NICE National Institute for Health and Care Excellence

NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

Diagnostics Assessment Programme

Point-of-care creatinine tests to assess kidney function before administering intravenous contrast for computed tomography (CT) imaging

Final scope

October 2018

1 Introduction

The medical technologies topic oversight group selected and routed point-of-care creatinine tests to assess kidney function before administering intravenous contrast for computed tomography (CT) imaging for guidance development by the Diagnostics Assessment Programme on the basis of a briefing which was published as a NICE medtech innovation briefing. The final scope was informed by discussions at the scoping workshop on 25 September 2018 and the assessment subgroup meeting held on 10 October 2018. A glossary of terms and a list of abbreviations are provided in appendices A and B.

2 Description of the technologies

This section describes the properties of the diagnostic technologies based on information provided to NICE by manufacturers and experts. NICE has not carried out an independent evaluation of this description.

2.1 Purpose of the medical technologies

Point-of-care (POC) creatinine tests enable rapid measurement of creatinine levels which can indicate if the kidneys are working properly. The focus of the assessment will be POC creatinine testing to assess kidney function before people have intravenous contrast for CT imaging. Testing is important because iodine-based contrast media can cause kidney injury, particularly in high-risk patients and those with known kidney dysfunction.

If patients do not have a recent creatinine measurement, their imaging may be delayed while a test is processed in the laboratory, or it may be cancelled and rescheduled. Alternatively, if the person is thought to be at low risk of kidney

injury the planned contrast agent may be given, risking kidney injury. Sometimes, to avoid the risk of kidney injury, people may have unenhanced imaging which is less accurate than contrast-enhanced imaging. This can negatively impact on clinical decisions related to treatment and could lead to the need for further tests to confirm a diagnosis. POC creatinine testing may reduce the incidence of delayed or cancelled scans, minimise the risk of kidney injury and improve the patient experience.

The risk of a creatinine measurement not being available in advance of a scan is greatest for people who have an out-patient appointment. People who are an in-patient or are admitted as a day-patient to have their scan are more likely to have a creatinine measurement available because they would have this as part of their pre-operative or pre-admission assessment, or as part of routine blood tests taken whilst they are in hospital. All angiography and interventional radiology and cardiology procedures would be performed as in-patient or day-patient appointments. This assessment therefore focuses on the area of greatest unmet need in terms of assessing kidney function before imaging, which is CT scans with intravenous contrast agent performed in the radiology department as out-patient appointments.

2.2 Product properties

Creatinine is a waste product made in the muscles. It passes in the blood to the kidneys and is excreted in the urine, therefore high levels in the blood might indicate that the kidneys are not working correctly. Creatinine levels can be combined with information on age, sex and race, using various different equations, to estimate another indicator of kidney function, glomerular filtration rate (GFR). This is a measure of the flow rate of blood passing through the kidneys. The NICE guideline on chronic kidney disease in adults recommends using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine equation to estimate GFR. Another frequently used equation is the MDRD (modification of diet in renal disease) equation.

2.2.1 Technologies

All the technologies included in table 1 are CE marked and measure creatinine using an enzymatic method. Devices are either handheld, table-top or portable and need very small samples of blood from either finger-prick or venous/arterial samples. Creatinine may be measured either as one component of a panel of parameters, or as a single measurement via a test card or cartridge specific for creatinine or kidney function. Only tests that can use whole blood as a sample, and that calculate estimated GFR have been included.

Table 1 List of devices with specifications

Device	Analyser	Parameters measured	Sample type (volume)	Analysis time	eGFR (equation)	Creatinine range (µmol/l)
Nova StatSensor (Nova Biomedical)	Handheld	Creatinine only	Whole blood (1.2 µl)	30 seconds	Yes (MDRD, Cockcroft-Gault, Schwartz and Counahan-Barratt)	27–1,056
i-STAT Alinity (Abbott)	Handheld	Multiple parameters; creatinine cartridge available	Whole blood (65 µl)	2 minutes	Yes	18–1,768
ABL90 FLEX PLUS (Radiometer)	Portable system	19 parameters	Whole blood (65 µl)	35 seconds	Yes (CKD-EPI, MDRD and Schwartz)	10–1,800
ABL800 FLEX (Radiometer)	Table-top	18 parameters	Whole blood (125–250 µl)	1 minute	Yes (CKD-EPI and MDRD)	10–1,800
epoc Blood Analysis System (Siemens Healthineers)	Handheld	11 parameters on one test card	Whole blood (92 µl)	<1 minute	Yes (CKD-EPI, MDRD and Schwartz)	27–1,326
Piccolo Xpress (Abaxis)	Table-top	Multiple parameters; kidney check panel available	Whole blood (100 µl)	<14 minutes	Yes (MDRD)	18−1,768
Dri-chem NX500 (Fujifilm)	Table-top	Multiple parameters, each with a different slide available	Whole blood (filter generates plasma; 10 µl)	5 minutes	Expected	

Abbreviations: CKD-EPI, chronic kidney disease epidemiology; eGFR, estimated glomerular filtration rate; MDRD, modification of diet in renal disease; µl, microlitres; µmol/l micromole per litre

The Schwartz equation is often used for children in NHS practice.

3 Target conditions

3.1 Contrast-induced acute kidney injury

3.1.1 Acute kidney injury

The term acute kidney injury (AKI) covers a range of injury to the kidneys which can result from a number of causes, often as a complication of another serious illness. The main role of the kidneys is to remove waste and excess fluid from the blood, as urine via the bladder. If AKI is present and not treated promptly, levels of salts and chemicals in the body can increase, which affects the fluid balance in the body and the ability of other organs to work properly (NHS website).

Some people are more likely to get AKI, including people:

- aged 65 or over
- who already have a kidney problem
- with a long-term disease, such as heart failure, liver disease or diabetes
- who are dehydrated
- with a blockage in their urinary tract
- with a severe infection or sepsis
- taking certain medicines**,** including non-steroidal anti-inflammatory drugs or blood pressure drugs, such as ACE inhibitors or diuretics.

AKI is seen in 13–18% of all people admitted to hospital, with older adults being particularly affected. The number of inpatients affected by AKI means that it has a major impact on healthcare resources. The costs to the NHS of AKI (excluding costs in the community) are estimated to be between £434 million and £620 million per year (NICE CG169).

3.1.2 Contrast-enhanced imaging

Contrast agents are chemical substances which are used to improve the quality of medical images by increasing the visibility of specific organs, blood vessels or tissues. This helps clinicians diagnose medical conditions because they can more easily distinguish healthy tissue from diseased tissue.

Contrast-enhanced imaging is performed for many reasons, for example:

- diagnosis and treatment of vascular diseases such as coronary artery disease and pulmonary thromboembolism

- diagnosis, staging and monitoring of cancer
- diagnosis of inflammatory and infectious diseases such as multiple sclerosis, meningitis and pancreatitis
- some types of trauma

Iodine-based contrast agents are used in CT imaging and can be administered intravascularly. Different types of agent are available and the dose can be adjusted depending on the type of scan and the risk level of the patient. Gadolinium-based intravascular contrast agents are generally considered to be much lower risk for causing AKI than intravascular iodine-based contrast agents, and are therefore not included in this scope.

Expert opinion is that contrast-enhanced CT scans are infrequently used in children, and would only be used if other imaging modalities, such as MRI, are not suitable. The scope therefore focuses on the use of contrast-enhanced imaging in adults.

3.1.3 Contrast-induced acute kidney injury

Contrast-induced acute kidney injury (CI-AKI) is one of the most important adverse effects of intravascular contrast media. The Contrast Media Safety Committee of the European Society of Urogenital Radiology recommends that the term contrast-induced AKI (CI-AKI) is reserved for cases where a causal relation can be shown between the administered contrast media and the deterioration in renal function. When a causal relationship cannot be determined, the term post-contrast AKI (PC-AKI) should be used. PC-AKI is defined as a sudden deterioration in renal function within 48−72 hours of the intravascular administration of iodine-based contrast media. However, in clinical practice it is usually difficult to distinguish CI-AKI from PC-AKI (van der Molen et al. 2018).

Incidence of CI-AKI in patients undergoing non-emergency CT scans with intravascular contrast agent is reported to be very low, at less than 1%. Incidence is reported to be higher in people who already have chronic kidney disease (4%), in critically ill patients (18%) and in people who have contrast-enhanced imaging performed in an emergency (10%) (Ozkok et al. 2017). Other risk factors include older age, diabetes, use of nephrotoxic drugs and reduced kidney function (for example, if a person is dehydrated or has congestive heart failure).

Short and long-term mortality rates have been found to be significantly higher in patients with CI-AKI compared with patients without CI-AKI. Further, a history of CI-AKI may be associated with development of chronic kidney disease and progression to end stage renal disease (Ozkok et al. 2017).

3.2 Diagnostic and care pathway

3.2.1 Assessment of risk for contrast-induced acute kidney injury

The NICE guideline on acute kidney injury: prevention, detection and management and the Renal Association guideline on the prevention of CI-AKI in adult patients both say that before using iodinated contrast agents for imaging, the presence of risk factors for CI-AKI should be identified and kidney function should be assessed. Both guidelines note, however, that risk assessment should not delay emergency imaging, that is, when the benefit of very early imaging outweighs the risk of delaying the scan or procedure. The Renal Association guideline on the prevention of CI-AKI in adult patients suggests that eGFR should be used to assess kidney function in stable outpatients whereas serum creatinine should be used to assess kidney function in acutely ill patients or patients with AKI.

The NICE guideline on acute kidney injury: prevention, detection and management recommends that an eGFR measurement should be taken within 3 months before administering iodinated contrast agents to adults. The European Society of Urogenital Radiology guideline on post-contrast acute kidney injury (2018) recommends that for people with an acute disease, an acute deterioration of a chronic disease or who are hospital inpatients, eGFR measurement should be taken within 7 days before contrast medium administration.

The threshold for eGFR at which there is a risk of developing CI-AKI varies across different guidelines. The European Society of Urogenital Radiology guideline on post-contrast acute kidney injury (2018) notes that an eGFR less than 30 ml/min/1.73 m^2 before intravenous contrast medium is a risk factor for AKI. The NICE guideline on acute kidney injury: prevention, detection and management notes that adults with an eGFR less than 40 ml/min/1.73 m^2 are at particular risk of CI-AKI, whereas the Renal Association guideline on the prevention of CI-AKI in adult patients states that the risk of CI-AKI becomes clinically important with an eGFR < 60 ml/min/1.73m^2. The Royal Australian and New Zealand College of Radiologists (RANZCR) guideline on iodinated contrast media (2016) notes that the risk of CI-AKI remains uncertain for people with an eGFR of less than 45 ml/min/1.73m^2, but if there is a risk, it is greatest in those with an eGFR of less than 30 ml/min/1.73m^2. The Royal College of Radiologists have endorsed the RANZCR guideline.

In addition to eGFR, guidelines note the following risk factors for CI-AKI in relation to the patient:

- age 75 years or over

- hypovolaemia (decreased blood volume)
- dehydration
- heart failure
- diabetes with co-existing chronic kidney disease
- cancer
- history of kidney disease (dialysis, kidney transplant, single kidney, renal cancer, renal surgery, AKI)
- sepsis
- nephrotoxic medication (aminoglycosides, NSAIDs, amphotericin B)

Increased risk of CI-AKI in relation to the CT scan include:

- increasing volume of contrast agent
- multiple administrations of contrast media within a few days.

Intra-arterial administration of contrast agent is also associated with increased risk of CI-AKI, however, this is outside of the scope for this assessment.

Questionnaires for the assessment of risk associated with administering intravascular iodinated contrast agent are available from the European Society of Urogenital Radiology and RANZCR. Local protocols in hospitals are also likely to contain questionnaires on risk assessment.

The Renal Association guideline on the prevention of CI-AKI in adult patients suggests that patients identified to be at high risk of CI-AKI are discussed with a renal physician to assess whether the potential benefit from the administering iodinated contrast outweighs the increased risk of CI-AKI.

Two surveys of UK NHS trusts were conducted in 2015 (Cope et al. 2017 and Harris et al. 2016). Both aimed to assess screening practices before administration of intravascular contrast for imaging, strategies to minimise the risk of kidney injury, and follow-up to detect kidney injury. Harris et al. focused on review of local policies, whereas Cope et al. focused on auditing compliance with local policies. Both studies found wide variation in clinical practice, and Cope et al. found poor compliance with current UK guidance, therefore not all patients had creatinine measured before administration of intravascular contrast for imaging.

3.2.2 Prevention of contrast-induced acute kidney injury

The Renal Association guideline on the prevention of CI-AKI in adult patients suggests that unenhanced scanning or alternative imaging techniques should be considered in patients with risk factors for developing CI-AKI. Alternatively it suggests that the lowest possible volume of a low or iso-osmolar iodinated

contrast medium should be used in patients with risk factors for developing CI-AKI.

Guidelines also recommend that adults having iodinated contrast agents should be offered intravenous volume expansion (either isotonic sodium bicarbonate or 0.9% sodium chloride) if they are at increased risk of CI-AKI.

The NICE guideline on acute kidney injury: prevention, detection and management additionally recommends that:

- adults having iodinated contrast agents should consider temporarily stopping ACE inhibitors and angiotensin receptor blockers if they have chronic kidney disease with an eGFR less than 40 ml/min/1.73 m^2.

- care should be discussed with a nephrology team before iodinated contrast agent is offered to adults with contraindications to intravenous fluids if they are at increased risk of CI-AKI.

This NICE guideline is being updated, and is expected to publish in April 2020. The update will focus on the prevention of AKI in adults having iodinated contrast agents, specifically on the use of intravenous volume expansion.

Clinical experts have noted that decisions relating to imaging will depend on the individual patient and their risk factors and on the type of CT scan they are having. Generally, all patients having a scan would be asked to orally hydrate in advance of their appointment. If the eGFR is less than 30 ml/min/1.73 m^2, a radiologist and a renal specialist would be involved in the decision on whether to continue with the scan. If the decision is to go ahead with the scan, the patient would either continue with oral hydration or have intravenous hydration. If intravenous hydration is needed the CT scan would have to be rescheduled. The patient would also be asked to have a blood test with their GP 48 hours after the scan to check eGFR and monitor for development of AKI. If the eGFR result suggests PC-AKI or renal dysfunction, the GP will refer the patient to a renal specialist.

Sometimes CT scans may be performed with a lower dose of intravenous contrast agent in people at high risk of kidney injury. Lower doses of contrast agent will usually enable satisfactory clinical decision making, however, lower doses generally cannot be used in people with a larger than average body weight or a significantly slow cardiac output.

3.2.3 Detection and management of acute kidney injury

The NICE guideline on acute kidney injury: prevention, detection and management recommends that acute kidney injury should be detected using the RIFLE, AKIN or KDIGO definitions, by using any of the following criteria:

- a rise in serum creatinine of 26 micromol/litre or greater within 48 hours
- a 50% or greater rise in serum creatinine known or presumed to have occurred within the past 7 days
- a fall in urine output to less than 0.5 ml/kg/hour for more than 6 hours in adults

It also recommends that serum creatinine should be monitored regularly in all adults, children and young people with or at risk of acute kidney injury.

The European Society of Urogenital Radiology guideline on post-contrast acute kidney injury (2018) defines post-contrast and contrast-induced AKI as an increase in serum creatinine of 26 micromol/litre or more, or an increase in serum creatinine of 1.5 or more times baseline (KDIGO definition of AKI) in the 48 to 72 hours following contrast medium administration.

In terms of treatment, the NICE guideline on acute kidney injury: prevention, detection and management recommends:

- renal replacement therapy (dialysis) in some situations,
- loop diuretics for treating fluid overload or oedema in people waiting to have dialysis, and in people who don't need dialysis.

3.3 Patient issues and preferences

If a creatinine measurement is not available, a scan may be delayed, or may need to be cancelled and rescheduled. This would be an inconvenience to patients and their carers or families in terms of time and expense taken to travel to the hospital and any time spent waiting at the hospital. Also, the potential anxiety associated with having a scan may be experienced over a longer time period if the scan is delayed or rescheduled. If a point-of-care creatinine test was available in these situations, the inconvenience and anxiety could be reduced.

4 Comparator

The alkaline picrate (Jaffe) method is a colourimetric assay often used in laboratories for creatinine testing, but can be affected by interfering substances including ketones, some drugs, and bilirubin. Testing can also be

done using an enzymatic method, which is less prone to interference, but is more expensive. Both methods take only minutes to give a result, however, taking into account sample delivery, testing and reporting, the turnaround for an urgent sample is around 1 hour. In order to reduce error and maximise the comparability of creatinine measurements between laboratories, methods should be calibrated against isotope-dilution mass spectrometry (ID-MS). ID-MS may be used as a reference standard method, however, it is not suitable for high-throughput use (Association for Clinical Biochemistry and Laboratory Medicine).

For non-emergency administration of intravenous contrast for CT scans, a creatinine test can be done up to 3 months in advance of the scan (unless the person has an acute disease, an acute deterioration of a chronic disease or has recently been in hospital). Therefore, a blood sample can be taken at a GP surgery and sent to the laboratory for non-urgent processing. If this has not been arranged and a person does not have a creatinine measurement available on the day of the scan, a blood sample could be taken at the hospital and sent for urgent processing by the laboratory before the imaging takes place. Alternatively, the imaging could go ahead without a creatinine measurement, particularly in people who are low risk for CI-AKI.

5 Scope of the assessment

Table 2 Scope of the assessment

Decision question	Does point-of-care creatinine testing before administering intravenous contrast for outpatient CT imaging represent a clinically- and cost-effective use of NHS resources?
Populations	Adults who need non-emergency intravenous contrast for a CT scan performed in an outpatient appointment and who do not have a recent* creatinine measurement. Where data permits, the following subgroups may be considered: • People with known existing kidney disease • People at high risk of AKI *Recent is defined as within 3 months for people who are low risk for kidney injury, and within 7 days for people with cardiorenal syndrome, an acute disease or an acute deterioration of a chronic disease.
Interventions	• Nova StatSensor (Nova Biomedical) • i-STAT Alinity (Abbott) • ABL90 FLEX PLUS (Radiometer)

	• ABL800 FLEX (Radiometer) • epoc Blood Analysis System (Siemens Healthineers) • Piccolo Xpress (Abaxis) • Dri-chem NX500 (Fujifilm)
Comparators	1. Non-urgent laboratory based serum creatinine measurement: (a) Jaffe method; (b) enzymatic method. 2. Urgent laboratory based serum creatinine measurement: (a) Jaffe method; (b) enzymatic method. 3. No testing, clinical judgement alone
Healthcare setting	Secondary care (radiology department)
Outcomes	Intermediate measures for consideration may include: • Diagnostic accuracy of POC creatinine tests compared with laboratory-based creatinine tests (based on either creatinine or eGFR) • Agreement between POC creatinine tests and laboratory-based creatinine tests (based on either creatinine or eGFR) • Test failure rates • Number of delayed, or cancelled and rescheduled scans • Volume of intravenous contrast material used • Number of unenhanced scans • Number of hospital admissions • Hospital length of stay
	Clinical outcomes for consideration may include: • Acute kidney injury (either post-contrast or contrast-induced) • Fall in baseline eGFR or rise in baseline creatinine • Temporary renal replacement therapy • New onset chronic kidney disease of stage 3 or worse • End stage renal disease with the need for renal replacement therapy • Mortality
	Patient-reported outcomes for consideration may include: • Health related quality of life
	Costs will be considered from an NHS and Personal Social Services perspective. Costs for consideration may include: • Costs of testing • Set up and support costs for POC testing

	• Staff time and training • Phlebotomy appointments for blood sample • Cost of imaging and associated costs (contrast agents, intravenous hydration, etc.) • Cost of follow-up imaging or other testing • Cost of cancelled or delayed CT scans • Costs associated with the treatment of kidney disease • Cost associated with the treatment of the underlying clinical condition
	The cost-effectiveness of interventions should be expressed in terms of incremental cost per quality-adjusted life year.
Time horizon	The time horizon for estimating clinical and cost effectiveness should be sufficiently long to reflect any differences in costs or outcomes between the technologies being compared.

6 Other issues for consideration

Most evidence identified during scoping relates to the diagnostic accuracy of POC creatinine tests compared with laboratory creatinine measurement. It is likely that linked evidence modelling will be needed to estimate the occurrence of post-contrast AKI, chronic kidney disease, end stage renal disease and death.

The clinical outcomes relating to the underlying reason for performing imaging may be affected by:

- Performing unenhanced imaging or imaging with lower doses of contrast agent
- A delay in performing imaging because the initial scan was rescheduled due to absence of creatinine measurement

The effect may be different across different clinical indications. These outcomes may need to be considered in the assessment.

7 Potential equality issues

NICE is committed to promoting equality of opportunity, eliminating unlawful discrimination and fostering good relations between people with particular protected characteristics and others.

Kidney disease occurs more frequently in males, people over the age of 60, and those of African-Caribbean, African or South-Asian family origin. The

estimated GFR equation can be adjusted to reflect the race, age and sex of the patient. Estimated GFR should be interpreted with caution in people with extremes of muscle mass, for example, in bodybuilders, people who have had an amputation or people with muscle wasting disorders.

In addition, people who have an ileostomy are at an increased risk of becoming dehydrated and may need special consideration when pre- and post-scan hydration is recommended.

8 Potential implementation issues

The adoption team collated information from healthcare professionals working in NHS organisations who have experience of either testing creatinine, doing contrast-enhanced imaging or requesting contrast-enhanced imaging. It noted that the potential benefits of point-of-care creatinine testing are greatest when:

- people have to wait longer than 3 months after referral
- the clinical condition has changed since referral for the scan (for example new comorbidities)
- a last minute decision is made to use contrast-enhanced imaging.

No contributors were using point-of-care creatinine tests to assess kidney function before contrast-enhanced imaging, but all reported implementing protocols to increase the availability of eGFR at the time of the scan. These include:

- targeting primary care to ensure eGFR is requested at the time of scan referral
- radiology only booking imaging once eGFR is available.

The key considerations for adoption highlighted through discussions with expert contributors are described below.

Quality assurance

Quality assurance processes must be in place to give confidence in the reliability of the result. This includes ensuring:

- staff are trained and competent to use the technology
- regular internal and external quality control tests
- the technology receives regular maintenance services.

Manufacturers are likely to provide training at the point of purchase and offer additional training for a fee.

Care pathway

Differences in clinical protocols exist between sites in terms of:

- how recent the eGFR result should be for unstable patients and those with comorbidities
- the eGFR/creatinine thresholds used to determine intervention
- the approaches used to reduce the risk.

Some groups are more likely to attend for a scan without a creatinine/eGFR result available. These include:

- people on a monitoring programme
- people referred from primary care.

Cost

When creatinine is measured by a laboratory the cost is covered by the referrer's budget. Adoption of POC creatinine in radiology will move the cost of creatinine measurement to radiology budgets. In addition to the POC creatinine device purchase, ongoing costs would include regular purchase of the internal quality control samples and participation in an external quality assurance scheme.

Some of the POC devices are blood-gas analysers which offer creatinine testing and also measure multiple other clinical parameters. It may not be cost-effective to run one of these in radiology for the sole purpose of creatinine measurement.

Clinician confidence/acceptance

For clinicians to have confidence in POC creatinine tests it would have to be shown that results from the POC device were repeatable and reproducible and correlated well with laboratory results.

It would be important for clinicians to have an eGFR result calculated from the creatinine measurement. Different eGFR algorithms are available and clinicians would need to ensure that the one used on the POC device was the same one as is used in the laboratory to allow comparison of results if necessary.

IT infrastructure

Sites would like devices to connect with their laboratory IT systems to allow results to be uploaded. This would enable POC teams to remotely monitor performance and activity.

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Appendix A Glossary of terms

Acute kidney injury
Acute kidney injury is a condition that affects the structure and function of the kidneys. It can be caused by many different conditions and is defined based on serum creatinine levels and urine output.

Angiography
A type of x-ray used to check blood vessels, both arteries and veins. It uses a special dye (contrast agent) which is injected into the blood before imaging. The dye highlights the blood vessels to help clinicians spot problems or plan treatment.

Chronic kidney disease
A long term condition characterised by a loss of kidney function over time. It is normally asymptomatic.

Contrast agents
Chemical substances which are used to improve the quality of medical images by increasing the visibility of specific organs, blood vessels or tissues.

Creatinine
Creatinine is the waste product of creatine, which the muscles use to make energy. Creatinine is excreted in the urine via the kidneys. High levels in the blood might indicate that the kidneys are not working correctly.

End stage renal disease
End stage renal disease occurs when chronic kidney disease reaches an advanced state. The kidneys do not work well enough to support the body, therefore dialysis or a kidney transplant is needed.

Glomerular filtration rate
A measure of the flow rate of blood passing through the kidneys.

Nephrotoxic drugs
Drugs that can cause damage to the kidneys.

Appendix B Abbreviations

AKI	Acute kidney injury
AKIN	Acute kidney injury network
CI-AKI	Contrast-induced acute kidney injury
CT	Computerised tomography
eGFR	Estimated glomerular filtration rate
KDIGO	Kidney disease: improving global outcomes
PC-AKI	Post-contrast acute kidney injury
POC	Point of care
MRI	Magnetic resonance imaging
RANZCR	Royal Australian and New Zealand College of Radiologists
RIFLE	Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease

Appendix C References

The Association for Clinical Biochemistry and Laboratory Medicine Analyte monograph on creatinine [online; accessed 27 September 2018]

Bellomo R, Ronco C, Kellum JA, et al. (2004) Acute renal failure - definition, outcome measures, animal models, fluid therapy and information technology needs: the Second International Consensus Conference of the Acute Dialysis Quality Initiative (ADQI) Group. Crit Care. 8(4):R204-12

Cope LH, Drinkwater KJ and Howlett DC (2017) RCR audit of compliance with UK guidelines for the prevention and detection of acute kidney injury in adult patients undergoing iodinated contrast media injections for CT. Clin Radiol. 72(12), 1047-1052

Harris MA, Snaith B and Clarke R (2016) Strategies for assessing renal function prior to outpatient contrast-enhanced CT: a UK survey. Br J Radiol. 89(1067): 20160077

KDIGO Clinical Practice Guideline for Acute Kidney Injury (2012) [online; accessed 3 September 2018]

Mehta RL, Kellum JA, Shah SV, et al. (2007) Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. Crit Care. 11(2):R31

NHS (2018) Acute kidney injury [online; accessed 3 September 2018]

Ozkok S and Ozkok A (2017) Contrast-induced acute kidney injury: A review of practical points. World J Nephrol. 6(3), 86-99

van der Molen AJ, Reimer P, Dekkers IA, et al. (2018) Post-contrast acute kidney injury - Part 1: Definition, clinical features, incidence, role of contrast medium and risk factors : Recommendations for updated ESUR Contrast Medium Safety Committee guidelines. Eur Radiol. 28(7), 2845-2855