chi Squared tests were used for categorical data and Independent t-tests were used to analyse continuous data sets. One-way ANOVA analysis was carried out for analysis on mean length of stay for different population samples. An alpha of 0.05 was deemed statistically significant.

3. Development of Web Based Learning resource (WBL)

Chapter overview:

In this chapter, I will describe the development and deployment of the web based learning resource.

The WBL can be accessed at:

<http://www.uhl-library.nhs.uk/aki/01intro.html>

Introduction

Postgraduate medical educators currently face several challenges when attempting to address the deficiencies in education and training. Introduction of the European Working Time Directive and the adoption of shift patterns has led to significant changes in the working patterns of trainee doctors (Lancet, 2010, Pickersgill, 2001). This has resulted in a reduction in the total number of hours of clinical experience a junior doctor now gains, as well as increasing fragmentation of the clinical team, making it increasingly difficult to deliver a formal education program (Temple, 2010). A recent review of postgraduate training identified that doctors need to be trained more effectively in a broader range of specialties, but at the same time more flexible training options need to be made available (Greenaway, 2013). Newer technologies such as simulation training and electronic resources have been suggested as a way to implement these changes (Temple, 2010).

The potential of web-based learning (WBL) tools and e-Learning resources to impact on postgraduate education is well recognized (Ruiz et al., 2006, Gordon et al., 2011). The effectiveness of WBL to transfer knowledge has been demonstrated in previous research studies carried out in controlled settings (Hadley et al., 2010, Gordon et al., 2011, Kulier et al., 2012).

Therefore, for this project we felt that developing a novel web-based electronic learning tool on AKI would be the perfect way to meet the educational needs of doctors in the postgraduate clinical setting, as well as developing a resource that is sustainable in the long term.

Pedagogical considerations

In order to be successful, it was vital that the WBL resource developed was based on sound learning theory. As previously described in **Chapter 1**, for this project we have chosen to use Malcolm Knowles learning theory specific to adult learners known as Andragogy (Knowles, 1973), as well as Constructivist learning theories (Lefoe, 1998). The purpose of the instructional tool developed was not simply to pass on factual knowledge, but to encourage students to develop an understanding of the topic and take into account their own past experiences.

With these principles in mind, we ensured that the WBL developed presented information in such a manner that allowed users to freely work through the tool at their own pace **Figure 20**. The resource delivers the learning content in the form of clinical cases; this ensures the learning material is relevant to the user. Each case is designed to encourage learning by discovery, and where possible, the data is presented in a format similar to how the user would see the information in a real life situation. Appropriate interactive segments were introduced to help improve user engagement **Figure 21**.

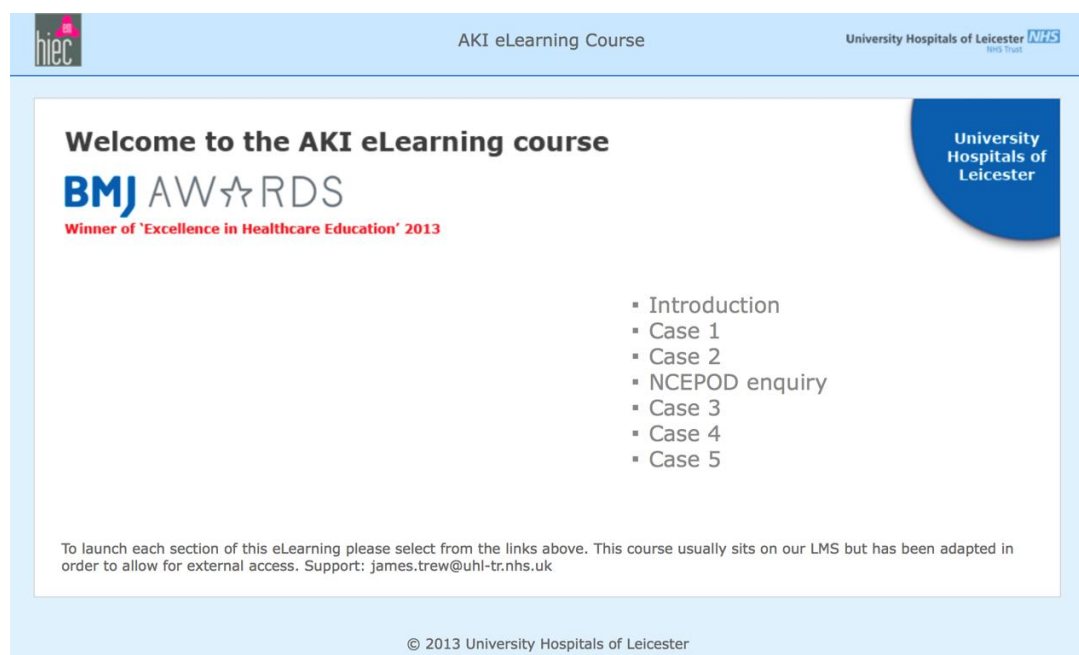


Figure 20: Web-based learning resource - Introduction to the tool is designed with constructivist approach in mind. Users are encouraged to work through cases at their own pace to help build on their understanding of the topic.

Case 1 - AKI Learning Module

University Hospitals of Leicester NHS Trust

Pleas
you

Biochemistry Haematology

S0102030 Peter Smith Age 56, Male
Outpatients Dept
Specimen No:CD123456A Biochemistry

09/11/2011 09:05 Serum

Sodium	126	mmol/L	(133 to 146)	Auth
Potassium	5.6	mmol/L	(3.5 to 5.3)	Auth
Urea	34.6	mmol/L	(2.5 to 7.8)	Auth
Creatinine	760	umol/L	(60 to 120)	Auth
eGFR (MDRD)	6	mL/min		Auth

Comments:
Multiply eGFR by 1.21 if Afro-Caribbean.
See www.emrn.org.uk website.

Glucose	5.4	mmol/L	(3.6 to 6.0)	Auth
Bicarbonate	18	mmol/L	(22 to 29)	Auth
Albumin	34	mmol/L	(35 to 50)	Auth
Adjusted Calcium	2.26	mmol/L	(2.2 to 2.6)	Auth
Inorganic Phosphate	2.58	mmol/L	(0.8 to 1.5)	Auth
Alkaline Phosphatase	158	iU/L	(30 to 130)	Auth
Alanine Transaminase (ALT)	38	iU/L	(2 to 53)	Auth
Total Bilirubin	7	umol/L	(0 to 21)	Auth
C-Reactive Protein	42	mg/L	(0 to 10)	Auth

■ Main menu

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Figure 21: Web-based learning resource – Visual cue. Each element of the resource is designed not to overwhelm the user with unnecessary interaction and present information in a format familiar to the user.

The layout and design of the resource itself was based on Cognitive Load Theory (CLT), ensuring that the users are given the maximum learning opportunity without being overwhelmed with information.

CLT is based upon our current understanding of human memory. When presented with new stimuli, we can only actively process a few elements of information at any one time, and the ability to recall these novel elements are limited (Miller, 1956). However, long-term memory developed through experience is not restrained in this way, but developing long-term memory requires repetition and rehearsal.

The ease by which novel stimulus is incorporated into long-term memory is partly dictated by how it is delivered and the impact of the content on the cognitive load. If too much information is presented at the same time, or if the way the information is presented is not optimal, the cognitive load can become overwhelming, and the students fail to assimilate the desired information. Three

main types of cognitive load have been suggested by CLT (Merriënboer and Sweller, 2005):

- The intrinsic load is defined by the nature of the learning objective. The only way to reduce the intrinsic load is to ensure the learning objectives are realistic and to break down complex tasks into small individual elements.
- Extraneous load is defined by the way the instructional tool presents new information to the user. Ensuring the design of the tool is optimised and presents information to the user in a logical manner helps to reduce extraneous load. Where suitable, different types of stimuli should be used to help ensure students are clear on how to complete the task at hand. However, care must be taken to ensure that visual cues or other stimuli do not distract the user from the information presented.
- Germane load is defined by how the already established long-term memory interacts with the new stimuli; this process is vital and seen as the last step in the learning process. Ensuring the information delivered is relevant and novel so that users have to engage deeper cognitive thinking is vital to this process.

We kept these principles in mind when designing the WBL.

Learning objectives

We used the principle of constructive alignment when developing the WBL to ensure our learning objectives matched those from the FY curriculum. We followed SMART principles (see below) for the development of the learning objectives, in order to design learning objective that will have an impact upon clinical practice (Reed et al., 2012).

The learning outcomes of the WBL resource were based on recommendations by the NCEPOD group, with a focus on increasing awareness of AKI and ensuring

appropriate investigations and management plans are carried out without delay. The target audience of the WBL was clinicians who manage patients with AKI. The learning objectives are described below:

Specific – The main aim of the project was to improve understanding of AKI. The specific learning objectives for these sessions were:

- 1: Identify patients who are at high risk of developing AKI.
- 2: Understand how to diagnose patients with AKI.
- 3: Understand the basic management principles of patients with AKI.

Measurable – We utilized two methods to measure the effect of the WBL (MCQ survey and e-mail feedback). We did not want to incorporate an assessment tool into the WBL as we felt this would detract from the learning experience.

Attainable – The learning objectives were designed to be realistic and achievable.

Relevant – AKI is a common clinical problem (incidence approximately 5% in both trusts).

Time-framed – The learning objectives are kept concise to ensure that they were achievable in a time sensitive environment. The WBL allows the user to 'pause' their progress through the tool and come back to complete the tool at a different time.

Resource development

Members of the project team (GX and RW), working closely with the clinical education department at UHL, designed the WBL over a period of 6 months.

We were keen to develop the WBL to take full advantage of advancing information technology (IT) resources (Bond, 1997). Visual stimuli has long been recognized as a way to aid learning and influence behaviour (Macklin, 1996), however current evidence on the benefit of using animated cues to facilitate learning is lacking (De Koning et al., 2009). We therefore chose to use simple visual cues to help prompt users to relevant information related to each case study. We were careful in ensuring that the information delivered was in small, easy to assimilate segments, so as to avoid cognitive overload **Figure 22**. The aim of the visual stimuli was to help reduce extraneous load, whilst the learning content of each section was to adjusted to avoid too much intrinsic load.

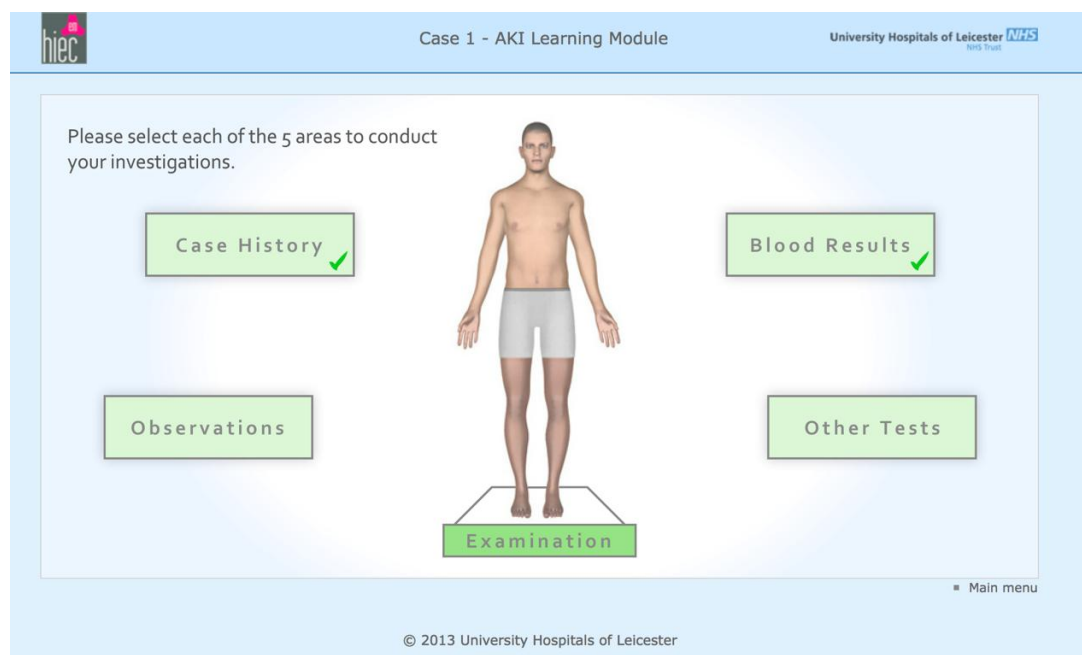


Figure 22: Web-based learning resource – Interaction. Example of how visual stimuli are used to engage the user and at the same time, guide them on the most suitable approach to assessing a patient with AKI. The interface is designed to be minimalistic to avoid distracting the user.

To help embed knowledge, each case builds on and repeats the important learning points from the previous case. As the user progresses through the cases, the complexity of the cases increases. Users with more prior experience can quickly skip over elements, which they are already with familiar with. We also ensured

that the intrinsic load is altered through out the WBL in order to avoid expertise reversal effect. This is when the intrinsic load does not change and the end user becomes distracted by the extrinsic load and very little new learning takes place.

In total, the WBL consisted of 7 segments, each of which was designed to take 5–10 minutes to complete, depending on the individual's prior knowledge. The user could choose to stop the WBL at any stage and save their progress after each segment; this allowed the user to return to the WBL at a later to stage to complete it.

Feedback

Feedback, when done correctly, has been recognized as one of the most powerful tools in enhancing learning. Effective feedback should help to guide students to recognize their weaknesses, whilst encouraging self-assessment and reflection (Swanwick, 2010). We were able to take advantage of modern IT resources and provide students with instant feedback on how well they are performing, through a number of formative multiple choice questions embedded into each case

Figure 23. These questions were designed to challenge users with complex clinical situations and encourage them to engage in higher cognitive thinking.

Feedback about the tool was sought using a 10-question web based survey, this was sent to all users who used the tool 1 month after the end of the project. The feedback tool included options for free text input **Appendix E**.

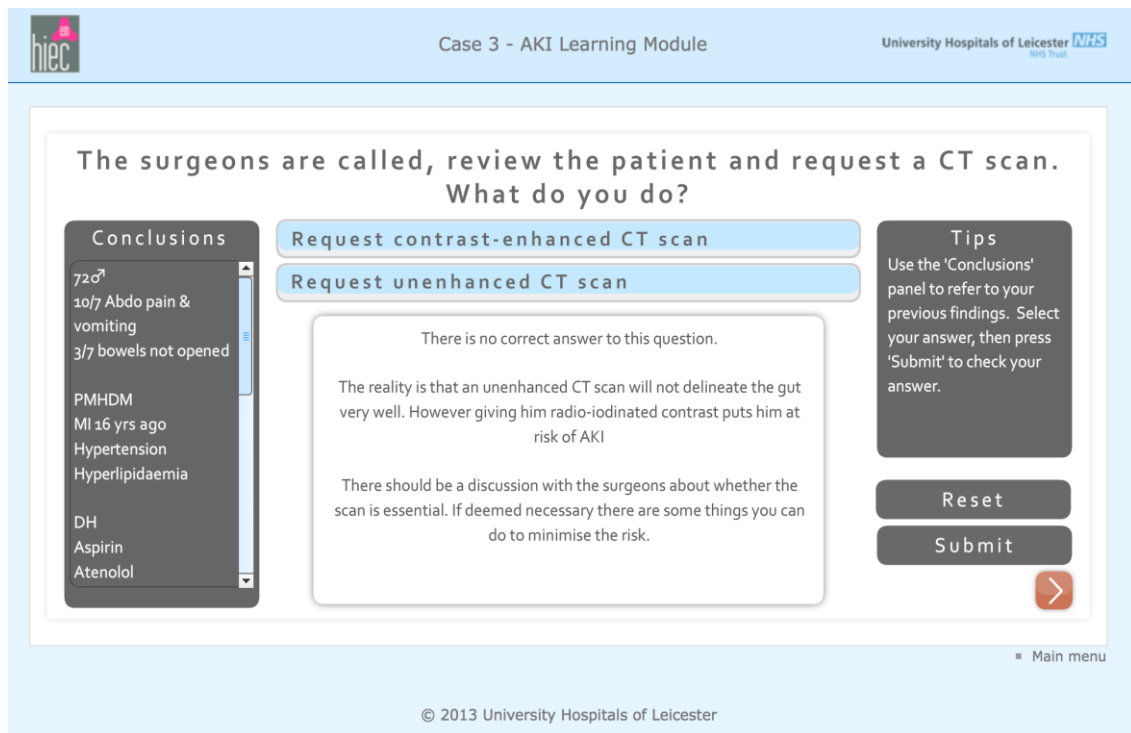


Figure 23: Web-based learning resource – Feedback. Example of a multiple-choice question presented to the user half-way through a case. Instant feedback is given to the user.

Analysis

In order to understand the impact of the WBL, we analysed the post-intervention MCQ survey on AKI knowledge and self-assessment **Appendix D**. I compared the results for those who said they had used the WBL, against those who had not used the WBL.

I carried out independent t-tests and Chi-squared tests to see if there was any difference in self-rated clinical behaviour and MCQ scores of those who used the WBL and those who did not. All statistical calculations were carried out with SPSS version 16.

Implementation

The tool was hosted on the UHL virtual learning environment (VLE) (<https://www.euhl.nhs.uk>), accessible to all staff working in the trust via the World Wide Web, and promoted internally via login-screen messages.

The tool was launched in March 2012 and its usage tracked till August 2012.

Foundation year 1 and 2 (FY) doctors working at UHL were sent e-mails about the WBL on 3 separate occasions during the implementation phase of the project. Because the number of FY doctors change due to natural work, the email were sent out by the deanery to ensure that all those. In-total 227 individuals were contacted by email. Usage and completing rate of the tool was tracked via the VLE.

Since the end of the project the WBL has remained active on the VLE, and can now be accessed at:

<http://www.uhl-library.nhs.uk/aki/01intro.html>

4. Integration into existing education resources

Chapter overview:

In this chapter, I will describe the development and implementation of the additional AKI educational sessions integrated into the existing educational program.

Introduction

As alluded to in the introduction of this thesis, existing teaching programs could be improved in order to maximize their educational value. For this project, specific lesson plans were developed to try and add educational value to these sessions with regards to AKI. These sessions formed an important part of the project, since it is recognised that in order for an educational program to be effective, they have to be sustainable in the long-term (Cantillon and Jones, 1999). As such, each of the sessions developed for the project were designed to be sustainable and incorporable into the existing educational programs.

Having well defined aims and learning objectives are the corner stone of lesson plans. The curriculum and learning objectives for the project were based upon the recommendations of the NCEPOD report into AKI (Stewart et al, 2009).

The broad key learning outcomes of these sessions are as follows:

- Improving awareness of AKI
- Understanding how to diagnose AKI
- Understanding how to investigate AKI
- Understanding how to manage AKI

The existing educational sessions at UHL and RDH comprised of 2 types of regular events:

1: Grand round teaching sessions – aimed at all doctors in the hospital.

2: Focused ‘protected’ teaching session for junior clinicians (FY and Other trainees) – specific to each clinical grade.

The learning objectives of each session were tailored to the target audience.

Grand round:

When developing the learning objectives and lesson plans, Knowles theories of adult learning and andragogic principles were kept in mind. An emphasis was placed on demonstrating the relevance of the topic to the target audience, in order to create engagement and motivation.

The learning objectives of these sessions aimed to give the target audience factual and conceptual knowledge, to ensure that the audience had the foundation knowledge needed to help motivate changes in practice and allow them to develop procedural knowledge on the topic, when accessing the other education tools (Krathwohl, 2002).

Learning objectives

S – Specific – The main aim of the project was to improve understanding about AKI. The specific learning objectives for these sessions were:

- 1: Understand high mortality and morbidity associated with AKI.
- 2: Understand how to diagnose patients with AKI.
- 3: Understand the management principles of patients with AKI.

M – Measurable – A Turning point survey was carried before the start of the teaching session to measure baseline knowledge: this was the baseline MCQ survey on AKI knowledge/confidence. The survey was repeated at the end of the project period, along with additional teaching sessions on AKI: this was the post-intervention MCQ survey on AKI knowledge/confidence.

A – Attainable – The learning objectives were designed to be realistic and achievable.

R – Relevant – AKI is a common clinical problem (incidence approximately 5% in both trusts); this was emphasized at the start of the sessions.

T – Time-framed – The learning objectives were kept concise and to a minimal, to ensure they were achievable during the 30-40 minute time frame of the session.

These sessions usually took place during natural breaks in the working day (often lunch time). There was a variation in the clinical experience, as well as the size of the audience. This required the team member delivering the session to use their experience and tailor the learning objectives for the audience; since it is likely that senior clinician would have more clinical knowledge than junior clinicians.

The lesson plan

Because of the large number of clinicians in each session and variations in clinical experience, the use of 'problem based learning' approach was felt to be inappropriate. Instead, the information was presented in a more traditional lecture-based format. The team were aware that traditional didactic lectures often provide only limited educational value (Davis et al., 1999) and therefore used the baseline/post-intervention MCQ survey on AKI knowledge / confidence as a way to increase audience engagement and interaction. Turning point handsets allowed for accurate, real time data capture, and allowed the tutor to adjust the lecture according to the response Figure 24.

Which of the following would reliably indicate that someone has Chronic Kidney Disease?

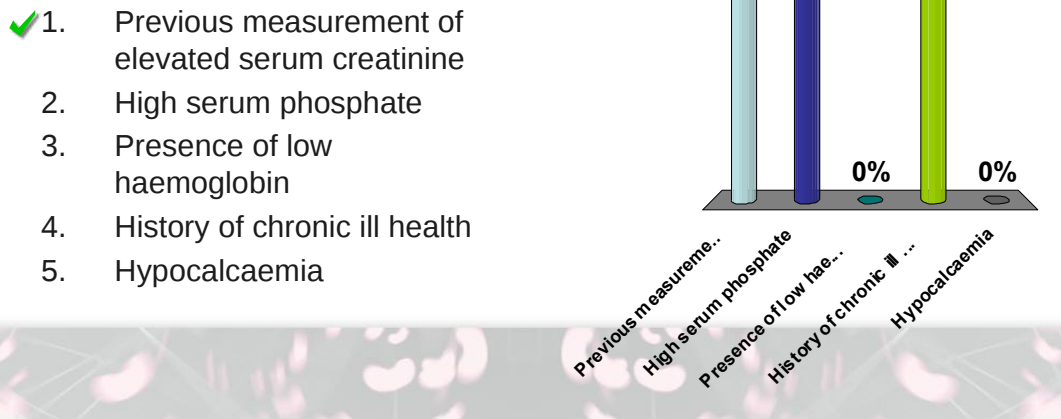


Figure 24: Live feedback guiding lesson plan. Example showing how the audience answered one of the questions on chronic kidney disease. The tutor is able follow on the discussion according to answers given. In this case, the tutor can see little educational value for the audience of time spent discussing the topics of low haemoglobin or hypocalcaemia, given that no one chose those answers.

The lesson plan for the sessions are documented as below:

- 0- 5 minutes: Introduction to the subject, set the theme, present data on the mortality/morbidity associated with AKI.
- 5-10 minutes: Capture baseline data knowledge and confidence of audience on AKI, using Turning point software. 8 questions in total.
- 10-40 minutes: Using data from baseline line survey to disseminate information on AKI, using 15 MCQs as prompts on how to diagnose, investigate and manage patients. Data on the MCQ results are captured using Turning point software.
- 40-50 minutes: Questions and feedback about the session from the audience.

Small group sessions

As well as the large grand round teaching sessions, the trust also delivers more focused teaching sessions for clinicians through 'protected time' small group sessions. These sessions have an advantage over grand round teaching since all the clinicians in the sessions are of a similar clinical experience, therefore, it is possible to develop more focused learning objectives compared to grand round sessions. These sessions also often take place away from the work place environment and therefore present a better opportunity to engage clinicians, since they are relaxed and more receptive to take on new concepts (Knowles, 1990). As well as factual and conceptual knowledge, these session aimed to teach procedural knowledge.

Learning objectives

As described in **Chapter 2** we used the concept of constructive alignment and SMART principles to develop the learning objectives for these sessions.

S – Specific –The specific learning objectives for these sessions were:

- Understand high mortality and morbidity associated with AKI.
- Formulate appropriate investigations for patients with AKI.
- Formulate appropriate management plan for patients with AKI.

M – Measurable – A Turning point survey was carried before the start of the teaching session to measure baseline knowledge: this was the baseline MCQ survey on AKI knowledge/confidence. The survey was repeated at the end of the project period along with additional teaching sessions on AKI: this was the post-intervention MCQ survey on AKI knowledge/confidence.

A – Attainable – The learning objectives have been designed to be realistic and achievable using a lesson plan designed around problem-based learning.

R – Relevant – AKI is a common clinical problem (incidence approximately 5% in both trusts).

T – Time-framed – The learning objectives are designed to be achievable with-in the timeframe of 1-1.5 hours.

The lesson plan

The sessions were delivered as a series of case-based discussion in order to make the learning material relevant. The sessions were structured based on constructivist principles (Glaserfeld, 1989b). Engagement is key, the tutors encourages an informal nature to the sessions so that clinicians feel comfortable discussing cases. The aim of these sessions was to encourage clinicians to develop procedural knowledge by working through several cases by themselves, with prompting from the tutor. Visual stimuli were used to prompt important concepts and to ensure that the clinicians are taking the discussion in the right direction Figure 25.

A CASE 1:

- Clinically dry, stoma bag is full, Apyrexial.
- B/P 88/50
- No signs of LVF
- Normal abdominal examination
- UO: 100 ml in 12hrs - Dark

B Mortality: AKI

Table 2. Mortality associated with selected changes in SCr^a

Criterion	Unadjusted OR (95% CI)	Age- and Gender-Adjusted OR (95% CI)	Multivariable OR (95% CI) ^b	Area under ROC Curve
↑ SCr ≥ 0.3 mg/dl	6.9 (5.2 to 9.0)	6.6 (5.0 to 8.7)	4.1 (3.1 to 5.5)	0.84
↑ SCr ≥ 0.5 mg/dl	11.1 (8.7 to 14.2)	10.6 (8.3 to 13.6)	6.5 (5.0 to 8.5)	0.86
↑ SCr ≥ 1.0 mg/dl	19.9 (15.1 to 26.1)	19.0 (14.4 to 25.0)	9.7 (7.1 to 13.2)	0.84
↑ SCr ≥ 2.0 mg/dl	36.4 (24.3 to 54.6)	37.7 (25.0 to 56.9)	16.4 (10.3 to 26.0)	0.83
↑ SCr by 25%	4.0 (3.0 to 5.2)	3.9 (3.0 to 5.2)	2.0 (1.2 to 3.9)	0.83
↑ SCr by 50%	5.9 (4.6 to 7.5)	5.8 (4.6 to 7.5)	4.4 (3.4 to 5.7)	0.84
↑ SCr by 100%	8.9 (6.9 to 11.4)	9.2 (7.1 to 11.8)	6.5 (4.9 to 8.6)	0.84
↑ SCr by 50% to a minimum peak of 2.0 mg/dl	16.9 (12.8 to 22.3)	15.9 (12.0 to 21.0)	7.9 (5.8 to 10.9)	0.84
↑ SCr ≥ 0.5 mg/dl with baseline SCr < 2.0 mg/dl or ↑ SCr ≥ 1.0 mg/dl with baseline SCr ≥ 2.0 and < 5.0 mg/dl	11.0 (8.6 to 14.0)	10.5 (8.2 to 13.4)	6.5 (5.0 to 8.5)	0.86

C

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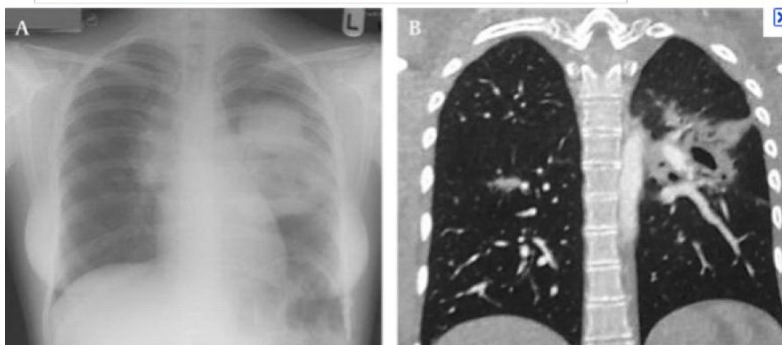


Figure 25: Relevant visual cues to motivate small group sessions. Real life cases are used to keep the learning content relevant (A), latest evidence on the topic is presented in an interactive way (B), visual stimuli is used to further increase engagement (C).

The lesson plan for the session are documented as below:

- 0 - 5 minutes: Introduction to the subject, set the theme, present data on the mortality/morbidity associated with AKI.
- 5-10 minutes: Capture baseline data knowledge and confidence of audience on AKI, using turning point software. 8 questions in total.

- 10-50 minutes: Using data from baseline line survey, disseminate information on AKI. Audiences were asked to work through cases, each case highlighting the importance of early diagnosis, investigation and management of patients with AKI. Data on the MCQ results are captured using Turning point software.
- 50-60 minutes: Questions and feedback about the session from the audience.

Implementation

Members of the project team disseminated the educational sessions according to the pre-determined lesson plans and learning objectives.

GX, RW, RB, SC	Delivered the sessions at UHL
NS, GX	Delivered the sessions at RDH

In total, 3 Grand round sessions were carried out between August 2011 and August 2012. The first session took place October 2011 in the 'pre-intervention' phase; a second session in March 2012 in the 'intervention phase' and a third session took place in June 2012 in the 'post-intervention' phase.

In total, 18 small group sessions were carried out between August 2011 and August 2012. 7 sessions took place during the 'pre-intervention phase', 5 additional sessions took place in the 'intervention phase' and 6 sessions took place in the 'post-intervention phase'.

In total, at least 505 clinicians at UHL and RDH were exposed to the educational sessions carried out in this project. Clinicians may have been exposed to more than

one educational session during the project period. All data collected during the sessions were anonymous.

In total, 357 clinicians took part in the Turning point MCQ survey on AKI confidence and knowledge in the 'pre-intervention phase' and 148 clinicians took part in the MCQ survey on AKI confidence and knowledge in the 'post-intervention phase'. All clinicians who took part in the MCQ survey were from the same cohort and worked in UHL and RDH between August 2011 – August 2012.

5. Experimental one-to-one face-to-face teaching

Chapter overview:

In this chapter, I will describe the development and deployment of the one-to-one, face-to-face experimental intervention.

Introduction

Providing feedback to individuals on large courses or in a non face-to-face setting is difficult. The power of face-to-face interaction in its ability to increase engagement cannot be underestimated. In their project on improving AKI awareness, Forde *et al* showed that directly visiting clinical areas can have a very positive impact on solidifying knowledge and gathering feedback on education resources first hand (Forde et al., 2012).

We are all capable of learning from direct experiences, which we conceptualize with past experiences, in order to build new knowledge. As described earlier on in the thesis, experiential learning (EL) provides a potential way to engage clinicians directly through direct feedback/experience on a specific clinical scenario. Kolb proposed a learning theory built on the concept of direct experience Error! Reference source not found. (Kolb, 1981), and later defined EL as (Kolb, 1984):

"The process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience"

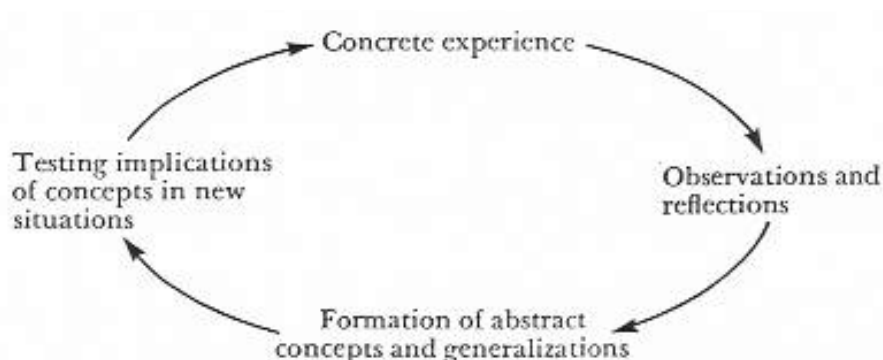


Figure 26: Four stages of the learning cycle key to experiential learning. Adapted from (Kolb, 1981).

This process requires the learner to move from being completely focused on a specific task whilst experiencing a new stimuli, to a phase of reflection, in a short period of time, something which places a large cognitive load on the learner and something that is not easily achievable without the right environment.

The concept of EL has been trialled using simulation technology in undergraduate medical training (Morgan et al., 2002). However, despite the use of mannequins and a specific simulation environment, the advantage of using the experiential method over more traditional teaching methods has been hard to prove.

The learning 'experience' is key to the EL process, as well as how the learner then conceptualized that experience. The current postgraduate curriculum for junior clinicians places emphasis on using good quality feedback to maximize learning experiences (Carr, 2006b). This is achieved by using items such as the mini-clinical evaluation tool (Min-CEX). Therefore, it seems logical to use these tools as a form of feedback/reflection in an EL based learning program.

The concept of using face-to-face interactions to increase engagement and provide feedback to junior doctors was therefore trialled for this project. A member of project team visited clinical areas where patients with AKI presented, reviewed the clinical management of a patient with AKI, and then discussed the case with the clinician who carried out the clinical assessment, and where appropriate completed a Mini-CEX tool to help the clinician conceptualize their learning experience.

Learning objective development

We were aware that delivering clinical teaching in a ward based environment presents many challenges. Often, there is a lack of clear objectives and external factors such as time pressures and competing demands for the clinician's time mean that it can be difficult to execute the lesson plan (Spencer, 2003). Therefore, having a set of clear and achievable learning objectives is vital.

The aim of these sessions was to give learners direct feedback about their performance on the management of patients with AKI. The sessions took place in the clinical environment and therefore a number of variables such as timing of each session and discussion points varied dramatically depending on the clinical case being discussed.

The learning objectives for these sessions were therefore focused on clinical management. We followed the SMART principles in finalizing the learning objectives (Reed et al., 2012):

S – Specific – The main aim of the project was to improve understanding of AKI. The specific learning objectives for these sessions were:

- 1: Understand how to diagnose patients with AKI.
- 2: Understand the management principles of patients with AKI.

M – Measurable – Mini-CEX evaluation forms were completed for learners taking part in the sessions.

A – Attainable – The learning objectives were designed to be realistic and achievable.

R – Relevant – The learning objectives were achieved by direct reflection on case managed by the clinician.

T – Time-framed – The learning objectives were adapted to fit into the time frame available for the case based discussion.

Lesson plan

EL in its purest form requires the learner to be prepared to experience new stimuli and not be held back by past experiences (Kolb, 1981). It is possible to deliver this kind of experience in a controlled and safe simulated environment (Morgan et al., 2002). However, delivering this kind of experience in a practical and cost-effective setting remains challenging.

This phase of the project was carried out on the Medical Assessment Unit (MAU) at UHL because it was recognized that a large number of patients with AKI present to MAU, therefore, the topic is of high relevance to the clinicians in that clinical area. Throughout the process, we had patient safety as our top priority, as stated by the GMC guidance on good clinical practice (GMC, 2009a). The MAU is staffed by a large number of clinicians, which gave the project team a chance to recruit clinicians to the project without endangering clinical care.

In addition, all members of the team who took part in this phase of the project, have direct clinical experience on MAU, so are acutely aware of any situation that may pose a risk to patient safety. Senior MAU consultants were made aware of the plan and the project was advertised by promotional posters Figure 27. No specific contact details for the project team was given in the poster to ensure that clinicians were not tempted to contact the project team about the management of patients with AKI directly.



Figure 27: Promotional poster for the face-to-face teaching.

Each day, a member of the project team visited the MAU, where patients with AKI were identified via the electronic alert system, and the team member reviewed the clinical notes of appropriate patients to identify if any clinicians on MAU were involved with their care. Once a clinician was identified, the team member made a decision on whether it was suitable to approach the clinician and offer face-to-face teaching.

The decision to approach the clinician was based on several factors:

- 1: How busy the MAU environment was.
- 2: How busy the clinician was.
- 3: How likely the clinician was to be required to carry out additional clinical duties within the next 30 minutes.

Once the clinician was approached the following lesson plan followed:

- 1) Introduction made to the clinician – and if agreeable the teaching session continued.
- 2) Notes of the case reviewed for
 - Risk factors identification
 - Diagnosis
 - Clinical assessment
 - Investigations
 - Management

Clinicians were asked to reflect on the above points and discuss areas where plans could have improved. Additional themes were assessed as below:

- How confident they were at managing AKI
- How well things were done
- How things could be done better
- Did they feel more confident post education
- Have they had recent AKI education
- Offer to complete Mini-CEX tool

To help with clinical teaching, we developed specific visual learning aids to help the tutor and student maximize the learning opportunity. These consisted of short but concise slides, which were presented on portable electronic displays (iPads) but also available in physical media format. These teaching aids addressed key

points and helped to generate discussion and were used as visual aids to help reinforce key teaching messages Figure 28, See **Appendix F** for full slides.

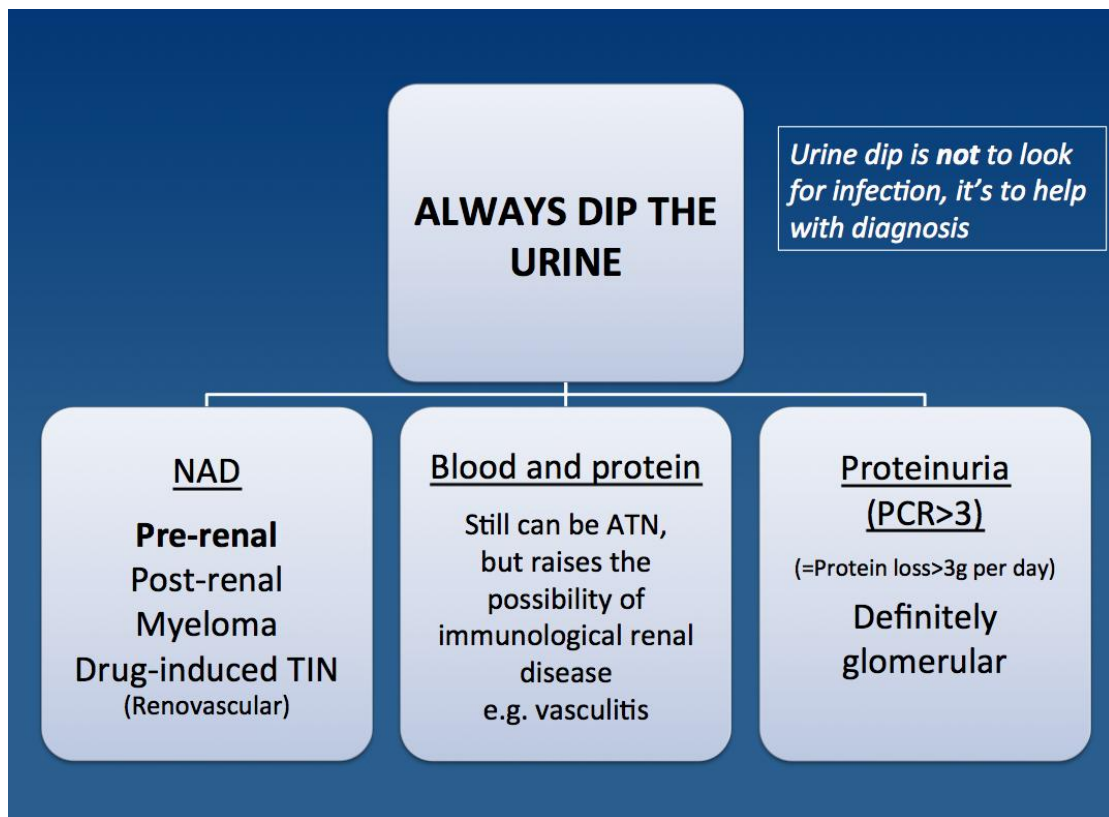


Figure 28: Visual cues used to help facilitate one-to-one teaching. This was displayed on an Apple iPad.

Implementation

The experimental phase of the face-to-face intervention was carried out between April and May 2012. GX and RB carried out session at UHL. In total, the members delivered 32 separate sessions.

Engagement with junior doctors was excellent and no concerns regarding clinical service disruption were raised. Towards the end of the 8-week period, clinicians on MAU were keeping notes of interesting cases aside for discussion with the visiting team member.

However, in order to deliver an effective AKI teaching session, the team had to remove the junior doctor from the clinical environment for 20-30 minutes, and on several occasions, teaching sessions were abandoned due to clinical service pressures. In addition, the project team had concerns about the long-term feasibility of delivering face-to-face teaching in the postgraduate setting. The aim of the project was to develop sustainable education interventions; therefore, it was decided not to continue the face-to-face teaching beyond the experimental phase. These issues are discussed in more detail in **Chapter 7** of the thesis.

6. Results

Chapter overview:

In this chapter, I will describe the results generated from the project. The results are presented in four sections: clinical results, education data, results specific to the use of the WBL tool and results of the face-to-face sessions.

Clinical results

Incidence, mortality and length of stay data

The electronic alert system for AKI recognition became fully active in January 2012 at UHL, in time for the intervention phase of the project. This was delayed compared to the original plan due to unforeseen complications with integration of the alert system with existing IT systems.

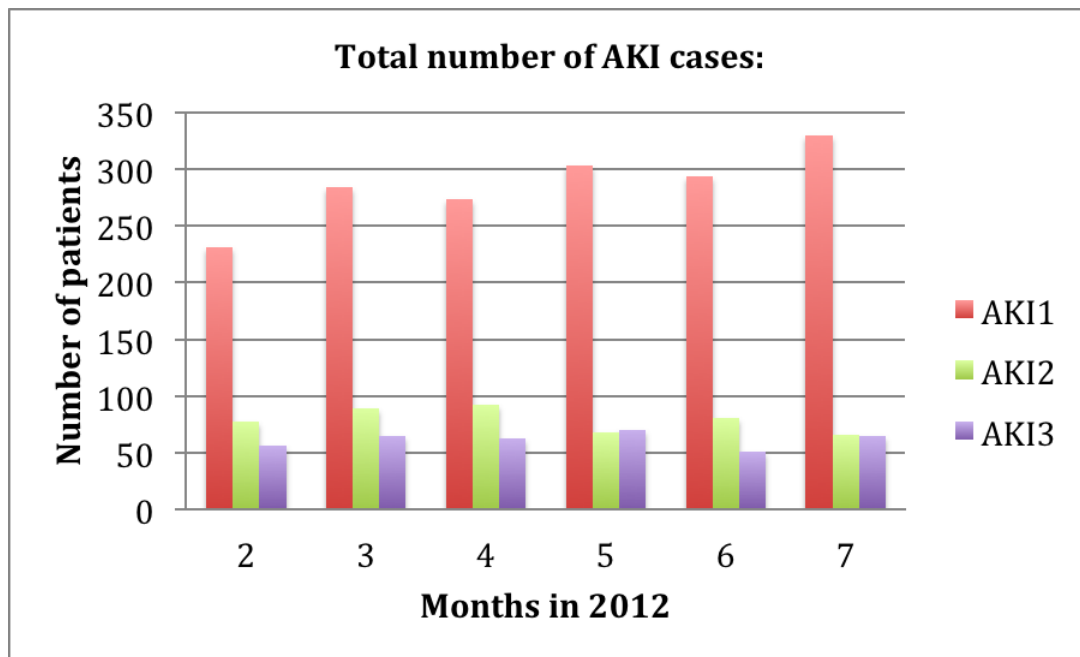
In total, over a period of 6 months (February to July 2012), there were 2555 individual cases of AKI identified at LRI.

From the database the following clinical data was acquired:

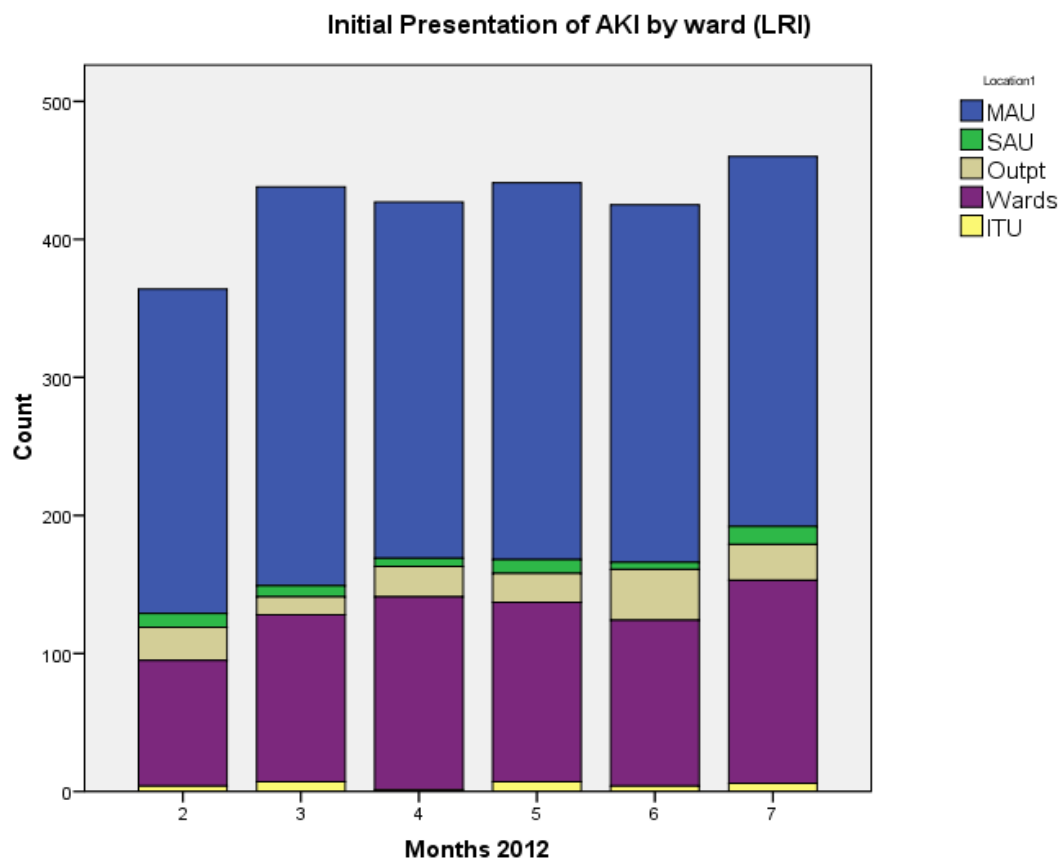
- Age
- Sex
- AKI severity (as previously described in Chapter 1 of the thesis)
- Length of stay (LOS) = Date of Discharge – Date of Admission
- Inpatient mortality (died during admission episode)

A breakdown of AKI staging is shown in Graph 1, whilst Graph 2 shows a breakdown of where patients with AKI first presented. In total, 64% of patients with AKI were first diagnosed on either the medical or surgical admissions wards, where as those who were first diagnosed on a ward were predominantly from medical/care of the elderly wards.

There was no significant difference in the proportion of patients presenting with different stages of AKI severity during the project ($X^2 = 17.2$, $p = 0.69$). There was no difference in the male/female ratio ($X^2 = 5.00$, $p = 0.42$) or ethnicity between the different months of the project ($X^2 = 2.76$, $p = 0.74$) Table 4.



Graph 1: Number of AKI cases identified at Leicester Royal Infirmary, classified by staging and severity.
 Y axis = Patient number, X axis= months of the project



Graph 2: Breakdown of location/clinical area where diagnosis of AKI was first made at Leicester Royal Infirmary. X axis = Months of the year (February to July 2012). MAU = Medical Assessment Unit, SAU =

Surgical Assessment Unit, Oupt= Out Patients area, Wards = Clinical areas which are not MAU/SAU/ITU, ITU = Intensive Care Unit.

Months	Caucasian (n)	% Caucasian	Male(n)	% Male
2	322	88.50%	182	50.00%
3	385	87.90%	211	48.20%
4	364	85.20%	185	43.30%
5	383	86.80%	197	44.70%
6	368	86.60%	192	45.30%
7	394	85.70%	218	47.40%

Table 4: Breakdown of all AKI patients according to ethnicity and sex split by months (February to July 2012).

The average length of stay for AKI patients was 12.1 ± 13.4 days and the average age of patients was 76.9 ± 14.7 years.

AKI stage 1, 2 and 3 were associated with an inpatient mortality rate of 14%, 25% and 34.5% respectively ($X^2 = 95.76$, $p < 0.05$). There was no statistical difference in the overall patient mortality rate through the project period on a month-by-month basis ($X^2 = 10.29$, $p = 0.07$).

Comparing the mean age across the project period on a month-by-month basis, there was a statistically significant difference between groups as determined by one-way ANOVA ($F = 2.51$, $p = 0.031$). A Tukey post-hoc test revealed that the mean age was significantly higher in month 4 (78.04 ± 14.39 years) compared to month 5 (75.12 ± 15.4 years). There was no statistically significant difference in age between the other months **Table 5**.

Comparing the mean length of stay across the project period on a month-by-month basis, there was a statistically significant difference between groups as determined by one-way ANOVA ($F = 3.56$, $p < 0.05$). A Tukey post-hoc test revealed that the length of stay was significantly higher in month 2 (13.24 ± 16.6 days, $p = 0.04$) and month 4 (13.42 ± 14.3 days, $p = 0.013$) compared to month 6 (10.39 ± 11.5 days). There were no statistically significant differences in length of stay between other months

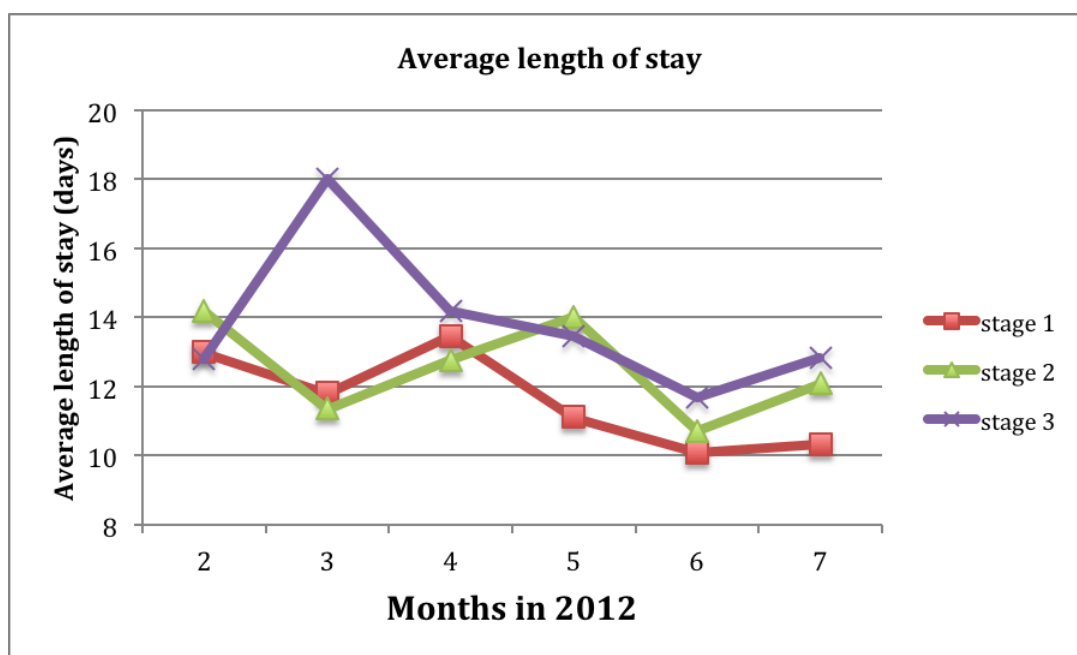
Table

5.

Column1	Months	N	Mean	Std. Deviation	Lower Bound (CI)	Upper Bound (CI)
Length of stay	2**	364	13.2	16.6	11.5	15.0
(In days)	3	438	12.6	13.3	11.4	13.9
	4**	427	13.4	14.3	12.1	14.8
	5	441	11.9	13.4	10.7	13.2
	6**	425	10.4	11.5	9.3	11.5
	7	460	10.9	11.5	9.9	12.0
Age	2	364	78.0	13.6	76.6	79.5
(In years)	3	438	76.9	16.2	75.4	78.4
	4**	427	78.0	14.3	76.7	79.4
	5**	441	75.2	15.4	73.7	76.6
	6	425	77.1	14.0	75.8	78.5
	7	460	76.0	14.5	74.7	77.4

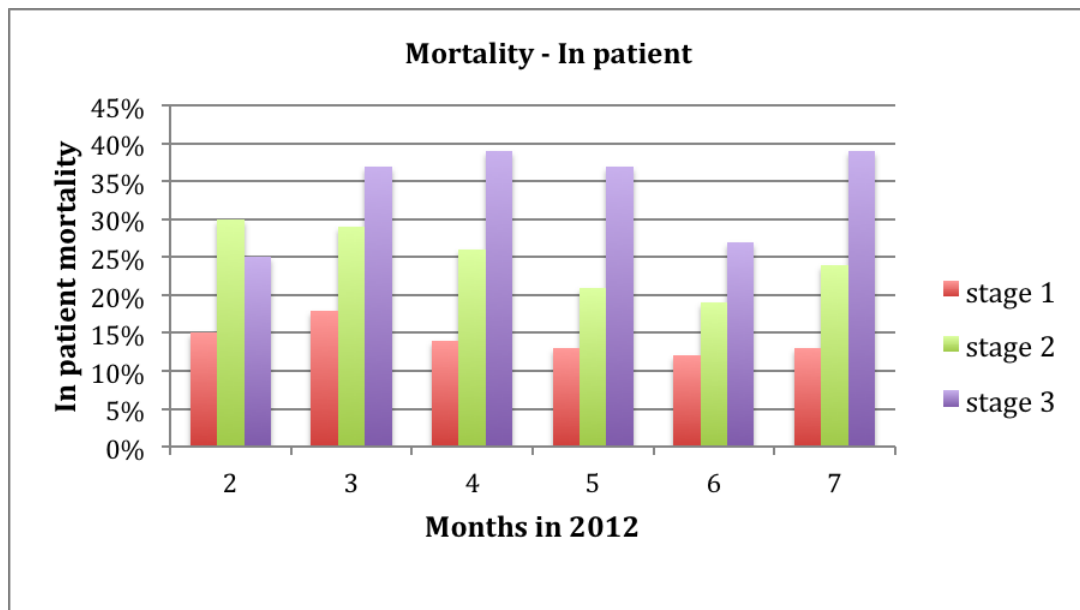
Table 5: One-Way ANOVA analysis of clinical data. Length of stay (in days) and Age (in years) comparison between different months of the project. CI = 95% mean confidence interval. ** P<0.05 on Tukey post-hoc analysis

A breakdown of average LOS according to month and AKI staging is shown in Graph 3. There was a trend for the LOS to get lower with time, especially for the stage 3.



Graph 3: Average length of stay, according to months and AKI staging. Stage 1 = AKI stage 1, Stage 2 = AKI stage 2, Stage 3 = AKI stage 3.

The inpatient mortality for the AKI stage 1 patients was 15% in February compared to 12.7% in July, but this was not statically significant ($X^2 = 6.34$, $p = 0.27$) Graph 4.



Graph 4: In-patient mortality, according to months and AKI staging. Stage 1 = AKI stage 1, Stage 2 = AKI stage 2, Stage 3 = AKI stage 3.

Splitting the data according to 'intervention' (Months 2 - 4) and 'evaluation' phases of the project (Months 5 - 7), there was no difference in Male/Female ratio ($X^2 = 0.38$, $p = 0.54$) and Ethnicity ($X^2 = 0.35$, $p = 0.55$) between the two phases of the project. There was a significant difference in AKI severity ($X^2 = 11.7$, $p < 0.05$) and in-patient mortality ($X^2 = 7$, $p < 0.05$) Table 6. The intervention phase group had a mean age of 77.64 ± 14.8 years compared to the evaluation phase group of 76.1 ± 14.67 years; this was a statistically significant difference as determined by one-way ANOVA ($F = 6.94$, $p < 0.05$).

Month	N	%Male	% Caucasian	%AKI stage 1	In hospital mortality
Feb/March/April	1230	47%	87.10%	64.1%**	21.2%**
May/June/July	1325	45.80%	86.30%	69.9%**	17%**

Table 6: Comparison of demographic data, AKI severity, and in-hospital mortality between 'intervention' and 'evaluation' phase of the project. ** $p < 0.05$

The intervention phase group had a mean length of stay 13.09 ± 10.05 days compared to the evaluation phase group of 11.09 ± 9.12 days; this was a statistically significant difference as determined by one-way ANOVA ($F = 14.00$, $p < 0.05$).

Audit

At UHL, the notes of 24 patients who had developed AKI stage 3 in February 2011 were audited. A repeat audit into AKI care was repeated for 28 patients with AKI stage 3 in July 2012, after the deployment of the educational interventions.

At Royal Derby Hospital (RDH) 132 sets of notes were audited in 2010 and 77 in 2012. Patients with all stages of AKI were included with an equal proportion of patients in each AKI stage. Data audited included the number of patients in whom a renal ultrasound scan was performed within 24 hours of admission and the number of patients receiving urinalysis within 24 hours.

NS carried out audit at RDH and GX was not involved in the data analysis and audit design. The audit department guided by GX and RW carried out audit at UHL.

At UHL, there was a significant increase in the number of patients who had a renal ultrasound scan performed within 24 hours of admission following the educational intervention compared to the initial audit: 53.6% versus 20.8% ($X^2 = 5.9$, $p < 0.05$). In addition, there was a tendency towards a greater percentage of patients having evidence of urinalysis being carried out following the intervention (71.5% versus 58.3%, $X^2 = 1$, $p = 0.3$) Table 7.

At RDH, there was a trend towards a greater percentage receiving a renal ultrasound within 24 hours post-intervention compared to pre-intervention, (54.2% versus 45.3%, $p = 0.3$) and a trend towards more patients having urinalysis performed (57.1% versus 40.3%, $p = 0.2$) Table 7.

	Centre 1 +		Centre 2 *	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Urine dipstick	58.30%	71.50%	40.30%	57.10%
Renal imaging with-in 24hrs	20.8%*	53.6%*	45.30%	54.20%

Table 7: Clinical audit data for investigation of AKI in 2 centres (Centre-1 = Leicester Royal Infirmary, Centre-2 = Royal Derby Hospital). Centre 1: Pre-intervention n = 24, post-intervention n = 28. AKI stage 3; Centre 2: pre-intervention n = 132, post-intervention n = 77. AKI stage 2 and 3; *p < 0.05

Educational data

357 doctors participated in the baseline pre-interventional MCQ questionnaire sessions that were conducted over a 4-week period at the start of the project. Following the implementation phase of the project, 148 doctors from the same cohort who had participated in the baseline surveys and been exposed to the intervention, participated in post-intervention MCQ questionnaire sessions over a 4-week period.

Due to the time frame of the project, the project team surveyed fewer groups of doctors in the post-intervention sessions. The results of the pre- and post-intervention questionnaires are presented in this section.

Pre-intervention and post-interventional survey

In total, 357 doctors were invited to take part in pre-intervention questionnaire. Of these, 319 provided full demographic data and their results were analysed. One hundred and forty-eight doctors from the same cohort of clinicians were invited to take part the post-intervention questionnaire, 137 completing demographic data Table 8. Completion rate for each part of the MCQ survey ranged from 89% to 100%.

	Foundation year 1 doctors	Foundation year 2 doctors	Core trainee doctors	Specialist trainee doctors	Consultants	Other
Pre-Intervention (n=319)	127	73	58	44	15	2
Post-Intervention (n=137)	59	27	30	10	11	0

Table 8: Breakdown of clinicians according to grades, comparison between pre-intervention and post-intervention questionnaire. N = number of participating clinicians.

Ninety-four percent of clinicians reported receiving previous teaching on AKI.

Reported awareness of local clinical guidelines on AKI increased significantly in the post-intervention survey compared to the pre-intervention survey, 64% v 26% respectively ($X^2 = 60.2$, $p < 0.05$).

Regarding the questions on self-assessment:

- When asked: *"If a patient under your care develops AKI how often would you consider it diagnosed?"*

50% of doctors pre-intervention thought they diagnosed AKI most of the time (satisfactory practice) compared to 68% post-intervention ($X^2 = 12.1$, $p < 0.05$) Graph 5.

- When asked: *"If a patient under your care develops AKI how often would you initiate further investigations?"*

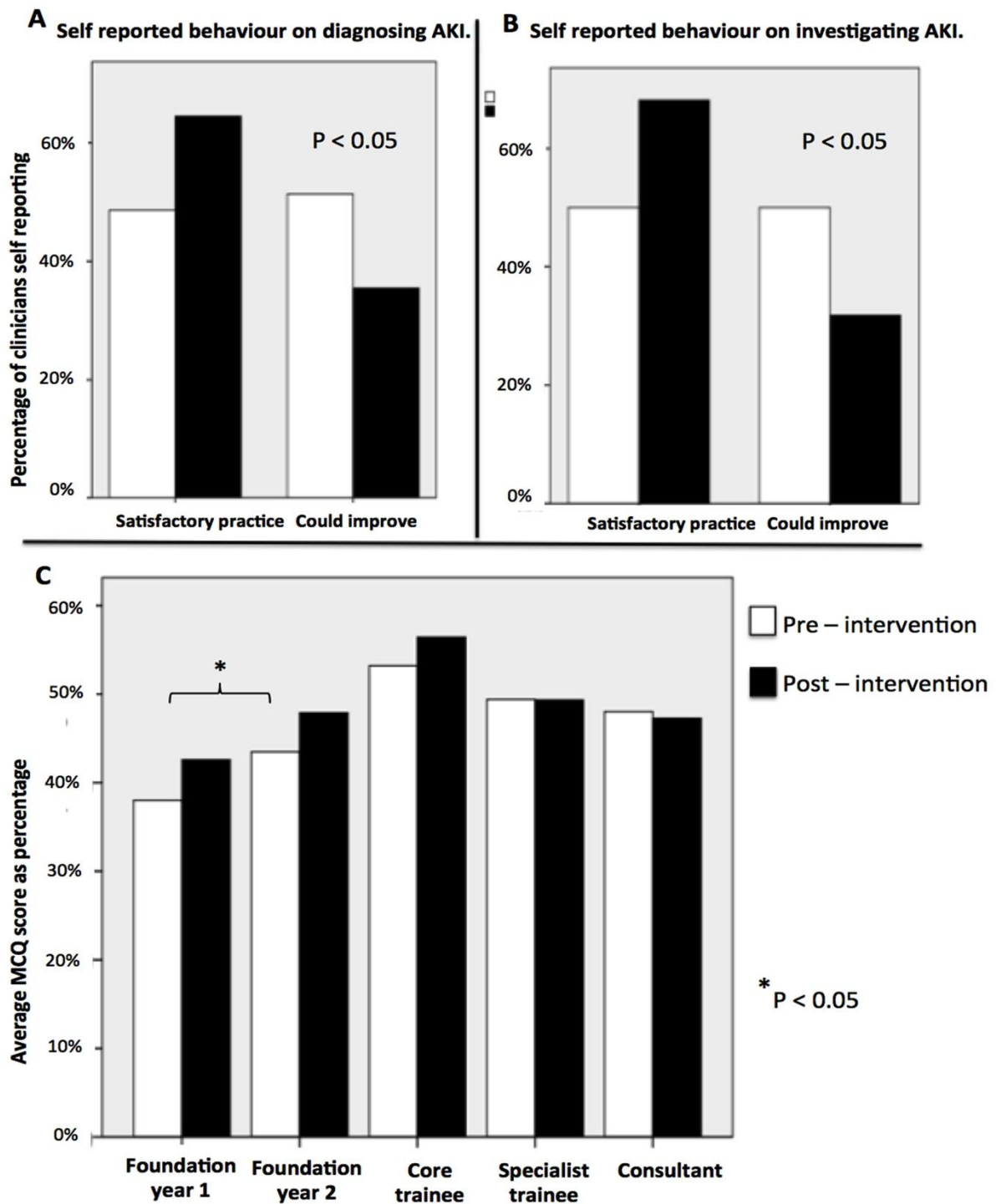
48% of doctors pre-intervention thought they initiated further investigations for AKI most of the time (satisfactory practice) compared to 64% post-intervention ($X^2 = 9.5$, $p < 0.05$) Graph 5.

- When asked: *"If a patient under your care develops AKI how often would you initiate a basic management plan?"*

65% of doctors pre-intervention thought they initiated basic management plans for AKI most of the time compared to 64% post-intervention. This difference was not significant ($X^2 = 2.5$, $p = 0.10$)

- When asked: *"How would you grade your confidence in diagnosing AKI most of the time?"*

58.8% doctors pre-intervention said they were confident in diagnosing AKI most of the time, compared to 68.4% post-intervention ($X^2 = 3.58$, $p = 0.06$).



Graph 5: Comparison of coded questionnaire results pre- and post-intervention. Clinician behaviour in diagnosing patients with AKI (A), and investigating patients with AKI (B). Comparison of mean scores for 15 MCQ questions on AKI, pre- and post-intervention. Clinicians with less than 24 months clinical experience showed significant improvement in mean scores (C)

Analysis of MCQ questions testing knowledge

There was a trend towards improvement in clinicians' overall scores in the multiple-choice questions on AKI knowledge between the pre- (mean score = 44% $\pm$ 17.6%) and post-intervention questionnaires (mean score = 47.3%, $\pm$ 17.3%, $p = 0.06$). In the initial survey, FY doctors achieved a mean score of 40% $\pm$ 16.4% on the 15 MCQs designed to test knowledge. The follow-up survey showed that the mean score for FY doctors had increased by 4%, (Mean = 44.3%, $\pm$ 13.8%, $p < 0.05$) Graph 5.

FY doctors scored lower in the MCQs to test knowledge pre-intervention compared to more senior doctors (all doctors above FY grade), 40% $\pm$ 16.4% versus 50.8% $\pm$ 17.6% ($p < 0.05$). This difference in MCQ scores was maintained in the post-intervention survey, FY doctors scored 44.3%, $\pm$ 13.8%, versus 52.4% $\pm$ 21% for more senior doctors ($p < 0.05$).

Effect of clinical experience on survey results

To explore whether the self-reported changes in AKI investigation and diagnosis could be explained by increasing clinical experience amongst the doctors during the project period, we compared the baseline survey findings of Foundation year 2 (FY2) doctors (12 months experience at the beginning of project) ($n = 73$) with those of Foundation year 1 (FY1) ($n = 59$) doctors at the end of the intervention period (12 months experience at the end of project).

- There was difference in awareness of AKI guidelines; 18.8% versus 69.5% ($X^2 = 33.46$, $p < 0.05$) when comparing FY2 doctors pre-intervention versus FY1 doctors post-intervention.
- When asked: *"If a patient under your care develops AKI how often would you consider it diagnosed?"*

51.4% of FY2 doctors pre-intervention thought they diagnosed AKI most of the time, compared to 79.3% of FY1 doctors post-intervention ($X^2 = 10.7$, $p < 0.05$).

- When asked: *"If a patient under your care develop AKI how often would you initiate further investigations?"*

35.7% of FY2 doctors pre-intervention thought they initiated investigations most of the time, compared to 59.3% of FY1 doctors post-intervention ($X^2 = 7.17$, $p = 0.07$).

- When asked: *"If a patient under your care develops AKI how often would you initiate a basic management plan?"*

78.3% of FY2 doctors pre-intervention thought they initiated basic management plans for AKI most of the time, compared to 45.8% of FY1 doctors post-intervention, this difference was significant ($X^2 = 14.46$, $p < 0.05$).

- There was no significant difference in the mean MCQ scores between the two groups, $43.3\% \pm 15.8\%$ for FY2s versus $42.6\% \pm 13.4\%$ for FY1s ($p = 0.74$).

Web based learning tool

Web learning resource feedback

292 individuals accessed the WBL resource between March and August 2012. The overall completion rate for those who accessed the WBL package was 65% (n=190). 39% of those who completed the WBL package were doctors (n=74), 40% were nursing staff (n=76), and 21% allied health care professionals (n=40). 45 of the 72 doctors whom completed the WBL were FY grade doctors.

The 190 individuals who completed WBL were sent the feedback survey, of whom 46 (24%) responded. 41 (87%) felt more confident about managing AKI after completing the WBL tool and 37 (80%) said the WBL content was highly relevant to their daily clinical work. 44 (96%) would recommend the tool to others.

Focussing on the 20 clinicians who completed the feedback survey, 18 (90%) said they felt more confident about managing patients with AKI after completing the tool. 19 (95%) said the WBL content was relevant to their daily work and that they would recommend the tool to their colleagues. When asked what prompted them to access the WBL package, 8 (40%) clinician responders said they had accessed the WBL as a direct result an e-mail sent to them, 7 (30%) logged on after that seeing the WBL advert on the UHL home screen, and 5 (25%) through 'word of mouth'.

Web learning resource: Post-intervention MCQ questionnaire analysis

27 (20%) out of the 137 clinicians taking part in the post-intervention survey had accessed the WBL tool before the time of the evaluation and took part in the MCQ and Self-assessment survey.

There was no significant difference between the clinical grade of doctors who had completed the WBL compared to those who had not ($X^2 = 5.4$, $p = 0.37$).

The average MCQ scores of those who had done the WBL was $50.4\% \pm 17.3\%$, compared to $46.7\% \pm 17.4\%$ for those who had not ($p = 0.33$). This compares to the pre-intervention MCQ score of 44%.

The results of the self-assessment survey on clinician confidence on AKI are shown in Table 9. Note the paradoxical result that despite more clinicians who had used the WBL reported themselves to be more confident at managing patients with AKI (86% verses 69.9%), they felt AKI was diagnosed less often than those who had not done the WBL (56% verses 72%).

Questions	Used tool (n=27)	Not used tool (n=110)
Q1 "If a patient under your care develops AKI how often would you consider it diagnosed?"	56% reported satisfactory practice in diagnosing AKI.	72% reported satisfactory practice in diagnosing AKI ($X^2 = 2.38$, $p = 0.122$).
Q2 "If a patient under your care develops AKI how often would you initiate a basic management plan?"	67% reported satisfactory practice in the managing AKI patients.	65% reported satisfactory practice in the managing AKI patients. ($X^2 = 0.06$, $p = 0.812$).
Q3 "If a patient under your care develop AKI how often would you initiate further investigations?"	74% reported satisfactory practice in the investigating AKI patients.	72% reported satisfactory practice in the investigating AKI patients ($X^2 = 0.03$, $p = 0.867$).
Q 4 "How would you grade your confidence in diagnosing AKI most of the time"	88.5% reported they were confident in diagnosing AKI.	69.9% reported they were confident in diagnosing AKI ($X^2 = 3.68$, $p = 0.055$).

Table 9: Results of self-assessment survey. Comparing those who had done the web based learning tool on Acute Kidney Injury (AKI) (n=27), with those who had not (n=110), post-intervention questionnaire results. n = number of participating clinicians

Face-to-face teaching

Due to this part of the project only being limited to the trial phase, analysis of the records kept for the face-to-face meetings has not been carried out. This is due to the small number of results generated, as well as the fact the aim of thesis is to consider the development of sustainable educational resources. The trial phase of the project clearly demonstrated that the face-to-face teaching approach was not a sustainable option in the long-term. More discussion about this aspect of the project can be found in **Chapter 7** of the thesis.

7. Discussion and closing statement

Chapter overview:

At present, there is no clear evidence to demonstrate that any particular intervention is effective in improving outcomes for patients with AKI. A UK National Consensus meeting on AKI, “Management of Acute Kidney Injury: the role of fluids, e- alerts and biomarkers”, was held at the Royal College of Physicians Edinburgh in 2012 to review the latest evidence and produced national guidance on how to improve care (Christie, 2012). One of the key themes identified at the meeting was the importance of delivering basic elements of care well. This is echoed in the recently published UK national guidelines on AKI (Christie, 2012, NICE, 2013).

The aim of this project was to increase awareness and knowledge about AKI through education with the following hypothesis:

Education of doctors using a multifaceted education package on Acute Kidney Injury is effective at improving knowledge and confidence on the topic, as well as clinical outcomes.

Although this project was not a randomized intervention and the results subject to bias, we have demonstrated the potential benefit of a multifaceted, structured educational intervention to improve awareness on AKI, along with improvements in self-reported confidence in clinical practice. We also identified a trend towards better clinical care in both the clinical audit results of AKI care and length of stay/mortality data, but this data is currently hard to interpret due to our limited understanding about AKI prognosis.

We found that despite developing a high quality of web based e-learning resource, clinicians still preferred to be taught in a face-to-face manner, and that traditional postgraduate education sessions can be improved by applying sound educational theory in addition to making use of newer technologies.

We also showed that AKI is not simply a condition that is confined to secondary care, and the majority of patients with AKI in hospitals actually develop it prior to admission. There is an urgent need to better understand how the condition develops in the community, as well as how seasonal variations impact on clinical outcomes.

In this chapter, I will discuss the implications of the results in relation to potential confounding factors and complete this thesis with a discussion about the overall impact of the project, as well as identify additional areas for future research.

Clinical outcome findings

Incidence data

The automated AKI e-alert system we used for the project identified 2555 cases of AKI over a period of 6 months, in a population size of roughly 980,000 (Office_for_National_statsics, 2011); this gave us an crude an annual incidence of over 5000 per million population (pmp)/year. This figure is higher than the incidence of AKI reported elsewhere in the UK, a figure 1811 pmp/year was previously reported in Scotland (Ali et al., 2007), but this figure is much lower than what has been recently reported. Challiner *et al* found by applying the RIFLE criteria of AKI to a group of un-selected emergency admissions to hospital it was found that 23.6% had a degree of AKI (Challiner et al., 2014).

The difference in incidence data of AKI can be partly explained by how AKI defined and study population selected. Ali *et al* divided patients with raised serum creatinine into AKI and Acute on Chronic Renal Failure, combining these two figures together and the incidence of AKI rose to 2147 pmp (Ali et al., 2007). Ali *et al* also had access to geographical data on patients who were 'visiting' the region and excluded 202 cases of AKI from their calculations, which if included in the incidence, would have led to a significant rise in the reported figure. They also excluded a large number of 'unclassified' cases but the criteria used for exclusions wasn't clear, and patients who had no previous blood test results were also excluded from the results. In comparison Challiner *et al* used an un-selected population group, and patients whom did not have a pervious had a baseline creatinine generated based on an 'ideal' eGFR of 75mls/min, in a similar manner to the AKI diagnosis algorithm used in our project.

The AKI data generated from our database doesn't include geographical data, therefore, it was impossible to exclude 'visitors' from the study data. Although I

excluded patients on dialysis from the database, I did not have enough clinical data available to make an accurate assessment of whether patients had 'CKD' or enough clinical data to create a 'un-classified group' as Ali *et al* had done. The AKI incidence we report accounted for roughly 5% of the total admissions at UHL during the study period. This figure is significantly lower than the incidence figure reported by Challiner *et al* for a number of reasons. Most importantly our incidence figure comes from one single hospital with-in the trust, due to the complexities associated with deploying the AKI alert tool I did not have any AKI data on the other two major hospitals with-in the trust. These other clinical areas cover specialties such as cardiology and nephrology where patients are at high risk of AKI, so it is likely the incidence of AKI would have been higher had data from these areas been included in the analysis.

This suggests that despite what appears to be a large difference in the incidence of AKI reported in our project compared to other published literature, analysis shows that our AKI database is valid, and differences can be accounted for by the way in which CKD and AKI is defined and how incidence figures are reported (e.g., excluding visitors to the region, inclusion criteria of the baseline population). However this demonstrates our understanding about AKI is still evolving, therefore would be incorrect to draw definitive conclusions regarding the mortality and length of stay data generated from this dataset.

One interesting observation from our results is that over 60% of patients with AKI had the diagnosis made whilst on an Acute Admissions Unit (AAU). By definition AAUs are the 'front door' to the hospital and most patients on AAUs have been directly admitted from the community. Given AKI is diagnosed by changes in serial blood tests carried out in a short time period such a high percentage of AKI been found on AAUs suggest that either:

1. Patients admitted to AAUs are sub-optimally managed and are developing AKI as a result; or,

2. Patients are admitted to hospital already suffering from AKI, the diagnosis is made on the AAU because that is where patients are having serial blood tests for the first time.

The NCEPOD report into AKI management may support argument 1, given we know AKI is poorly managed, however, it does not explain why so many patients are developing AKI on AAUs compared to other ward areas.

The hypothesis suggested in point 2 therefore seem more likely. It suggests that patients have already developed AKI in the community before being admitted to hospital. This finding is supported by other groups in the UK who have reported a similar trend in 'community' AKI admissions (Wonnacott et al., 2014). This has a big implication on strategies employed to improve patient care, and suggests that purely focusing on secondary care to improve outcomes in AKI may not be appropriate, and there is a need to engage community healthcare professionals as well.

Though the NCEPOD group reviewed the care of patients with AKI in the secondary care setting, we have little or no knowledge about the quality of care being delivered to AKI patients in the community, nor the disease prognosis/outcomes. It is also important to highlight that many current guidelines and focus of research into AKI management is based in the critical care setting (Palevsky and Weisbord, 2009), but we found only a small proportion of patients with AKI are treated in the critical care setting. Therefore, research findings carried out in a critical care setting may not be relevant in less well staffed medical areas, or indeed in the community. Our data therefore suggests that further research into this area of AKI needs to be carried out urgently.

Mortality

The inpatient mortality of all AKI patients in the database was 19%, with more severe forms of AKI associated with significantly increased mortality (14% for stage 1 AKI, rising to 34.5% for stage 3 AKI); this is similar to figures reported in the local region (Selby et al., 2012). There was no difference in gender or ethnicity of patients with AKI as the project progressed, but there was a trend towards lower AKI mortality as the project progressed from the implementation to evaluation phase (21.2% to 17%). This fall in mortality however was associated with a fall in the mean age of the patients between the implementation and evaluation phase of the project (77.6 years versus 76.1 years). We also noted that patients in the evaluation phase of the project seemed to develop less severe AKI than in the implementation phase (69.9% with Stage 1 AKI versus 64.1%).

The original plan of the project was to have 9 months of clinical data, so that we could compare 3 months each of pre-intervention, intervention and post intervention phases. However, a technical delay meant that the AKI alert system was not in place until the implementation phase of the project. Therefore, it is difficult to ascertain if the changes seen between the intervention and evaluation phase of the project is due to true changes in practice or other confounding factors.

Given that AKI is often caused by hypo-perfusion, there is a strong argument to suggest that septic shock causing hypo-perfusion may well induce AKI in a number of patients, with sepsis itself already known to be linked to worse outcomes (Ronco et al., 2008). Indeed, the link between sepsis and AKI has been demonstrated in several studies (Waikar et al., 2006, Ali et al., 2007, Zarjou and Agarwal, 2011). It therefore seems logical to suggest that increased episodes of sepsis may be associated with increased incidence of AKI, or worse prognosis. Given that we know certain forms of respiratory sepsis have strong seasonal variations in how they present (Lofgren et al., 2007), the incidence of AKI may also be associated with such seasonal variations. As such, even if I had 12 months of mortality data on AKI, I could still not be certain that changes in mortality is associated with changes in practice and not other factors such as seasonal variations in the incidence of sepsis.

Understanding how mortality figures may relate to quality of care is also not clear. Mortality is described as a 'hard' outcome, as in it is easy to measure and its definition is clearly understood. It has long been suggested that mortality may be a good measure of quality of care, however, studies trying to define quality of care from mortality figures have shown this is not a simple task.

Park *et al* looked into the mortality rates of patients with coronary heart disease in the 1990's. They looked at mortality data for similar age groups between different hospitals and then quantified the quality of care the patients received through review of medical records (Park et al., 1990). When the team compared the quality of care in hospitals with high death rates against hospitals with a 'normal' death rate, they found there was little objective difference in the quality of care delivered. The authors therefore concluded that factors such as random variation, severity of illness and socio-economic inequality, could all account for differences in mortality rather than the quality of care.

In the UK, it has been shown that social economic status has a clear impact on mortality even without taking co-morbidities into account (Ecob and Jones, 1998). Hospital mortality rates have been reported to vary between 3.4% to 13.6%, with even the number of doctors on duty having been linked to variations in mortality (Jarman et al., 1999). A way to try and understand how different factors may influence mortality is to calculate a standardized mortality ratio (SMR) for the hospital in question. The SMR is designed to take into account factors such as co-morbidities and age, and allow hospitals to be compared and outliers with higher than expected mortality rates identified.

However, concerns exist regarding the suitability of using SMRs to gauge quality of care. Though to some extent, 'fixed' variable such as age, gender, deprivation (based on address) are easy to incorporate into adjustment calculations, others such as 'case mix' (accounting for co-morbidities) adjustment requires information submitted by individual hospitals and is therefore subject to bias.

Current SMRs in the UK are provided by a group known as Dr Foster Intelligence unit. Mohammed *et al* studied the SMR reported by Dr Foster in relation to how variables such as 'case mix' are adjusted (Mohammed et al., 2009). Dr Foster uses clinical coding to help determine co-morbidities and therefore it would be safe to assume that errors in coding may impact on the SMR. Mohammed *et al* found that there were differences in coding quality between different hospitals, as well as how hospitals classified 'emergency' patients, therefore implying that SMR may be strongly influenced by factors not related to clinical care or even fixed demographics data.

Different coding practices can in fact have a large impact on SMRs, if the change in practice occurs over an extended period of time. In 2009 Dr Foster reported Mid Staffordshire to be one of the five 'most improved hospitals in the UK', but during the same time frame, it is now known that standards of care at Mid Staffordshire were significantly below what is expected (Francis, 2013). The discrepancy between actual quality of care being delivered and the SMR reported by Dr Foster was partly explained by changes in coding practice in Mid Staffordshire, and shows the danger associated with using statistical methods to 'correct' crude mortality figures. In fact, crude mortality rates in the UK have not fallen between 2004 – 2009, but the SMR have showed an adjusted fall of over 7% in the same time frame (Hawkes, 2010).

The UK government reviewed the use of SMR in light of the Francis report and has developed a new tool to measure mortality known as the Summary Hospital Mortality Index (SHISM) (Department_of_health, 2012). This new marker will identify hospitals where the mortality rate is higher than expected once corrected for age, sex, method of admission and comorbidities. It will use a different method of correction compared to the SMR reported by Dr Foster.

But it has been shown that there is significant variation in 'adjusted' mortality ratios produced by the most popular statistical tools/methods used by different hospitals/governments worldwide (Shahian et al., 2010). Shahian *et al* asked four well-known commercial companies who specialise in producing SMR, to use their

individual tools and predict mortality in 83 Massachusetts hospitals over a period of 3 years; the Dr. Foster Unit being one of the companies studied. The team then compared the results generated by the four different methods and found significant variations in expected mortality rates, despite the same underlying clinical data being used Figure 29. This shows that reproducibility between the different methods is poor and puts into doubt the validity of using corrected mortality ratios as a marker of outcome, regardless of which tool is used.

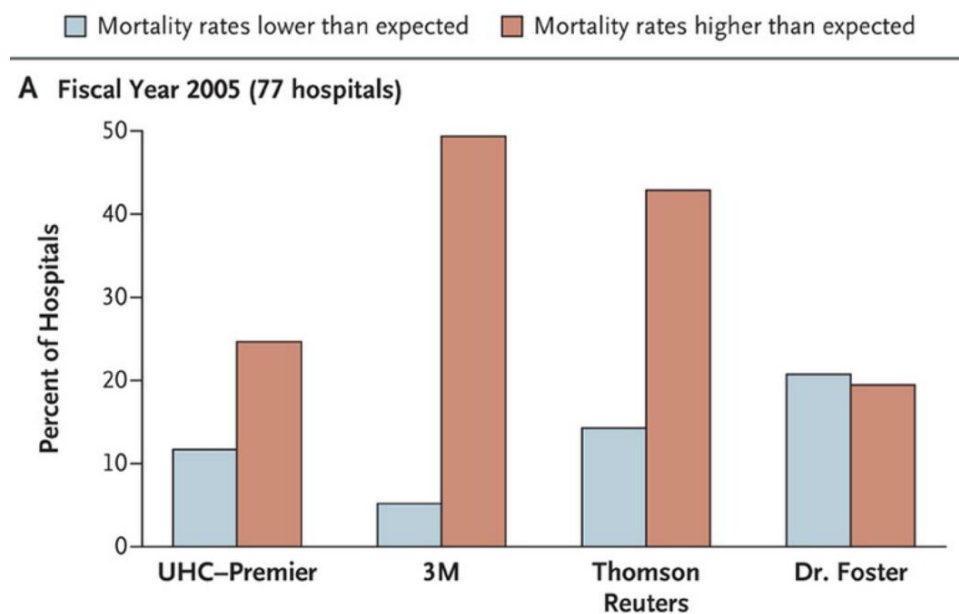


Figure 29: Mortality rate prediction. Percentages of hospitals with mortality rates higher or lower than expected for fiscal years 2005 to 2007, according to four measurement methods (X axis), taken from (Shahian et al., 2010)

Therefore, even if I had collected 12 months of mortality data and had access to more detailed demographic data such as income, in addition to understanding how seasonal variations may impact on disease severity; understanding the meaning of changing mortality rates would still not have been easy.

However, it is reassuring to see a slight downward trend in mortality, suggesting at least no 'harm' has been caused by the introduction of the intervention. But at present I feel that it is impossible to draw any further conclusions from the mortality data.

Length of stay

The mean length of stay (LOS) for patients with AKI we reported is similar to that previously published (Selby et al., 2012). During the project period, there was a drop in LOS between the intervention and evaluation phase of the project, from 13.09 days to 11.09 days. As reported earlier, the mortality rate tended to be lower during the evaluation phase, therefore the drop in LOS was not due to excess mortality.

The current political and healthcare agenda is very much focused on reducing LOS as a way to reduce cost and improve efficiency in the NHS. Exact cost for hospital beds in the NHS is hard to ascertain, but the NHS institute suggests in 2013 the cost of a single NHS hospital bed was £225/day (NHS_Institute, 2013). Broadly speaking, assuming a reduction in mean length of stay of 2 days over the study period, there would have been a reduction of 4139 bed days for AKI patients, assuming 19% mortality; associated with a cost saving of £931,298 over the study period.

However, much like mortality data, LOS is also subject to confounding factors such as patient demographics. It has been recognized for a long time that there are variations in LOS data in the NHS (Clarke, 1996). Indeed, trying to predict LOS is an almost impossible task, which even the most senior clinicians struggle with (Durstenfeld et al., 2014).

In addition, there appears to be variations in the cost of care as the patient moves through the NHS. One study looked at LOS and cost of care for ITU patients, and found that the treatment costs were much higher for the first few days of care compared to the rest of the care period. It was shown that although using median and mean LOS data yield slightly different results, the overall trend is much the same (Rapoport et al., 2003). These findings were echoed by Taheril *et al*, who reviewed the cost associated with the care of patients in a large tertiary hospital. It was found that the mean LOS for patients was just over 10 days and the cost of care in the last 24hours only accounted for 2.4% of the total cost of care (Taheri et

al.). It appeared that the first few days of hospital admission accounts for the bulk of healthcare costs and this finding remained true regardless of whether the patient had spent time on intensive care, under went a major operation or was just admitted to a ward.

Therefore, it is hard to fully understand the meaning behind the changes in LOS data for my project, but even if there was a reduction in mean LOS of just 0.5 day, this could translated to a total annual saving of £541,325 for the trust, on bed days alone.

AKI is also associated with the development of CKD and the need for renal replacement therapy (Van Berendoncks et al., 2010). Therefore, any reduction in the morbidity of the disease will also reduce the long-term impact of the disease on both patients and the healthcare system, though estimating this figure is impossible at present without longer term follow-up data.

Audit of clinical care

The clinical audit of medical notes carried out at both sites taking part in the project demonstrated improvements in recognized markers of good clinical care, as defined in the UK Renal Association guidelines (Lewington and Kanagasundaram, 2011). However, the audit suggested differences in practice between the two trusts. This difference may be partly explained by differences in how the educational resources were implemented due to logistical reasons.

91% of users accessing the WBL were based at UHL rather than RDH, the reason for this is most likely due to the fact that the WBL was hosted on the UHL VLE, which UHL staff would have been familiar with, but RDH staff would not have used previously. Also, a greater percentage of patients with AKI had their notes audited at RDH compared to UHL, which could explain the differences in audit findings, since the UHL data may be a false representation of the overall picture, given the small sample size. However, we acknowledge that overall, only a small percentage

of patients who suffered from AKI had their medical notes audited at both RDH and UHL.

It is impossible to ascertain exactly which elements of the intervention were most effective, or responsible for any of the differences noted in the clinical audit data. There are on-going clinical audits into AKI at both trusts, but since elements of the project have now been integrated into the regular educational programs at both trusts, interpreting the data from these on-going audits will be impossible in the context of understanding how effective the initial project has been. Equally, although the audit markers used were derived from national guidelines, there is no clinical evidence at present to suggest these markers correlate with better patient outcome or improved care.

Since completion of the project, NICE has published guidelines on the management of AKI in the UK (NICE, 2013). Key points in the guidelines focus on early identification and early investigation for patients with AKI, including ensuring patient's with AKI receive renal ultra-sound imaging with-in 24hours where no cause of AKI has been identified, and prompt documentation of urine-dipstick in all cases. I considered a retrospective re-auditing of clinical notes for patients with AKI against points raised by the NICE guidelines. However, given that we have identified over 2000 cases of AKI in just 6 months such an audit would require a significant amount of additional human resources, which is far beyond the scope of this project. But the advent of electronic prescribing and clinical observation recording means that future audits into the management and care of AKI patients could be much more inclusive and warrant further thought.

Summary

We have demonstrated a trend towards reduced inpatient mortality, a significant decrease in length of stay as the project moved from the implementation to evaluation phase, and evidence suggesting improved clinical practice via the clinical audit of notes of patients with AKI. In the original project plan, we had hoped to include 9 months of clinical data, but due to technical issues we were only able to start data collection during the implementation phase of the project, and therefore only had 6 months of clinical data.

However, in retrospect, the loss of three months of clinical data has not impacted on the findings of the project in a significant way. Though both mortality and length of stay data are 'hard' clinical outcomes, their results are subject to bias. How age, gender and co-morbidities impact on AKI outcome is currently unclear, and in addition, other factors such as seasonal variations are not yet fully understood.

Our incidence data also highlighted that a large proportion of patients with AKI in secondary care have most likely developed it in the community, before admission to hospital. This was an unexpected and previously unrecognised finding and clearly demonstrates just how little we currently know about AKI epidemiology.

Though the raw clinical results presented in this thesis are subject to bias and many confounding factors, they never-the-less have demonstrated that the educational interventions deployed in this project has done no harm to patients, and may have helped to change clinical behaviour for the better. More importantly, we have demonstrated a clear need to better understand AKI incidence, prognosis and treatment in both secondary and primary care in larger, more controlled clinical studies.

Educational results

The educational results of the project demonstrated that a well-designed multifaceted educational intervention deployed in a clinical setting can be effective in raising awareness about important clinical conditions. However there are limitations to these results; these are described in this section of the thesis.

Our intervention took place in a real world clinical setting rather than a controlled research setting. The results we report here reflect the real life situations and difficulties faced by postgraduate educators, and therefore may be of more relevance to educators than a project carried out in a controlled research setting, which would be hard to replicate in the real world.

Pre- and post-intervention MCQ survey

This project identified that although 94% of clinicians had received previous AKI education, less than half reported they would 'always' or 'almost always' investigate a patient with AKI, and only 26% were aware of the local guidelines. Following the intervention, there was a significant increase in the number of clinicians aware of local guidelines (26% v 64%) and there was a significant improvement in self-reported clinical behaviour, particularly with respect to making a diagnosis and initiating investigations in a patient with AKI **Graph 5**. This demonstrates that the intervention did have an impact on clinicians; however much like the clinical results, the results of the educational survey have a number of confounding factors:

1: Uncontrollable variables:

The complex acute care NHS environment that our project was set in, means that there are multi-professional teams involved in patient care, and patients will encounter many different doctors and nurses during an inpatient hospital stay

(Trebble et al., 2010a). As a consequence, it is difficult to clearly define how a change in an individual doctor's knowledge and confidence will affect the overall care of a patient. In addition, over the course of an academic year junior doctors' overall experience in managing patients of all types will increase.

To try and understand our findings in more detail, further analysis on the results was carried out. This found that FY1 doctors following the intervention (12 months experience) reported that they were more aware of AKI compared to doctors with 12-month experience at the beginning of the study (baseline FY2 doctors). This suggests at the very minimal that the intervention had increased awareness of AKI amongst junior doctors, which was one of the main aims of the project, since they are often the first cohort of clinicians to manage patients with AKI (MacLeod, 2009). There were however no differences in the mean MCQ scores between the two groups, but it is recognised that MCQs do not always provide an accurate reflection of real world knowledge (Epstein, 2007)

2: Difference in the number of physicians who took part in the initial and post educational questionnaire:

There was a difference in the number of physicians who took part in the initial and post-education questionnaires. In an ideal situation, the project team would have asked every clinician who took part in the initial pre-educational survey to take part in the post-educational survey, but due to a number of external factors outside of the control of the project team, such as annual leave and not wanting to disrupt clinical service, the evaluation phase of the project was carried out in a more limited fashion. However, the participants who took part in the post education questionnaire were from the same cohort as those who took part in the original. There was no significant difference in the demographics of the physicians questioned and completion rates of the two questionnaires were similar. Therefore, we feel that any bias due to incomplete sampling of the population has been minimized. There was a clear change in self-reported behaviour post-intervention, suggesting increased awareness of AKI towards the end of the

project, though it should be noted that self-reporting is not always an indicator of good clinical care (Davis et al., 2006).

In order to minimize selection and completion bias in the questionnaires results, we excluded clinicians who did not provide demographic information, but were still able to analyse 90% of responses. The questionnaires and education sessions were delivered in a large number of different geographical locations across the two Trusts and included a wide range of clinicians of different grades. All questions had a greater than 89% response rate; this reduces the effects of non-response bias. To increase validity of the questions, the questionnaire was developed with input from four independent consultants, as well as input from clinical educationalists. Anonymous data was collected electronically and the questionnaire delivered using the Turning Point system, to ensure a standardized format, to improve reliability. We therefore feel that the results of the questionnaire are an accurate reflection of clinicians' opinions, and demonstrate that overall the educational intervention had a positive impact on clinicians' knowledge on AKI.

3: MCQs testing knowledge:

The number of MCQ's used in our assessment was primarily designed to fit into 1 hour teaching sessions and were too small to generate good reliable psychometrics (McCoubrie, 2004). It is also not clear how reliable or valid pre- and post-test MCQs are at assessing meaningful transfer of knowledge (Wilkinson et al., 2009, Wang et al., 2007), or if the knowledge tested in MCQs actually translates into better standards of care for patients.

However, we did show that clinicians with more experience (all grades above FY doctors) scored higher in the knowledge based MCQs than FY doctors (50.8% versus 40%). These findings show that the MCQs used in the survey, though few in number, were still a valid test of knowledge on AKI, since it is expected clinicians with more clinical experience should score higher than those with less experience. The fact that the overall MCQ scores showed a trend towards improving post-intervention demonstrates that the educational intervention did have an impact on

clinician's knowledge regarding AKI. In addition when I examined how FY doctors performed in certain question themes, I found that post intervention the scores were higher in the themes of diagnosis and management. Again suggesting that the educational intervention had the desired impact on knowledge about AKI, however it should be noted each theme only contained a few MCQs, so any bias in MCQ design/difficult can have a large impact on results Figure 30.

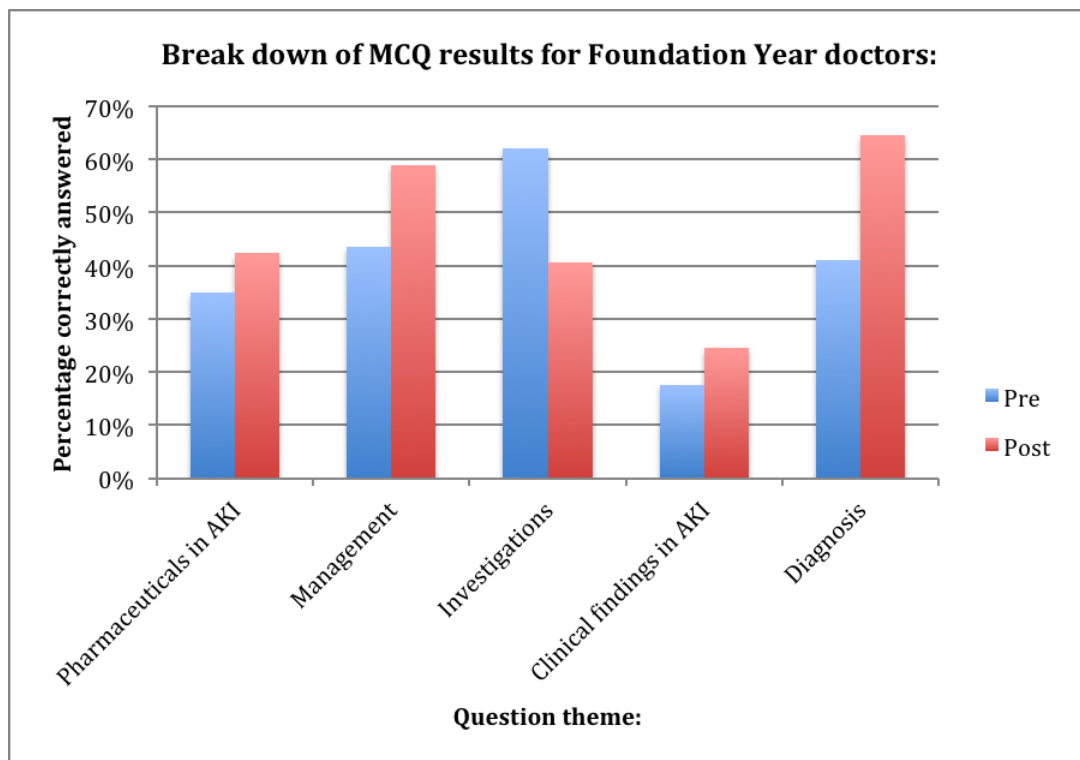


Figure 30: Break down of how Foundation Year doctors scored in the Multiple Choice Test assessing knowledge. Note post intervention, higher scores in areas of management and diagnosis.

Integration into existing educational sessions

As previously mentioned in the introduction, there is much that can be improved to optimise the way existing education sessions are run in the postgraduate setting. For this project, we delivered 21 educational sessions to over 500 clinicians over a 12 months period. All these sessions were delivered as part of the existing educational program in the local trust, therefore required little additional resources, but by ensuring each session had clear learning objectives, a lesson plan and delivered by a clinician with an educational background, we were able to demonstrate improvements in knowledge and confidence on the chosen topic. We

feel this demonstrates that by introducing sound educational methodology into existing educational sessions, we may be able to improve the overall quality of medical education delivered at the postgraduate level, without placing additional stress on already stretched resources.

The use of Turning Point software **Figure 18** greatly increased user engagement in the teaching sessions delivered. The Turning Point software allowed the tutor to tailor the learning content of the session to match the learning needs of the audience, in order to maximize learning opportunity. Unfortunately, due to the varying format/venue/timing of these sessions, it was not possible to collate any formal feedback that could be applied to the sessions as a whole.

Web based learning tool usage

We successfully developed and deployed a web based learning (WBL) resource based on constructivist theory in response to the educational recommendations of the 'Adding Insult to Injury' NCEPOD report (MacLeod, 2009). The WBL tool was introduced into an uncontrolled real world clinical environment and although heavily promoted, did not form part of mandatory training. To our knowledge, this is the first time the impact and use of a WBL package has been described in a bonafide postgraduate clinical setting. Given that e-learning methods are being increasingly used to deliver essential NHS training to doctors in the UK, there is a need to understand their effectiveness in a real world setting.

Uptake of the WBL was lower than expected despite having been heavily promoted on the internal intranet and by direct individual e-mails to FY doctors. 227 FY doctors were emailed about the WBL Roughly 20% percentage of the FY doctors working contacted by email completed the WBL (n=45) and only 20% of the total number of clinicians who participated in the post-intervention MCQ survey had used the tool. The reasons for this are not clear and warrant further study.

We know there are several barriers to the advancement of electronic learning resources in the NHS (Childs et al., 2005). These include IT resource limitations as well as software limitations hindering the design of the tool, resulting in a poor quality resource being produced. But the feedback we received about the tool itself were all positive, and the fact that the tool won the 'Excellence in Healthcare Education' Category at the BMJ awards show that the educational quality of the WBL is high. So these particular barriers did not hinder our WBL package.

Nearly half of the clinicians who returned feedback about the WBL tool had accessed it following an e-mail prompt, demonstrating that the e-mails had reached their intended target audience. In addition, the large number of allied healthcare professionals who accessed and completed the WBL, despite not being the main target audience (or receiving individual e-mails), shows that the internal promotion of the tool was adequate and that the IT provision was straightforward to access and sufficient to cope with demand.

Previously, Childs identified pedagogical concerns not only in relation to the instructional design of e-Learning resources, but also regarding the need for learners to change their learning styles in order to engage better with e-learning resources. (Childs et al., 2005). Goh and Clapham recently demonstrated that even though younger clinicians are comfortable with accessing technology, they prefer to receive e-learning as a part of a blended educational package rather than as a standalone replacement for more traditional methods of teaching (Goh and Clapham, 2014).

Clinicians who completed the WBL had a trend towards higher scoring in the MCQs designed to test knowledge: 50.4% versus 46.7%, suggesting the WBL successful at transferring knowledge.

Interestingly, in the self-assessment questions on AKI management, when asked "If a patient under your care develops AKI how often would you consider it diagnosed?", only 56% of those who completed the WBL said "almost all of the time", compared to 72% for those who did not. This is despite 88.5% of those who

had done the WBL saying that they were confident in diagnosing AKI, compared to 69.9% for those who had not done the WBL.

We think these results are important and reflect the unconscious incompetence that is associated with the under-diagnosis AKI in those who had not used the WBL compared to those who had (Manthey and Fitch, 2012). Current epidemiological data supports the consensus opinion that AKI has been consistently under-diagnosed (Ali et al., 2007). Therefore, we feel this paradoxical finding demonstrates that the WBL did indeed have an impact on the individuals that used it by highlighting what they didn't know compared to those who did not use it.

Organizations such as the British Medical Association and Royal College of Physicians have developed high quality WBL resources, but the poor uptake of the WBL shown in our project clearly demonstrates the need for postgraduate educators to better understand the factors governing real life uptake and learning benefits of WBL. Greater understanding of how different learning styles may impact on the effectiveness of e-learning, as well as what motivates learners to engage with non-mandatory e-learning resources is necessary. The differences between physicians and other health professionals in acceptance of e-learning resources also warrant further research.

The findings relating to WBL usage are limited by bias that need to be considered when interpreting these results.

1: Selection bias:

Selection bias is always a concern when you are not able to sample the entire population of the study and even more so, when sampling is voluntary. Due to the flexible nature of the clinical environment and the fact that none of the elements of the AKI learning package were mandatory, it is not possible to be sure of the exact number of clinicians who were exposed to the other elements of the educational intervention package, though we were able to track the number of clinicians who logged into the VLE to use and complete the WBL during the project period. The

demographics of the clinicians who took part in the post-intervention survey are however reflective of the clinician groups targeted by the project.

Despite these confounding factors and not achieving statistically significant results with respect to the transfer of knowledge, we feel that the findings reported are still important. It is recognized that though evidence exists about the effectiveness of electronic learning tools compared to traditional tools, there is little literature about just how effective these tools are in the postgraduate/adult learning setting (Cook, 2009).

Our findings have shown just how clinicians in a real world clinical settings are utilizing WBL tools, rather than in controlled study environments where engagement with learning materials is enforced. For this reason, it is valid as a model and the findings need to be understood, as increasing amounts of postgraduate education (including topics pertaining to patient safety) is delivered in this way.

Face-to-Face trial sessions

The face-to-face teaching sessions were very successful, created engagement with clinicians and greatly increased awareness of AKI on the wards. I personally carried out the majority of these sessions and from an educationist point of view, I feel they delivered the most benefit. The ability to engage with clinicians directly after they had seen a patient with AKI helped to re-enforce important learning points and also helped to create interest in the topic. Towards the end of this phase, clinicians were keeping lists of patients they were keen to discuss with me; a clear sign that they were actively considering AKI during their day-to-day jobs and that they were developing as independent learners.

Though the sessions were focused in on using EL theory, with minimal instructional design being a key concept in EL, I found that most clinicians needed some guidance to ensure that they developed logical and rational learning points

from their experience. It has been suggested that providing little or no guidance to students can lead to the formation of inappropriate knowledge and delay the development of expert reasoning (Kirschner et al., 2006). I feel that the main value of the sessions was the fact that I was able to utilise my knowledge on the subject to help guide clinicians through the discussion about their learning experience, and then re-enforce the message by providing direct feedback, something that was only possible if carried out in a one-to-one and face-to-face setting.

However, the main aim of the project was to design an educational intervention that was effective and sustainable in the clinical environment. After analysis of the face-to-face sessions, the project team found the sessions were time consuming and in order to be sustainable, would require specific resources to be directed towards creating a routine Nephrology outreach service. But the role of an outreach service is to be actively involved in the care of a patient (Esmonde et al., 2006), which is a very different role from what I was practicing in this project, which was to purely facilitate the transfer of knowledge.

Though I feel that face-to-face teaching in the clinical environment offers great engagement and educational value to clinicians, due to the time consuming nature of the sessions, it would be impossible to expect an expert educationalist to deliver this kind of teaching to huge number of clinicians working in the local NHS trust (over 500), without considering how current educational resources are allocated and delivered. Therefore, the limited results gathered from the session were not analysed.

Sustainability

An important aspect of the project was to develop teaching resources that are sustainable. Since the end of the project, additional teaching sessions on AKI have been incorporated into the hospitals routine educational program. This includes regular teaching sessions on AKI for FY1, FY2, core medical trainee doctors, and specialist trainee doctors on an annual basis. Grand round presentations on AKI

have also taken place bi-annually since the end of the project. Members of the project team continue to be involved with senior managers within the trust regarding monitoring, auditing AKI care, and to ensure the educational material delivered remains up-to-date and relevant.

Sustainability of e-learning resources is a more difficult problem to over-come. Barriers include, a lack of dedicated funding to update resources, a lack of integration with more established teaching programs, unclear accountability, and technical support to ensure the resources is updated in keeping with IT developments (Gunn, 2010). The WBL developed has been recognised for its high quality at the BMJ Awards and currently we are in discussion with other trusts about disseminating the WBL. Through this process we aim to keep the WBL updated and relevant. Though it is currently no longer promoted on the trust intranet, I have been in active discussions with NHS England regarding incorporating the WBL on a national AKI/CKD web based education resource page (<https://www.thinkkidneys.nhs.uk>).

We are also considering how to explore the concept of face-to-face teaching. Currently an AKI 'out-reach' service is been trialled with-in the trust. There may be scope to develop this service to include an educational aspect, in addition to providing a clinical service.

Implications of our findings and the need for further work

The aim of this project was to test the hypothesis that:

Education of doctors using a multifaceted education package on Acute Kidney Injury is effective at improving knowledge and confidence on the topic, as well as clinical outcomes.

By taking into account other literature and my own results from this project, I have come to the conclusion that there is no single answer that can fully address the hypothesis posed at the start of this thesis.

It has long been recognized that delivering learning resources through didactic lectures is not an effective way to teach adults (Bryner, 1995). Equally given the changing working patterns of NHS workers, there is a need for healthcare education to adapt and reflect the changing needs of staff. Developing high-quality easy access e-learning tools may be one solution to this problem (Jadad and Delamothe, 2004). Previously reports have suggested that electronic learning may be a practical way to engage adult learners (Wee, 2012, Kulier et al., 2009, Ruiz et al., 2006). Indeed e-learning tools offer directors of medical education another way to engage staff. However, our findings show that even when an e-learning resource is designed with sound pedagogical principles and is able to deliver the relevant educational content without technological barriers, adequate engagement is not guaranteed.

A recently published single centre study from Ulster (Forde et al., 2012) used a check-list approach in conjunction with an educational program to increase awareness of AKI. Through engagement with clinical staff on the ward and recognition that changes to practice required a gradual stepwise approach, the team was able to increase recognition of AKI and increase the completion rate of the AKI checklist. Our findings build upon the findings of the Ulster group. Our project includes data on clinician's self-reported clinical practice, demonstrating increased awareness of local guidelines and a trend towards higher knowledge scores; as well as clinical audit data demonstrating a trend in improving clinical practice. This suggests that an educational intervention may be an effective and powerful way to improve outcomes in patients suffering from AKI.

There is however only limited evidence about how postgraduate education can directly impact on clinical outcomes. A meta-analysis exploring the impact of postgraduate education on evidence based medicine and clinician behaviour concluded that the most successful education programs were integrated into

practice, rather than being delivered as standalone sessions (Coomarasamy and Khan, 2004). Furthermore, Oxman *et al* studied how educational interventions could change professional behaviour, and concluded that there is no single intervention that can improve quality, but that changing the practice of professionals is a complex task, and the best chance of success comes from developing a suitable range of interventions deployed in a carefully planned manner (Oxman et al., 1995). The outcome of this project supports these findings and shows the importance of developing a structured multifaceted educational intervention to suit different learning styles of individuals.

Further research into how different learning styles of clinicians influence engagement with electronic instructional resources is needed. The findings of our project suggest that clinicians in general, still prefer to engage with face-to-face teaching methods. Further research is also needed into how web-based instructional tools may be best used to complement face-to-face teaching and how they can gain widespread acceptance by users. Their effectiveness at improving healthcare outcomes also warrants further study. Our findings reiterate that despite advances in information technology in recent years, the role of more traditional teaching methods involving expert tutors should not be overlooked when developing future postgraduate education interventions, regardless of cost and time pressures. **SUI**

Finally, our project shows that we need to develop a much greater understanding of the incidence and prognosis of AKI before we can hope to truly understand how any intervention can improve outcomes. Of particular importance is the need to better understanding of the trend identified in our results showing that nearly 60% of patients with AKI first developed it in the community.

In summary, the project has identified the following:

- AKI is common in the secondary care population; however 60% of patients with AKI first develop it in the community.
 - This finding needs to be validated in other centres and further research is needed in this area to allow us to better understand how to prevent AKI in the community.
- Currently, baseline knowledge and confidence on AKI is poor in non-specialist.
- Our knowledge about AKI prognosis and incidence needs to be evolved further; this will enable us to better understand the impact of any intervention on mortality and length of stay figures.
 - The newly published NICE guidance on AKI, along with the advent of electronic prescribing and note keeping could potentially make much larger and more inclusive audits/studies into AKI prognosis a simpler task.
- A multifaceted educational intervention developed through sound educational theory and integrated into the existing education program can increase confidence and knowledge on AKI.
 - Web-based learning resources need to be implemented with care and should not be seen as a replacement for traditional teaching methods.
- Face-to-Face, one-to-one teaching generated the best form of engagement and educational value, however, there is a challenge to sustaining this type of intervention in real life clinical practice without significant additional resource commitments.

Next steps

In light of the findings reported in this project, I have started to explore some of the questions raised in more detail. So far, I have been involved in the following projects:

- An assessment of **Knowledge of Acute Kidney Injury amongst Primary Care Professionals:**

Community health care professionals were polled before the start of face-to-face teaching sessions using a pre-designed Turning Point survey designed to assess awareness and confidence levels. They were then asked to answer 10 MCQ's on AKI diagnosis, risk reduction and clinical management to determine baseline knowledge levels.

- **Patients' Perceptions And Awareness About Medicines Management To Prevent Acute Kidney Injury:**

CKD patients attending nephrology outpatient clinics were studied using a survey assessing knowledge and confidence of medicines management during times of illness. These results were used by a group of Nephrologists, GPs and Renal Pharmacists to design a leaflet advocating sick day rules. The leaflets contained a series of structured questions about the clarity and utility of the leaflet as well as a section inviting free text comments that patients were asked to complete and return.

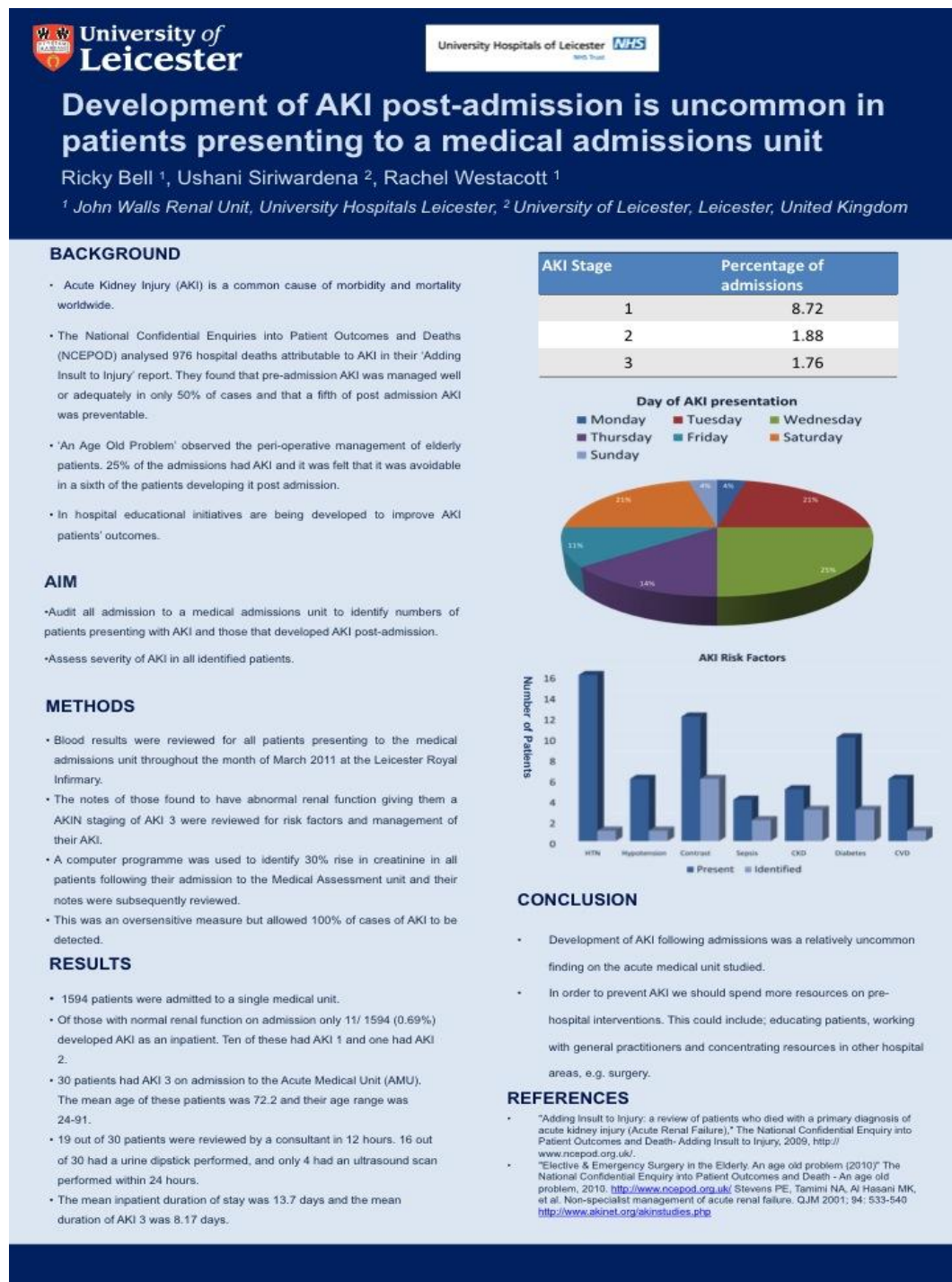
I aim to continue and develop my research skills and interest on the topic of AKI and plan to apply for an academic clinical lectureship post in the autumn of 2014, with a view of developing a project looking at AKI in the community.

8. Appendices

Appendix A: Results of Clinical Audit carried out in UHL in 2011.	150
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Appendix A: Results of Clinical Audit carried out in UHL in 2011.

Raw data from the audit was given to my self for this thesis, and results adjusted so that they could be compared to the post-intervention audit for this project.



Appendix B: Confirmation of Authorisation from Chief Executive Officers UHL

Taken from original funding application to East Midlands Health Innovation and Education Cluster East Midlands allowing the project to proceed.

Authorisation



- **Malcolm Lowe-Lauri:** CEO University Hospitals of Leicester.
– Malcolm.lowe-lauri@uhl-tr.nhs.uk
- **Stewart Petersen:** Educational Provider Lead: Head of department, Medical and Social Care Education, University of Leicester.
– Sxp@leicester.ac.uk
- **Supporting application:**
 - **Theresa Grieve:** Research & Development Derby Hospitals NHS Foundation Trust
T.grieve@derbyhospitals.nhs.uk
 - **David Hetmanski:** Assistant Director of Research and Development, University Hospitals of Leicester NHS Trust
David.hetmanski@uhl-tr.nhs.uk
- **Simon Sheppard:** Divisional Finance Lead, University Hospitals of Leicester.
– Simon.sheppard@uhl-tr.nhs.uk

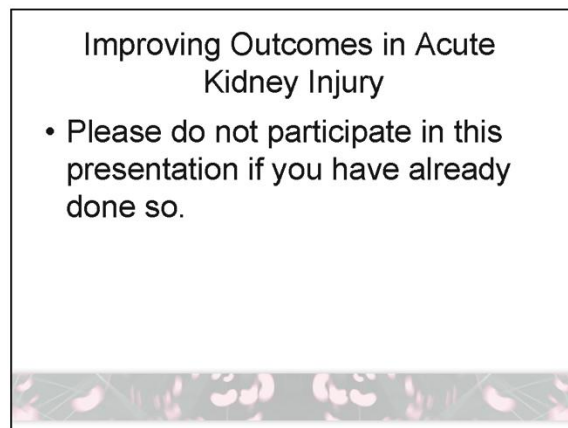
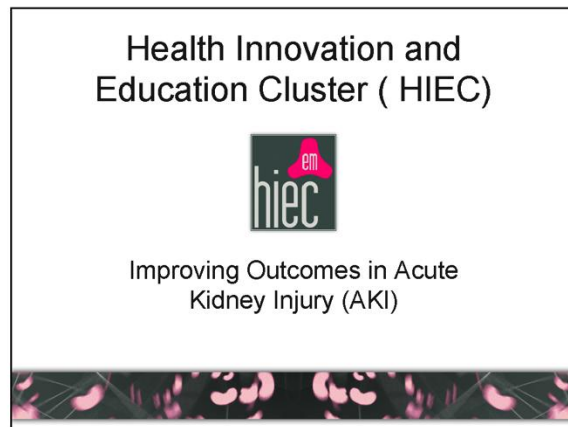
East Midlands HIEC

2

Appendix C: Pre intervention MCQ survey on AKI:

Including questions on confidence and knowledge – Part re-formatted suitable for

14/07/2014



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print.

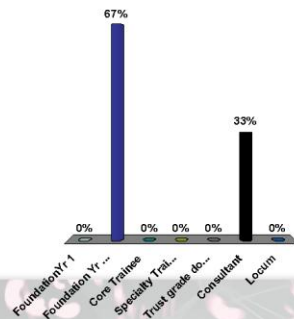
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Turning Point

- Use your handset to register your response to the question
- The software will register your last response so you can change your mind whilst the voting is still 'open'
- We will be registering votes from each handset but we have not assigned handsets to individuals
- There may be an option to enter more than 1 response- the facilitator will inform you if this is the case

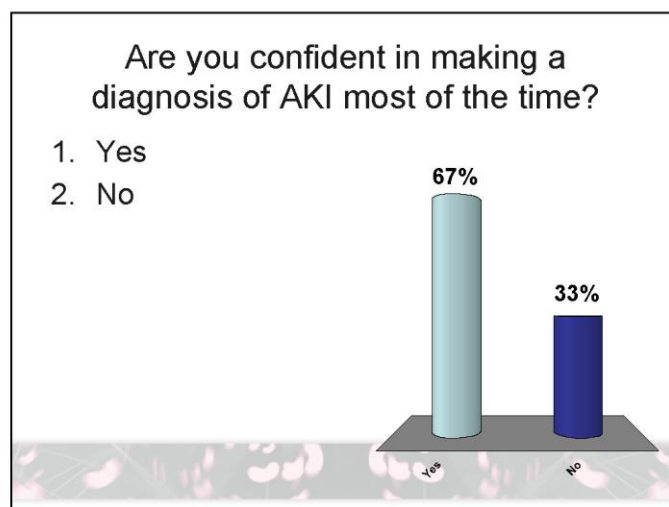
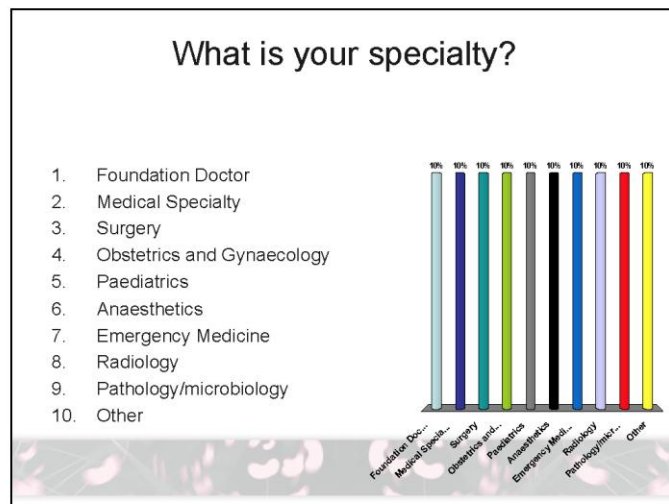
If you are a doctor- what is your grade?

1. FoundationYr 1
2. Foundation Yr 2
3. Core Trainee
4. Specialty Trainee
5. Trust grade doctor
6. Consultant
7. Locum



2

14/07/2014

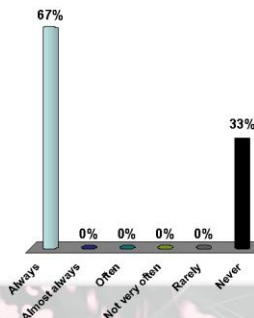


3

14/07/2014

If a patient under your care develops AKI how often would you consider that it is recognised and diagnosed?

1. Always
2. Almost always
3. Often
4. Not very often
5. Rarely
6. Never



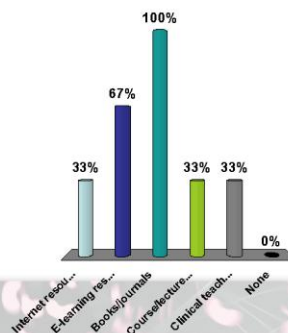
If a patient under your care develops AKI how often would you initiate a basic management plan?
(e.g. medication review, starting intravenous fluids etc.)



14/07/2014

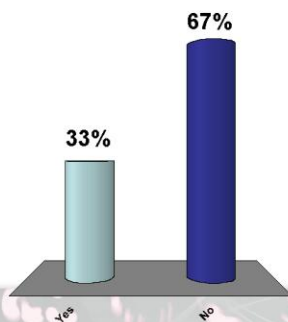
Have you used any resources to improve your knowledge of AKI?
Please tick all that apply

1. Internet resource
2. E-learning resource
3. Books/journals
4. Course/lecture/ seminar
5. Clinical teaching
6. None



Are you aware of UHL guidelines on AKI?

1. Yes
2. No



**MCQ questions on knowledge (re-formatted for easier reading in thesis):
CORRECT ANSWERS IN BOLD, RED AND CAPITALS**

Q1: Which of the following would reliably indicate that someone has Chronic Kidney Disease?

1. **PREVIOUS MEASUREMENT OF ELEVATED SERUM CREATININE**
2. High serum phosphate
3. Presence of low haemoglobin
4. History of chronic ill health
5. Hypocalcaemia

Q2: Which of the following is not a recognised risk factor for the development of AKI?

1. Age
2. **FEMALE GENDER**
3. ACE inhibitor treatment
4. Resident in a nursing home
5. Type 2 diabetes

Q3: A 60-year-old diabetic woman visited her GP with tiredness and a widespread rash. Blood pressure was 146/90. Medication: glicazide, amlodipine, aspirin & atorvastatin. She had started diclofenac 3 weeks ago for back pain.

serum creatinine 640 µmol/L (60–110)
urinalysis + protein

What is the most likely cause of her renal impairment ?

1. ☐ **ACUTE INTERSTITIAL NEPHRITIS**
2. ☐ Acute tubular necrosis
3. ☐ Acute glomerulonephritis
4. ☐ Chronic kidney disease
5. ☐ Diabetic nephropathy

Q4: A 47 year-old diabetic man attended A&E complaining of haemoptysis, epistaxis and oliguria. He had suffered a myocardial infarction 2 years previously. Blood pressure was 196/99. Medication: glicazide, losartan, amlodipine aspirin and simvastatin. He had started furosemide recently. Investigations:

serum creatinine 684 µmol/L (60–110)

urinalysis +++ blood +++ protein

What is the most likely cause of his acute kidney injury ?

1. Acute interstitial nephritis
2. Acute tubular necrosis
3. **ACUTE GLOMERULONEPHRITIS**
4. Renovascular disease
5. Diabetic nephropathy

Q5: A 76-year-old diabetic woman was referred following an episode of diarrhoea and vomiting. Past medical history: hypertension and ischaemic heart disease. On examination, pulse rate was 110 beats per minute, blood pressure 100/60. Medication: glicazide, losartan, aspirin and simvastatin.

Investigations:

serum sodium 134 mmol/L (137–144) serum potassium 5.6 mmol/L (3.5–4.9)
 serum bicarbonate 14 mmol/L (20–28) serum urea 26.0mmol/L (2.5–7.0) serum
 creatinine 690 µmol/L (60–110)

What would be your initial step in management ?

1. ☐ **STOP LOSARTAN**
2. ☐ Start sodium bicarbonate
3. ☐ Start metronidazole
4. ☐ Stop aspirin
5. ☐ Start IV dextrose and insulin

Q6: A 63-year-old diabetic man with an ischaemic right leg was admitted for an angiogram.

Investigations:

serum creatinine 225 µmol/L (60–110)
 estimated glomerular filtration rate 22 mL/min (>60)

What treatment would you prescribe to reduce the risk of contrast nephropathy?

1. IV mannitol
2. Oral n-acetylcysteine
3. Oral nifedipine
4. IV sodium bicarbonate 8.4%
5. **IV SODIUM CHLORIDE 0.9%**

Q7: A 53 year old man suffered diarrhoea and vomiting for 5 days and was admitted to hospital. He was also known to have treated hypertension. On examination, urine output was 10 ml/h, he appeared dehydrated and blood pressure was 96/60mmHg.

Investigations:

Urinalysis negative

Serum creatinine 147 $\mu\text{mol/l}$ (3 weeks ago known to be 76 $\mu\text{mol/l}$). Metabolic acidosis with base excess of -3.6 mEq/l.

He is commenced on IV fluids.

What do you aim to achieve with fluid replacement ?

1. Systolic blood pressure of 100 mmHg within 6 hours
2. Systolic blood pressure of 130 mmHg within 6 hours
- 3. SYSTOLIC BLOOD PRESSURE OF 130 MMHG WITHIN 2 HOURS**
4. Systolic blood pressure of 100 mmHg within 2 hours
5. Correct the acidaemia with IV 1.4% sodium bicarbonate

Q8: In a man with oligo-anuric AKI with a background of COPD and severe pulmonary hypertension which of the following is the most reliable guide to fluid replacement?

1. Insertion of a central venous catheter
2. Skin turgor
3. Assessment of peripheral oedema
- 4. ASSESSMENT OF A POSTURAL HAEMODYNAMIC CHANGES**
5. Serial chest X-rays to assess interstitial shadowing

Q9: A man with a past medical history of bladder cancer presents to hospital with AKI.

A urine output of 2.4L is charted for the previous 24 hours. Urinalysis is positive for a trace of blood. CRP is 45

An ultrasound is reported as moderate hydronephrosis on the right side and modest on the left.

Which of the following is the most appropriate course of action?

1. A full vasculitic screen
2. An urgent nephrological evaluation
- 3. AN URGENT UROLOGICAL EVALUATION**
4. Immediate empirical treatment for urosepsis

5. Re-imaging in 1 week to evaluate developing hydronephrosis

Q10: A 67 year old man was admitted to hospital with chest pain. He also had a history of intermittent claudication.

During his admission he was treated with a diuretic. Blood pressure was 143/78 mmHg and bedside urinalysis was positive for a trace of protein.

His eGFR was stable throughout his admission at between 35 and 40ml/min.

Which of the following is a 'red flag' to the safe prescription of an ACEi:-

1. Postural hypotension
2. Proteinuria
3. The absence of a renal ultrasound scan
4. CKD Stage 3B
5. **BILATERAL DEFICIENCY OF A DORSALIS PEDIS PULSE**

Q11: A 76 year old man is admitted having been found collapsed on the floor.

PMH: DM and hypertension.

DH: ramipril 5 mg od, aspirin 75 mg od, metformin 500mg bd, simvastatin 20 mg od and diclofenac 50mg prn.

On admission Cr 398 $\mu\text{mol/L}$ (96 $\mu\text{mol/L}$ 6 months ago). Urine dipstick blood +, prot +, leucocytes + and nitrites+.

Which of the following does not affect tubular function?

1. Diclofenac
2. Gentamicin
3. **METFORMIN**
4. Myoglobin
5. Ramipril

Q12: A 65 year-old man is admitted with oliguria and malaise. His Creatinine is 526 $\mu\text{mol/L}$. There are no significant pointers as to the cause on history or examination. Acute interstitial nephritis is suspected.

Which of the following medications is commonly association with acute interstitial nephritis?

- A. Bisoprolol

B. OMEPRAZOLE

- C. Ramipril
- D. Sertraline
- E. Simvastatin

Q13: When urea and electrolytes are tested, the results now also give an estimated GFR.

In which of the following patients is eGFR be most likely to be an accurate reflection of the actual GFR?

- A. 128 kg Caucasian male with same Cr three months previously
- B. 61 KG WOMAN WITH SAME CR THREE MONTHS PREVIOUSLY**
- C. 68 kg pregnant woman with same creatinine pre-pregnancy
- D. 70 kg Asian male with same creatinine six weeks previously
- E. 70 kg Afro-Caribbean woman who had a creatinine of 162 $\mu\text{mol/L}$ six weeks previously

Q14: A 62 year old diabetic man is admitted with acute kidney injury (AKI) presumed secondary to severe diarrhoea and vomiting. On admission, he was hypoglycaemic and his metformin and pioglitazone were stopped. Symptomatically he improves but his renal function remains impaired. His blood sugars have started to climb in response to improved oral intake.

Which of the following oral anti-hypoglycaemics is safe to prescribe in a patient with AKI?

- A. Acarbose
- B. GLICLAZIDE**
- C. Metformin
- D. Pioglitazone
- E. Exenatide

Q15: A 76 year old man is about to be discharged home having recovered from an episode of AKI on background chronic kidney disease. All his medications were stopped on admission but his renal function is now back to his normal baseline with eGFR of 42mls/min.

What advice would you give the GP about restarting his original medication?

- A. Don't restart aspirin
- B. Don't restart ramipril
- C. Don't restart metformin

- D. **START RAMIPRIL BUT WITH-HOLD IF HAS GASTROENTERITIS**
- E. Start aspirin but with-hold if has gastroenteritis

Appendix D: Post intervention MCQ survey on AKI:

Including questions on confidence and knowledge.

14/07/2014

Health Innovation and
Education Cluster (HIEC)



Improving Outcomes in Acute
Kidney Injury (AKI)
S Carr, R Westacott, R Baines

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If you are a doctor- what is your grade?

1. FoundationYr 1
2. Foundation Yr 2
3. Core Trainee
4. Specialty Trainee
5. Trust grade doctor
6. Consultant
7. Locum

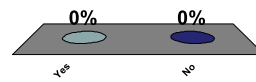


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Have you done the AKI eLearning tool?

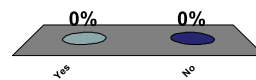
1. Yes
2. No



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Are you aware of local (UHL/Derby) guidelines on AKI?

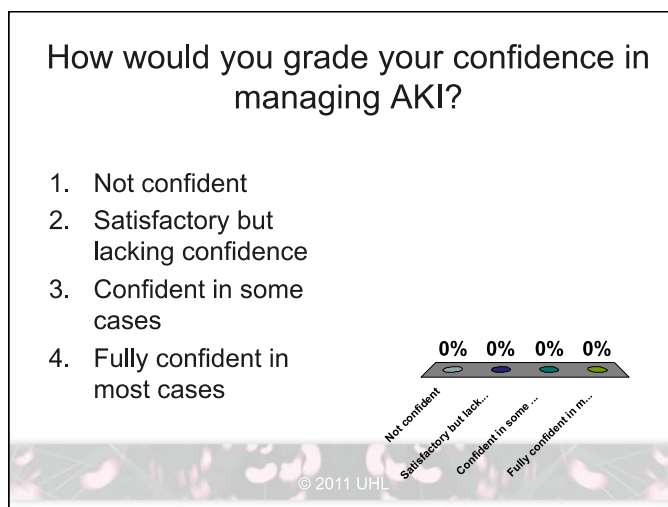
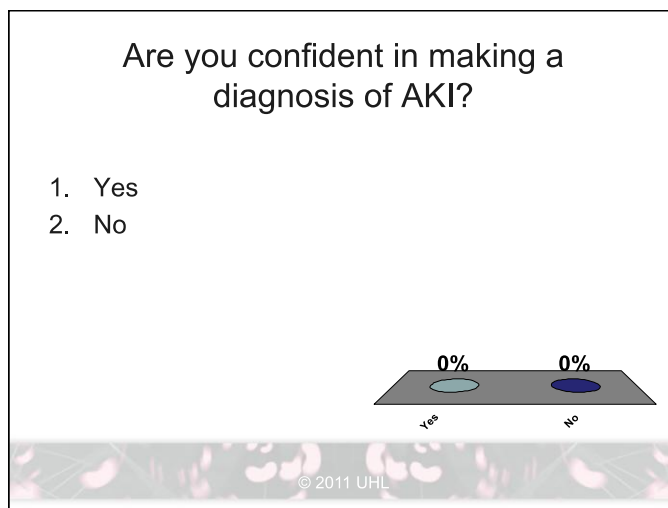
1. Yes
2. No



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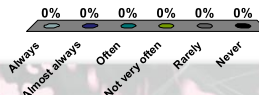


3

14/07/2014

If a patient under your care develops AKI how often would you consider that it is recognised and diagnosed?

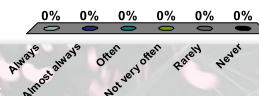
1. Always
2. Almost always
3. Often
4. Not very often
5. Rarely
6. Never



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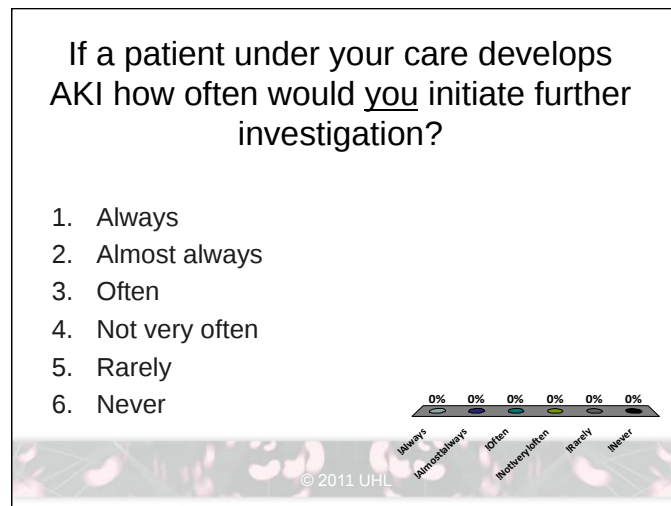
If a patient under your care develops AKI how often would you initiate a basic management plan?
(e.g. medication review, starting intravenous fluids etc.)

1. Always
2. Almost always
3. Often
4. Not very often
5. Rarely
6. Never



© 2011 UHL

14/07/2014



**MCQ questions on knowledge (re-formatted for easier reading in thesis):
CORRECT ANSWERS IN BOLD, RED AND CAPITALS**

Q1: Which of the following is a recognised risk factor for the development of AKI?

- A. Caucasian ethnicity
- B. Family history of AKI
- C. Low BMI
- D. MAJOR SURGERY**
- E. Male gender

Q2: A 57 year old man presents with SOB and oedema. He is found to have serum creatinine 420umol/l
Which of the following is the most reliably indicates the presence of Chronic Kidney Disease?

- A. High serum phosphate
- B. History of chronic ill health
- C. Hypocalcaemia
- D. Presence of low haemoglobin
- E. PREVIOUS ELEVATED SERUM CREATININE**

Q3: A 62-year-old diabetic woman visited her GP with tiredness and malaise.

Medication: glicazide, amlodipine, aspirin & atorvastatin. She had started paracetamol 3 weeks ago for back pain.

On examination: afebrile, Blood pressure was 190/90.

Previous HbA1c was recorded as 6.5%, Previous urine dip + of Protein.

Investigations:

serum creatinine 640 $\mu\text{mol/L}$

urinalysis +++ Protein

+++ Blood

What is the most likely cause of her renal impairment ?

- A. ACUTE GLOMERULONEPHRITIS**
- B. Acute interstitial nephritis
- C. Acute tubular necrosis
- D. Diabetic nephropathy
- E. Urinary tract infection

Q4: A 76-year-old diabetic woman was referred following an episode of diarrhoea and vomiting. Past medical history: hypertension and ischaemic heart disease.

On examination, pyrexial 38°C, pulse rate 110 beats per minute, blood pressure 100/50. Medication: glicazide, losartan, aspirin and simvastatin.

Investigations:

serum sodium 134 mmol/L serum potassium 5.6 mmol/L serum bicarbonate 14 mmol/L serum urea 26.0 mmol/L serum creatinine 690 $\mu\text{mol/L}$.

What would be your initial step in management ?

- A. Start IV dextrose and insulin
- B. Start IV sodium bicarbonate (8.4%)
- C. START IV SODIUM CHLORIDE 0.9%**
- D. Start metronidazole
- E. Start salbutamol nebuliser

Q5: A 63-year-old diabetic man with an ischaemic right leg was admitted for an angiogram.

Investigations:

serum creatinine 225 $\mu\text{mol/L}$

eGFR 22 mL/min

What treatment would you prescribe to reduce the risk of contrast nephropathy?

- A. IV mannitol 15%
- B. IV sodium bicarbonate 8.4%
- C. IV SODIUM CHLORIDE 0.9%**
- D. Oral calcium resonium
- E. Oral N-acetylcysteine

Q6: A 53 year old man suffered diarrhoea and vomiting for 5 days and was admitted to hospital. He was also known to have treated hypertension.

On examination, urine output was 10 ml/h, he appeared dehydrated and blood pressure was 96/60mmHg.

Investigations:

Urinalysis negative

Serum creatinine 147 $\mu\text{mol/l}$ (3 weeks ago known to be 76 $\mu\text{mol/l}$). Metabolic acidosis with base excess of -3.6 mEq/l.

He is commenced on IV fluids.

What do you aim to achieve with fluid replacement ?

- A. Systolic blood pressure of 100 mmHg within 2 hours
- B. Systolic blood pressure of 100 mmHg within 6 hours
- C. SYSTOLIC BLOOD PRESSURE OF 130 MMHG WITHIN 2 HOURS**
- D. Systolic blood pressure of 130 mmHg within 8 hours
- E. Correct the acidaemia with IV 1.4% sodium bicarbonate

Q7: In a man with oligo-anuric AKI with a background of COPD and severe pulmonary hypertension.

Which of the following is the most reliable guide to fluid replacement?

- A. ASSESSMENT FOR A POSTURAL HAEMODYNAMIC CHANGE**
- B. Assessment of peripheral oedema
- C. Insertion of a central venous catheter
- D. Serial chest X-rays to assess interstitial shadow
- E. Skin turgor

Q8: A 65 year old man with a past history lymphoma presents with AKI. He has no urinary symptoms. On examination, Urine output is documented at 2L over the last 24hours. Temperature is recorded at 37.2 degrees.

Investigations:

Urine dip: + blood trace leucocytes

Renal USS -- moderate hydronephrosis on the right side and modest on the left.

Which of the following is the most appropriate course of action?

- A. A urgent CT to assess for abdominal pathology
- B. An urgent nephrological evaluation
- C. AN URGENT UROLOGICAL EVALUATION**
- D. Repeat the USS in 48hours to evaluate progression of hydronephrosis
- E. Start empirical treatment for urosepsis

Q9: A 67 year old man was admitted to hospital with chest pain. He also had a history of intermittent claudication.

During his admission he was treated with a diuretic. On examination, Blood pressure was 143/78 mmHg

Investigations:

Urinalysis - trace of protein.

eGFR was stable throughout his admission at between 35 and 40ml/min.

Which of the following is a 'red flag' to the safe prescription of an ACEi?

- A. Postural hypotension
- B. Proteinuria
- C. The absence of a renal ultrasound scan
- D. CKD Stage 3B
- E. BILATERAL DEFICIENCY OF A DORSALIS PEDIS PULSE**

Q10: A 60-year-old diabetic woman visited her GP with tiredness

Medication: glicazide, amlodipine, aspirin & simvastatin. She had started diclofenac 3 weeks ago for back pain.

On examination, Blood pressure was 146/90, widespread rash is noted.

Investigations:

serum creatinine 640 µmol/L

urinalysis + protein

What is the most likely cause of her renal impairment ?

- A. Acute glomerulonephritis
- B. ACUTE INTERSTITIAL NEPHRITIS**
- C. Acute tubular necrosis
- D. Chronic kidney disease
- E. Diabetic nephropathy

Q11: A 76 year old man is admitted having been found collapsed on the floor. He had a past history of hypertension and diabetes
Medication: Ramipril, Aspirin, Metformin, Simvastatin and Diclofenac

Investigations:

On admission serum creatinine 398 $\mu\text{mol/L}$ (96 $\mu\text{mol/L}$ 6 months ago). Urine dipstick blood +, protein +, leucocytes + and nitrites+.

Which of the following does not affect tubular function?

- A. Diclofenac
- B. Gentamicin
- C. METFORMIN**
- D. Myoglobin
- E. Ramipril

Q12: A 65 year-old man is admitted with oliguria and malaise. His creatinine is 526 $\mu\text{mol/L}$. There are no significant pointers as to the cause on history or examination. Acute interstitial nephritis is suspected.

Which of the following medications is commonly associated with acute interstitial nephritis?

- A. Bisoprolol
- B. OMEPRAZOLE**
- C. Ramipril
- D. Sertraline
- E. Simvastatin

Q13: In which of the following situations is eGFR a reliable estimate of kidney function?

- A. Acute kidney injury
- B. Malnutrition

C. PATIENT WITH SINGLE KIDNEY

- D. Patient been treated for UTI with trimethoprim
- E. Pregnancy

Q14: A 58 year old diabetic man was admitted with acute kidney injury (AKI) secondary to severe diarrhoea and vomiting. On admission, he was hypoglycaemic and his Metformin and Pioglitazone were stopped. Symptomatically he improves but his renal function remains impaired. His blood sugars have started to climb in response to improved oral intake.

Which of the following oral anti-hypoglycaemics is safe to prescribe in a patient with AKI?

- A. Acarbose
- B. Exanatide
- C. GLICLAZIDE**
- D. Metformin
- E. Pioglitazone

Q15: A 76 year old man is about to be discharged home having recovered from an episode of AKI on background chronic kidney disease.

All his medications were stopped on admission but his renal function is now back to his normal baseline with eGFR of 42mls/min.

What advice would you give the GP about restarting his original medication?

- A. Do not restart aspirin
- B. Don't restart Metformin
- C. Restart Ramipril
- D. START RAMIPRIL BUT WITH-HOLD IF HAS GASTROENTERITIS**
- E. Start Aspirin but with-hold if has gastroenteritis

Appendix E: E-mail survey sent to users of the Web Based Learning resource.

[SURVEY PREVIEW MODE] AKI eLearning tool survey.

10/07/2014 21:32

AKI eLearning tool survey.

[Exit this survey](#)

1. Tell us about yourself..

☐ Foundation year doctor

☐ Specialist trainee doctor

☐ Senior doctor

☐ Senior nursing staff

☐ Junior nursing staff

☐ Other (please specify)

2. How often do you deal with patients with Acute Kidney Injury

☐ All the time

☐ Often (once a week)

☐ Sometimes (once a month)

☐ Rarely

3. How did you learn about the Acute Kidney Injury eLearning tool..

☐ Insite website

☐ Email

☐ Word of mouth

☐ Other (please specify)

4. Regarding how you learn, please rank the different learning methods in order of preference...

1: Most preferred

2:

3:

4: Least preferred

 Lectures

 Books

 Courses

 eLearning

5. Did you find the Acute Kidney Injury eLearning tool easy to navigate?

[SURVEY PREVIEW MODE] AKI eLearning tool survey.

10/07/2014 21:32

Yes

No

If "No" any suggestions

6. How confident were you at looking after patient with Acute Kidney Injury before doing the AKI module?

Very confident

Confident

Not confident

7. How did completing the module affected your confidence in looking after patients with Acute Kidney Injury...

A lot more confident

A bit more confident

Not any more confident

Made me more confused

8. Did you feel the educational content of the module was relevant to your daily work...

Very relevant

Some relevance

Not relevant

9. Would you recommend the module to a colleague?

Definatly

May be

No

10. Any comments about how the module could be improved...

Done

Powered by **SurveyMonkey**
Check out our [sample surveys](#) and create your own now!

https://www.surveymonkey.com/s.aspx?PREVIEW_MODE=DO_NOT_USE...ION&sm=HZGxPJKurM4CZMY2wvh_2BzcF92bF_2FAjUzQQ_2FVyTpbo_3D

Page 2 of 3

Appendix F: Teaching slides used to aid the tutor in face to face teaching sessions.

Slide were presented on portable displays (iPads).

Causes of AKI

Pre-renal/ATN (80% of cases)

- Drug induced TIN
- Immunological renal disease

Post-renal obstruction (10% of cases)

- Myeloma

ALWAYS DIP THE URINE

Urine dip is not to look for infection, it's to help with diagnosis

- NAD**
Pre-renal
Post-renal
Myeloma
Drug-induced TIN (renovascular)
- Blood and protein**
Still can be ATN, but raises the possibility of immunological renal disease e.g. vasculitis
- Proteinuria (PCR > 3)**
(=Protein loss > 3g per day)
Definitely glomerular

Investigation of AKI

- Everybody:
 - Urine dip
 - Ultrasound
 - (obstructive symptoms, stage 2 or above)
 - Myeloma screen
 - (electrophoresis & serum free light chains)
- Active urine:
 - Nephritic screen
 - ANCA, Anti GBM
 - ANA
 - C3 + C4
 - Hep B and C
 - Anti-streptolysin O titre
 - Urine PCR

Immunological renal disease

- Urine dip $\geq 2+$ blood and $2+$ protein
- Systemic symptoms
- Vasculitic skin rash
- Haemoptysis, epistaxis

If suspected, refer without delay

AKI Stage

High Risk 1 2 3

- Discontinue all nephrotoxic agents when possible
- Ensure volume status and perfusion pressure
- Consider functional hemodynamic monitoring
- Monitor Serum creatinine and urine output
- Avoid hyperglycemia
- Consider alternatives to radiocontrast procedures
- Non-invasive diagnostic workup
- Consider invasive diagnostic workup
- Check for changes in drug dosing
- Consider Renal Replacement Therapy
- Consider ICU admission
- Avoid subclavian catheters if possible

AKI learning objectives:

- Recognise patients with AKI
- Recognise patients at risk with AKI
- Initiate appropriate investigations for patients with AKI
- Initiate appropriate treatment for patients with AKI, referral to specialist if needed.

AKI is a marker of an unwell patient

- 24% mortality rate in patients with AKI

**Rates displayed are unadjusted, crude mortality rates*

AKI is relevant to all specialties

Only 7.5% of patients under nephrology

AKI is preventable

...by doing the basics well

AJKD
Original Investigation

Early Nephrologist Involvement in Hospital-Acquired Acute Kidney Injury: A Pilot Study

Gaetano Bellomo, MD^{1,2}, David A. Asch, MD^{1,2}, Abdul Aziz, MD^{1,2}, Michael Rosman, MD^{1,2}, Zhou Zhang, MD^{1,2}, Rajashree Gopalakrishnan, MD^{1,2}, Ramona Balasubramanian, MD^{1,2}, and Peter W. G. De Azavedo, MD^{1,2}

Outcome: Primary outcome defined as a 2.5-fold increase in SCr level from admission. Measurement: Daily SCr until discharge.

Results: The 2 groups had similar characteristics at baseline and at the time of AKI. The intervention was completed at a mean of 13.1 $\pm$ 0.8 hours from the onset of AKI. Nephrology recommendations in the EARLI group included specific diagnostic, therapeutic, and preventative components. The primary outcome occurred in 12.8% of patients in the control group compared with 0.3% of patients in the EARLI group ($P = 0.02$). Patients in the EARLI group had a lower peak SCr level (1.8 ± 0.1 versus 2.1 ± 0.2 mg/dL in controls ($P = 0.01$)).

Management:

- Risk factors
- Investigations - causes
- Getting the basics right
- Monitoring

Table 6 | Causes of AKI: exposures and susceptibilities for non-specific AKI

Exposures	Susceptibilities
Sepsis	Dehydration or volume depletion
Critical illness	Advanced age
Circulatory shock	Female gender
Burns	Black race
Trauma	CKD
Cardiac surgery (especially with CPB)	Chronic diseases (heart, lung, liver)
Major noncardiac surgery	Diabetes mellitus
Nephrotoxic drugs	Cancer
Radiocontrast agents	Anemia
Poisonous plants and animals	

CKD, chronic kidney disease; CPB, cardiopulmonary bypass.

Dissemination of research:

Award:

- Winner of BMJ Group Award: Excellence in Healthcare Education Category, May 2013, London.

Paper published:

- **Xu, G.** Baines, R. Westacott, R. Selby, N. Carr, S. (2014) An educational approach to improve outcomes in acute kidney injury (AKI): report of a quality improvement project. *BMJ open*. 4(3).
- Bryne, J. **Xu, G.** Carr, S (2014). Developing an intervention to prevent acute kidney injury: Using the Plan, Do, Study, Act (PDSA) service improvement approach. Accepted by *Journal of Renal Care* (2014). in press

Papers under review:

- **Xu, G.** Westacott, R. Baines, R. Selby, N. Carr, S. (2014) The Challenge of Engagement: Web-based learning in the postgraduate medical arena.

Abstracts presented:

- **Xu, G.** Baines, R. Westacott, R. Trew, J. Kirtley, J. Selby, N. Carr, S. Changes in knowledge and confidence of general physicians and trainees on the subject of Acute Kidney Injury after exposure to a multifaceted education program. **Poster Presentation.** *International Society of Nephrology annual meeting 2013*, HongKong.
- **Xu, G.** Thompson, C. Baines, R. Westacott, R. Trew, J. Kirtley, J. Selby, N. Carr, S. Improving knowledge and confidence of general physicians and trainees on the subject of Acute Kidney Injury through novel education tools; Results from 2 UK teaching hospitals. **Poster Presentation.** *European Renal Association - European Dialysis and Transplant Association annual meeting 2013*, Istanbul.
- **Xu, G.** Thompson, C. Baines, R. Westacott, R. Trew, J. Kirtley, J. Selby, N. Carr, S. Variation in the confidence and knowledge of general physicians managing Acute kidney injury: a need for better education. **Poster Presentation.** *American Society of Nephrology annual meeting 2012*, San Diego.

- **Xu, G.** Baines, R. Westacott, R. Trew, J. Kirtley, J. Selby, N. Carr, S. Confidence and knowledge in dealing with AKI: Results of a survey of medical staff in 2 large UK teaching hospitals. **Poster Presentation.** *Renal Association meeting 2012*, Newcastle.
- **Xu, G.** Thompson, C. Baines, R. Westacott, R. Trew, J. Kirtley, J. Selby, N. Carr, S. Acute Kidney Injury: Reported previously education and use of educational resources by medical staff in 2 large UK teaching hospitals. **Poster Presentation.** *Renal Association meeting 2012*, Newcastle.

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