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Glomerular filtration rate and levels of electrolytes, urea and creatinine give a strong indication of kidney function and can guide treatment

ROUTINE BLOOD TESTS: PART 1 OF 4

Why do we test for urea and electrolytes?

Learning objectives...

After reading this article, you will be able to:

- **Describe the functions of the kidneys**
- **Explain what electrolyte levels tell us**
- **List the causes and treatment of renal disease**

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Abstract Blann A (2014) Routine blood tests 1: why do we test for urea and electrolytes? *Nursing Times;* 110: 5, 19-21.
Urea and electrolytes are the most commonly requested biochemistry tests. They provide essential information on renal function, principally in excretion and homoeostasis. Creatinine levels are a major factor in determining the estimated glomerular filtration rate, which is the gold standard marker of kidney health.

The tests' clinical value is in the diagnosis and management of acute kidney injury and chronic kidney disease, which, if left untreated, can lead to thrombosis and cardiovascular disease such as myocardial infarction and stroke.

Urea and electrolytes (U&Es) are the most frequently requested biochemistry tests. They provide useful information about several aspects of health, such as the volume of blood and its pH. The most important aspect of U&Es is what they tell us about kidney functioning.

Kidney function

The kidneys have the following three main functions:

- Homoeostasis: regulating blood volume, and maintaining the acid/base balance (pH) and levels of electrolytes, principally sodium and potassium;
- Endocrine activity: regulating blood pressure, supporting red blood cell production and contributing to blood calcium;
- Excretion: removing urea and creatinine.

Kidneys consist of millions of single-functional units called nephrons. The top of a nephron is known as the glomerulus; this is an important filter that interfaces directly with the blood and has a major role in regulating the composition of blood and urine.

Analysis of renal function

The major blood tests for homoeostasis and renal function are shown in Table 1.

Sodium and potassium are electrolytes – charged atoms (ions) that allow electricity to pass. They are written with a small plus or minus, indicating their electrical charge. HCO_3^- (bicarbonate) is important in determining the pH of the blood, indicating acidosis and alkalosis. The pH is defined by hydrogen ion (H^+) levels.

Urea is the major excretory product of our biochemical metabolism, while creatinine is a more specialised product of the breakdown of protein. Analysis of U&Es focuses on raised (hyper-) and reduced (hypo-) levels of these products and electrolytes.

Sodium

Raised sodium (hypernatraemia) can be caused by a salt-rich diet or by dehydra-

5 practice points

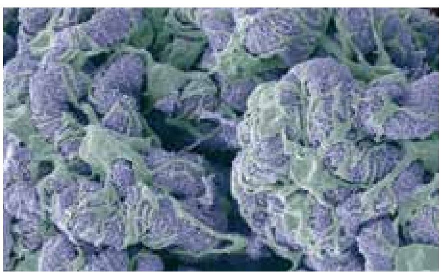
1 **Urea and electrolytes are the most commonly requested biochemistry test**

2 **Low sodium levels can cause oedema, which may lead to heart failure**

3 **High potassium levels can lead to cardiac arrest and, since treatment is short term, their cause must be established**

4 **The glomerular filtration rate is used to assess kidney function**

5 **Acute kidney injury can be reversed once the cause has been found but chronic kidney disease can only be slowed**



The glomerulus has a role in the regulating the composition of blood and urine

Alamy

tion, which can be identified by loss of skin elasticity. Another common reason for hypernatraemia is low blood volume, which can be the result of insufficient drinking or excessive loss of water in urine, sweat or diarrhoea.

The simplest treatment is to replace fluid orally; if this is not possible, water can be infused as part of a dextrose infusion.

Similarly, low sodium (hyponatraemia) may be due to the retention of water or excessive loss of sodium. It is the most common in-hospital electrolyte disturbance, affecting 15% of patients. Hyponatraemia may be accompanied by oedema, which is associated with heart failure and hypoalbuminaemia. In some cases, water retention can be treated with thiazide drugs.

Potassium

Raised potassium (hyperkalaemia) may be due to renal problems such as failure to excrete, acidosis (high pH) or potassium being released from damaged cells, such as red bloods cells or tumour cells destroyed by chemotherapy.

Whatever its cause, hyperkalaemia can be serious; high levels (over 7mmol/L) can contribute to cardiac arrest and can be fatal, which is why it is the most common and most serious electrolyte emergency. Treatment includes administering insulin and glucose to get potassium into the cells. However, this effect is transient and a rebound effect is possible so the root cause must be addressed and other treatments given for a longer-term effect.

Causes of low potassium levels (hypokalaemia) include the opposite of those of hyperkalaemia, for example alkalosis (low pH), as well as loss in diarrhoea and vomiting or from the kidney, or inappropriate use of corticosteroids or thiazide drugs. Treatment focuses on replacement orally or by adding potassium to an intravenous infusion. Care must be taken to avoid hyperkalaemia when using supplements.

Urea and creatinine

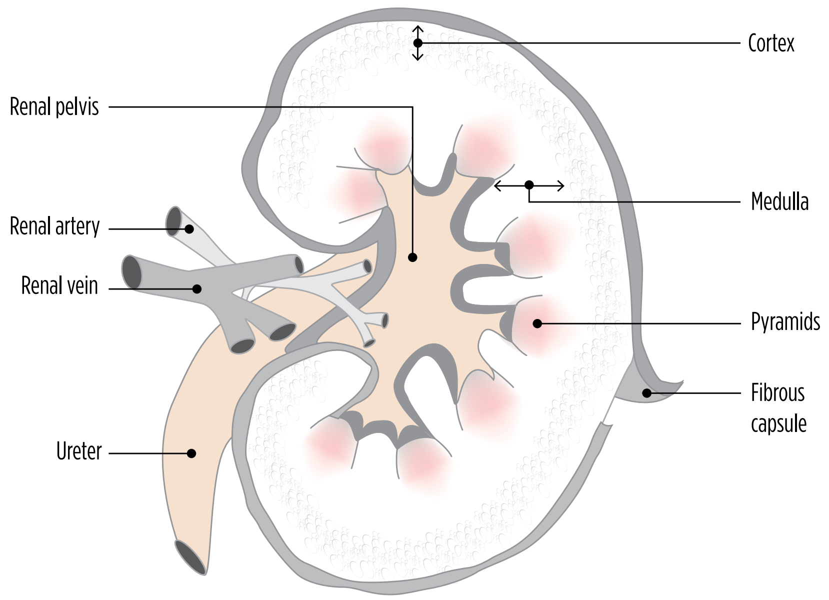
Urea and creatinine molecules help with the excretion of excess nitrogen. Urea, which is synthesised by the liver, is a good marker of acute renal disease. Creatinine is useful as a longer-term marker of renal function; it mainly arises from muscle so levels may be elevated after consumption of meat.

The glomerular filtration rate

Despite the value of the U&Es, the ultimate test of kidney function is the rate at which blood is filtered by passing over the glomerulus to begin urine production, known as the glomerular filtration rate (GFR). It is accepted that the GFR falls slowly with age, and the minimum level for concern is 90ml/minute/1.73m².

GFR was previously assessed by taking a 24-hour urine sample, but is now estimated (eGFR) from one of two equations. The Cockcroft-Gault equation uses serum creatinine, weight, age and sex, while the MDRD formula takes in to account age, sex, creatinine and ethnicity to determine the eGFR. Free online calculators are available for both equations (Box 1), but health professionals must check with their local pathology laboratory to find out which they should use.

FIG 1. **ANATOMY OF THE KIDNEY**



Renal disease

The most common causes of kidney problems can be grouped into the following three areas:

- Pre-renal disease is characterised by factors such as insufficient blood entering the kidney, which could be due to renal artery stenosis, abdominal aortic aneurysm or poor cardiac output as may be present in heart failure;
- True renal disease is often seen in septic shock, in glomerulonephritis (inflammation of the kidney), in the presence of toxins, in renal carcinoma (or secondary metastases) and in traumatic damage;
- Post-renal disease is present if there are problems in the genitourinary tract below the kidney such as with the ureter, the bladder or the urethra. The most common causes of this are kidney stones, cancer of the bladder or prostate, benign prostatic hyperplasia or infections. All these limit or prevent urine from flowing out, so that it will eventually back up to the kidneys themselves.

In both pre- and post-renal disease, there is nothing intrinsically wrong with the kidney itself or its functioning.

TABLE 1. **UREA AND ELECTROLYTES WITH MARKERS OF RENAL FUNCTION**

Markers	Reference range
Sodium	133-144mmol/L
Potassium	3.4-5.1mmol/L
Urea	3.0-8.3mmol/L
Creatinine	44-133µmol/L
eGFR	>90ml/min/1.73m²

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TABLE 2. STAGES OF CHRONIC KIDNEY DISEASE

Stage	eGFR	Description and management
I	>90	Normal renal function: control any cardiovascular risk factors present.
II	60-89	Mildly reduced renal function. The stage should not be diagnosed on eGFR alone but with urinalysis, structural abnormalities or genetic factors. Observe and control cardiovascular risk factors.
IIIa	45-59	Moderate decrease in renal function, with or without other evidence of kidney damage.
IIIb	30-44	Marked decrease in renal function, with or without other evidence of kidney damage. Statin and ACEI/ARB likely to be advisable. Check haemoglobin to identify anaemia. Blood pressure target <135/85
IV	15-29	Severely reduced renal function.
V	<15	Very severe (end-stage) renal failure. If appropriate, preparation for dialysis or transplant.

Blood pressure targets are lower in cardiovascular disease and diabetes

However, failure to correct pre- or post-renal disease will lead to renal disease.

Acute kidney injury

The importance of assessing for acute kidney injury (AKI) has been highlighted by the National Confidential Enquiry into Patient Outcome and Death (2009) as it occurs in 4.9% of hospitalised patients in the US.

NCEPOD recommends that all patients admitted as an emergency should have their U&Es checked. Such patients are also likely to benefit from cardiac monitoring, and health professionals should pay attention to fluid balance to maintain cardiovascular haemodynamics.

AKI may be defined in the laboratory by the ratio of the relative rise in urea being greater than the relative rise in creatinine, not simply the levels themselves. Other biochemical abnormalities include acidosis (because the kidney can no longer excrete hydrogen ions) and hyperkalaemia. If potassium levels rise dangerously, dialysis may be needed. In AKI, urine production is likely to decrease or even stop.

BOX 1. GLOMERULAR FILTRATION RATE CALCULATORS

- AES eGRF calculator using the MDRD equation: www.renal.org/egfrcalc/
- eGRF calculator using the Cockcroft-Gault equation: nephron.com/cgi-bin/CGSI.cgi

Recovery from AKI may be accompanied by a marked increase in urine production, so fluid balance may need to be checked, but normal levels of urine production can be expected to return. If the damage to the kidney in AKI is excessive, it may become permanently and irreversibly dysfunctional and may deteriorate to chronic kidney disease (CKD).

Chronic kidney disease

CKD is the progressive and irreversible destruction of kidney tissues, and is typically noted when the GFR falls below 60ml/minute/1.73m^2; it can be stratified into six stages (Table 2).

Using U&Es, CKD can be plotted by the relative rise in urea compared with the rise in creatinine. In contrast to AKI, in CKD there is a greater increase in creatinine and a slower rise in urea.

The consequences of CKD are similar to those of AKI, with disturbances in sodium, hydrogen and water metabolism – there may be too much or too little fluid excreted. If present, metabolic acidosis will be evident with a reduced level of bicarbonate; this may also contribute to hyperkalaemia. This may result independently from the patient being unable to excrete potassium and may be life threatening.

Low levels of calcium may occur due to the kidney losing the ability to promote calcium absorption in the intestines. Similarly, anaemia may develop as an impaired kidney will no longer be making erythropoietin (the hormone that controls red blood cell production).

Clinical features of CKD also include nocturia (resulting from uneven urine production) and hypertension. Good management will address sodium and water intake, and diuretics may be necessary, depending on the degree of renal function. Hyperkalaemia may be managed with resonium A, and a low-protein diet may help to reduce the amount of nitrogen, so it does not need to be excreted as urea and creatinine.

Management of renal disease

Wherever possible, the cause of the disease must be determined and addressed urgently. AKI is reversible and treatment depends on the cause.

Although CKD is essentially irreversible, its advance can be slowed down by treating the risk factors, such as high blood pressure (Table 2). Ideally, those with proteinuria, diabetes and microalbuminuria need to have a blood pressure of less than 120/80mmHg.

The National Institute for Health and Clinical Excellence has issued guidance for the management of CKD (NICE, 2008). Patients with severe CKD lose the ability to produce erythropoietin, so are at risk of anaemia. NICE also places importance on protein in the urine (detectable with dipsticks), but a better marker of renal damage is the ratio of albumin to creatinine in the urine (uACR). Increases in uACR imply falling renal function, and may direct the use of angiotensin-converting enzyme inhibitors (ACEIs) or angiotensin receptor blockers (ARBs).

Treatment and care of CKD is therefore conservative and, as renal function slowly deteriorates, the patient should be prepared physically and psychologically for dialysis, which is generally needed when the GFR falls to below 25ml/min. The remaining treatment is transplantation. However, when dialysis and transplantation are not possible, palliative care may be the only option. **NT**

- This article is based on Blann AD (2013) *Routine Blood Tests Explained.* Cumbria: M&K.

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Further reading

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