Anaesthesia for Renal Surgery

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Self Assessment

Before reading the tutorial please attempt the following multiple choice questions.

1. The kidney:
   a. Produces erythropoietin
   b. Is an intra-peritoneal organ
   c. Has no role in acid-base balance
   d. Nociceptive fibres travel with the parasympathetic input
   e. Pain is usually referred to the shoulder

2. With regards to renal function:
   a. Serum creatinine levels give an accurate indication of glomerular function
   b. Creatinine clearance increases with age
   c. Severe renal failure results in a metabolic acidosis
   d. Serum electrolytes become deranged with mild renal impairment
   e. Urinary specific gravity gives an indication of renal tubular function

3. In chronic renal failure:
   a. There is a macrocytic anaemia
   b. Hypertension is common
   c. Autonomic neuropathy may be present
   d. Pericarditis may occur
   e. Patients are not at increased risk of ischaemic heart disease

4. The following drugs have nephrotoxic potential:
   a. Non-steroidal anti-inflammatory agents
   b. Paracetamol
   c. Morphine
   d. Vecuronium

e.   Suxamethonium

5. In the full lateral position with the loin raised:
    a.   There is increased ventilation of the dependant lung
    b.   There is a reduction in functional residual capacity
    c.   Venous return is reduced
    d.   Damage to the common peroneal nerve may occur
    e.   The use of PEEP is contra-indicated

Key Points

Renal surgery is major surgery associated with significant post-operative pain and many complications including haemorrhage. Patients may have pre-existing renal impairment, or may develop it post-operatively.

Introduction

The kidney is one of the vital organs of the body. It has many functions, of which the main one is the filtration of plasma and excretion of waste products whilst maintaining water, osmolality, electrolyte and acid-base homeostasis. They secrete renin and have a role in the regulation of blood pressure and fluid balance, and also secrete erythropoietin.

25-hydroxycholecalciferol is converted to 1,25-dihydroxycholecalciferol (Vitamin D) in the proximal renal tubules, and so they are important for calcium homeostasis. Finally, they have a major role in the metabolism and excretion of many drugs.

The kidneys are situated on the posterior abdominal wall, with the diaphragm and 11th and 12th ribs posteriorly. They are about 10cm long, 5cm wide and 3cm thick. Sympathetic innervation is from T8 to L1, via the coeliac and aorticorenal ganglia. Parasympathetic input is from the vagus nerve.

The ureters receive sympathetic innervation from T10 to L2, via the aorticorenal and superior and inferior hypogastric plexus. Their parasympathetic input is from S2 to S4. Nociceptive fibres travel with the sympathetics to T10 to L1 (kidneys) and T10 to L2 (ureters). Pain is therefore usually referred to the lower back, flank, ilioinguinal region and scrotum or labia.

Surgery

Operations on the kidney include pyeloplasty (to overcome obstruction at the pelviureteric junction) excision of cysts, open nephrostomy, pyelotomy, pyelolithotomy, nephrolithotomy and partial or total nephrectomy.

Some of these operations have become largely unnecessary with newer techniques. Nephrostomy catheters can be placed percutaneously under radiological guidance. Stones can also be removed from the renal pelvis ureteroscopically, using laser to break up the stone. Renal stones may be broken into small pieces using lithotripsy, and the particles then passed naturally. Other operations may be performed laparoscopically, such as pyeloplasty and partial or total nephrectomy.

Open operations are usually performed in the full lateral position with either padding or table positioning ("breaking" the table in the middle) used to raise the loin and improve surgical access. The lumbar incision is the most common approach. The twelfth rib bed approach may be used for high lying kidneys or upper pole pathology. A thoraco-abdominal incision using any intercostals space from the eight to the eleventh gives excellent exposure for large renal masses. A transabdominal approach may also be used with the patient supine, and a transperitoneal or retroperitoneal approach to the kidney.

Pre-operative assessment

In addition to a routine anaesthetic assessment, particular attention must be paid to the renal function. Chronic renal failure often leads to hypertension, thought to be due to increased activity of the renin/ angiotensin system. Accelerated ischaemic heart disease and peripheral vascular disease may occur as a result. Oedema may be due to proteinuria and hypoalbuminaemia, or as a result of cardiac failure. Pericarditis can occur in uraemic patients. Peripheral and autonomic neuropathies may be present.

Urinalysis is one of the most readily available, inexpensive and informative laboratory tests. Haematuria and the presence of casts, bacteria, white cells may be found on microscopy. Urinary specific gravity is an index of renal tubular function. The ability to excrete concentrated urine (specific gravity >1.030) indicates good tubular function, whereas urinary osmolality fixed at that of plasma (specific gravity 1.010) is indicative of renal disease. Proteinuria greater than 150mg per day is abnormal and usually indicates severe glomerular damage. However, it may also occur due to abnormally increased concentrations of plasma proteins. Glycosuria usually indicates the presence of diabetes mellitus.

A full blood count may reveal anaemia (normocytic, normochromic), either due to excessive haematuria, or because of reduced production of erythropoietin by the failing kidney. Plasma creatinine and urea concentrations provide good information about general kidney function. Creatinine clearance can also be used to specifically measure glomerular filtration rate (GFR).

Creatinine clearance= $\underline{u}$ x v

p

Where u = urinary concentration of creatinine (mg/ 100mL)
      p = plasma concentration of creatinine (mg/ 100mL)
      v = urine volume (mL/ min)

A 2 hour test is usually used for convenience, however a 24 hour test is more accurate. Normal values are 85-125 ml/ min in women and 95- 140 ml/ min in men. Creatinine clearance decreases with age.

If impaired renal function is suspected, serum electrolyte concentrations should be measured, however these usually remain normal until severe renal disease is present. In severe renal failure, determination of arterial blood gases may reveal a metabolic acidosis due to impaired acid excretion by the kidney.

Other tests such as chest X-ray and ECG may be needed depending on the patient's symptoms, and on any other co-morbidities. All patients undergoing open or laparoscopic renal surgery should have blood taken for "group and save" or cross matching because of the risk of haemorrhage intra-operatively.

The patients condition should be optimised as far as possible prior to surgery. Hypertension should be well controlled with appropriate medication. Any urinary tract infection should be treated with appropriate antibiotics. Routine preoperative transfusion of anaemic patients is usually unwarranted as these patients have a chronic compensated anaemia, and transfusion can precipitate cardiac failure. For elective surgery, pre-operative iron or erythropoietin therapy may be used to increase haemoglobin levels. Patients with severe renal failure may have fluid and electrolyte disturbances. These should be corrected as far as possible, and dialysis may be used.

Diabetes mellitus is a common cause of renal problems, and an appropriate plan should be made for the management of such patients in the peri-operative period. Premedication may be used as necessary, and antacid prophylaxis should be considered in those with chronic renal failure.

Effects of drugs in patients with reduced renal function

The termination of action of most anaesthetic drugs is due to redistribution and metabolism, and is not dependant on renal excretion. Biotransformation of these drugs usually results in pharmacologically inactive forms of the parent compound which are water soluble and excreted in the urine. Accumulation of these products due to impaired renal excretion is not harmful.

Some drugs are eliminated unchanged in the urine. In particular non-depolarising muscle relaxants are largely excreted by the kidneys. The termination of action of a single small dose of such agents is by redistribution rather than excretion. However, when

maintenance doses are used, these should be smaller than for patients with normal renal function and the interval between doses should be increased. A clinical monitor of neuromuscular function, such as a train-of-four nerve stimulator should be used if available. Exceptions to this are atracurium and cisatracurium which are broken down by enzymatic ester hydrolysis and by nonenzymatic alkaline degradation (Hofmann elimination) to inactive products, and so are not dependant on renal excretion for their termination of action.

Succinylcholine (suxamethonium) is metabolised by pseudocholinesterase, and although levels of this enzyme are reduced in uraemia, values are rarely so low as to cause prolonged block. Succinylcholine administration does cause a rise in serum potassium, which may be dangerous in patients with severe renal impairment who already have an elevated potassium level. Renal excretion is also of major importance for the elimination of cholinesterase inhibitors (e.g. neostigmine) and their excretion is delayed in patients with impaired renal function to the same extent as non-depolarising muscle relaxants. Therefore, "recurarization" should not occur except for other reasons.

Other drugs which are largely excreted unchanged in the urine include atropine and glycopyrrolate, however a single dose will not cause clinical difficulties. Maintenance doses of digoxin must be reduced in proportion to the reduction in renal function, and blood levels are the most reliable guide to therapy.

Drugs which are extensively bound to albumin, such as many induction agents, will be affected by the reduction in albumin levels in uraemic patients. This results in an increase in the free fraction of the drug, and a reduction in the dose required to produce anaesthesia.

Inhaled anaesthetic agents are preferred for the maintenance of anaesthesia because their excretion is via the respiratory system, and so impaired kidney function will not alter the response to these agents. Enflurane and sevoflurane are both biotransformed to inorganic fluoride, although the plasma levels produced are below nephrotoxic levels. Isoflourane, halothane and in particular, desflurane are metabolised by the liver to a much lesser extent and so have no nephrotoxic potential.

Opioids are extensively metabolised in the liver, and therefore their pharmacokinetics and pharmacodynamics should be largely unaltered by renal disease. However, morphine and meperidine (pethidine) both have active metabolites which are excreted by the kidney and may accumulate in renal failure. Doses of these two drugs should therefore be reduced or limited.

Anaesthesia

Intra-operative
General anaesthesia with muscle relaxation and intermittent positive pressure ventilation (IPPV) is usually used for open or laparoscopic renal surgery. Due to the position of the

patient and the increase in intra-abdominal pressure associated with laparoscopic surgery, endotracheal intubation is recommended. Induction of anaesthesia may be with intravenous or inhalational agents, and a rapid sequence induction should be used in those known to have autonomic neuropathy. Maintenance should be with inhalation agents, preferably halothane, isoflurane or desflurane. Atracurium is the non-depolarising muscle relaxant of choice in those with impaired renal function.

Large bore intravenous access is mandatory because of the risk of sudden haemorrhage. Any limb with a working arteriovenous fistula must not be used for intravenous infusions. In those who may progress to needing dialysis, forearm veins should be preserved for the creation of future fistulae and therefore not used for venous access.

Positioning
The full lateral position has profound effects on the respiratory system. Ventilation of the lower lung is decreased whilst its perfusion is increased resulting in a large ventilation perfusion mismatch. There are also decreases in thoracic compliance, tidal volume, vital capacity and functional residual capacity. These problems may be exacerbated by any pre-existing respiratory disease. Difficulty with low arterial oxygen saturations during the operation may be overcome by increasing the fraction of inspired oxygen, or applying a small amount of positive end expiratory pressure (PEEP). Postoperative atelectasis of the lower lung is not uncommon.

"Breaking" the table or using a kidney bridge may kink or compress the inferior vena cava, particularly in the right lateral position, causing a decrease in venous return and therefore cardiac output.   Hepatic encroachment on the vena cava and mediastinal shift may further decrease venous return. Meticulous observation should be paid to cardiovascular parameters during patient positioning.

Neuropathies of the cervical plexus, brachial plexus and common peroneal nerves may occur in the lateral position due to stretching or compression of these nerves. Care should be taken to avoid excessive lateral stretching of the neck and both shoulders should be in a neutral position. The upper arm is usually placed on an arm support. All pressure points should be well padded. Any working arteriovenous fistulae should be wrapped to prevent inadvertent damage. A pillow is usually placed between the legs and the lower leg flexed.

Finally, the patient should be well secured on the table using back supports and strapping to ensure they do not roll or move position during surgery.

Monitoring
Routine monitoring of cardiovascular and respiratory parameters is particularly important because of the risks of problems occurring due to patient positioning. Invasive monitoring of blood pressure and central venous pressure may be used. This decision depends on the patient's pre-operative condition and on the risks of surgery.

Patients with end stage renal disease may benefit from central venous pressure monitoring to guide fluid requirements. However, central venous access may be difficult in those who have had previous haemodialysis lines inserted in the neck veins. Ultrasound guidance should be used in these patients if available. Excision of large renal masses may result in major haemorrhage and the use of invasive monitoring is recommended.

Renal surgery may take several hours and so attention must be paid to maintaining the patient's temperature as far as possible. Warmed intravenous fluids, warm blankets and heated mattresses may be used. The patient's temperature should be monitored if possible.

Fluid balance

Bowel preparation is usually given pre-operatively, which may cause patients to become dehydrated, particularly the elderly. Any patient with end stage renal disease who has had recent dialysis may likewise be fluid depleted pre-operatively. Appropriate fluid resuscitation must be given to any patients with signs of dehydration pre-operatively to avoid excessive hypotension at induction of anaesthesia. Otherwise, replacement fluids to compensate for pre-operative fasting and bowel preparation must be given early during surgery.

In addition to normal maintenance fluid requirements intra-operatively, evaporative losses from an open abdomen (10-30 mL/kg/h) and third space losses to bowel, omentum and retroperitoneum must be taken into account. Some blood loss is normal, and haemorrhage may occur at any time. Therefore fluid requirements intra-operatively are usually high.

Crystalloids are used for maintenance and third space losses. Potassium containing fluids should be avoided in those with impaired renal function. Colloid and packed red blood cells should be used for haemorrhage. Patients may have pre-existing chronic anaemia in which case they will tolerate less blood loss than those with higher haemoglobin levels. Other blood products such as fresh frozen plasma, cryoprecipitate and platelets may be required in the face of massive blood loss.

Urine output usually falls during surgery, but it can be used as a guide to fluid replacement. Postoperatively a urine output of 0.5-1.0 mL/kg/h should be the aim for those with normal renal function. Patients with impaired renal function are more problematic with regards to fluid balance. Anuric patients who are reliant on dialysis should ideally have strict attention paid to their fluid balance, and only have losses and maintenance requirements replaced. Dialysis may be used post-operatively if there is an element of fluid overload. Patients who have been recently haemodialysed are often relatively hypovolaemic.

Vasopressors and Antihypertensive agents

Patients with renal disease are frequently hypertensive, and at increased risk of cardiovascular instability intra-operatively. Treatment of hypotension should first be directed at any obvious cause, such as haemorrhage. If vasopressor administration is necessary, direct α-adrenergic stimulating drugs, such as phenylephrine, can be used. Unfortunately these drugs cause the greatest reduction in renal perfusion. However β-adrenergic stimulating drugs, which maintain renal circulation, cause myocardial irritability and so should not be used. A dopamine infusion can also be administered.

Hypertension may be a problem, particularly if a bilateral nephrectomy is being carried out for uncontrolled hypertension. Sodium nitroprusside is contra-indicated in those with renal impairment as thiocyanate, its final metabolic product, will accumulate and is potentially toxic. Trimethaphan and nitroglycerin are rapidly metabolised and suitable for use in these cases. Hydralazine is a slower acting agent, but may be used for post-operative control of blood pressure. Approximately 15% of the drug is excreted unchanged in the urine, so care should be taken in those with end stage renal failure. Labetolol and esmolol are extensively metabolised and commonly used.

Renal protection
Great care must be taken to avoid factors which can compromise renal function, particularly in those whose function is already impaired. Although surgery is the biggest risk factor, other contributory factors should be avoided as far as possible. These include hypotension, dehydration, sepsis and nephrotoxic drugs. Various methods have been used to try to protect kidney function in patients undergoing surgery. These include the administration of dopamine, diuretics, calcium channel blockers, angiotensin converting enzyme inhibitors and hydration fluids. However, a recent Cochrane database review concluded that there is no evidence that any of these interventions protect the kidneys from damage.

Complications of surgery
The kidney is a very vascular organ and haemorrhage is real risk. Bleeding can occur from the renal artery, the inferior vena cava, or from aberrant arteries. The risk is higher in the presence of malignant or infective processes where the kidney may be adherent to other structures. Techniques to reduce the need for blood transfusion such as cell salvage, acute normovolaemic haemodilution and anti-fibrinolytic drugs may be used where appropriate. Secondary haemorrhage occurring in the post-operative period is rare, but may necessitate re-laparotomy to identify the cause.

Renal cell carcinoma may invade the inferior vena cava (IVC), and extend as far as the right atrium. Complete occlusion of the IVC or tumour embolisation may occur intra-operatively. The exact extent of the lesion must be identified pre-operatively.

Cardiopulmonary bypass is required for those tumours extending into the right atrium, or if venous return is significantly compromised. Any reduction in venous return predisposes the patient to hypotension during induction of anaesthesia. Central venous pressure measurements may also not be accurate if there is an element of occlusion of the IVC.

Damage may occur to the pleura or diaphragm as the kidney lies in close proximity to the lungs. This is usually visible at open operation and a repair can be made. However a high index of suspicion, particularly during laparoscopic surgery must be maintained. Any sudden problems with the ventilation of the patient should be fully investigated and the surgeon informed of any concerns. Any pneumothorax may rapidly progress to a tension pneumothorax with the use of IPPV and can cause haemodynamic instability. Injury may occur to the small or large bowel, necessitating primary repair or a colostomy formation.

Laparoscopic surgery can result in significant hypercarbia and acidosis from the carbon dioxide used to create the pneumoperitoneum, particularly in prolonged operations. High intra-abdominal pressures splint the diaphragm, interfere with ventilation and obstruct venous return leading to significant haemodynamic alterations. When the retroperitoneum is invaded there is a risk that subcutaneous emphysema may extend along the tissue planes around the neck and cause airway obstruction after extubation.

The main post-operative complications are chest infection, paralytic ileus and a deterioration in renal function.

Post-operative pain relief
Open operations are associated with significant post-operative pain. Good analgesia is essential to allow effective coughing and early mobilisation and reduce the incidence of post-operative respiratory complications. Epidural analgesia is usually used unless contra-indicated. Regional analgesia should be avoided if there is any coagulopathy or thrombocytopenia, or recent haemodialysis with anticoagulation. A low thoracic epidural catheter is usually used, and a block to about T8 is required for good analgesia. Continuous infusions of a mixture of low dose local anaesthetic and opioid provide the best pain relief, although intermittent boluses can also be used. Epidural catheters should be left indwelling for the minimum time possible, but may be used for up to 5 days after surgery, depending on patient requirements.

An alternative to epidural analgesia is the placement of a subcostal catheter at the time of surgery, which can then be used for bolus doses or infusions of local anaesthetic agents. If no local anaesthetic technique is used, or if these techniques fail, patient controlled analgesia can be used. Fentanyl is a suitable drug for those with renal failure as it is largely metabolised in the liver. Morphine can be used with caution, and a reduction in both the dose and time interval between doses should be made for those with impaired renal function (usually a 0.5mg bolus dose with a 10 minute lock-out period).

Laparoscopic surgery is associated with reduced blood loss, less tissue trauma, less post-operative pain and shorter hospital stays. Epidural analgesia should not be necessary, although local anaesthetic infiltration of the wounds at the end of surgery is helpful. Patient controlled analgesia may be used, although opioid requirements are often low. For all patients a multi-modal approach to analgesia should be used. Unfortunately non-steroidal anti-inflammatory drugs are relatively contra-indicated because of their

nephrotoxic potential. They may be considered post-operatively in those with normal renal function. Paracetamol is a very useful adjuvant agent and safe to use in renal impairment. Oral opioids may be used for moderate pain.

Thromboprophylaxis should be used for all patients until they are mobilising well.

Summary

The patients pre-existing renal function and any other co-morbidities must be considered when planning anaesthesia for renal surgery. Invasive monitoring may be required. Positioning of the patient may lead to cardiovascular and respiratory changes. The possibility of major haemorrhage should always be remembered. Open operations on the kidney are painful and epidural analgesia should be used where possible.

Suggested References

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MCQ Answers

Question 1
    (a) True (b) False (c) False (d) False (e) False
    (b) The kidney is a retroperitoneal organ. (c) The kidney has an important role in maintaining acid base balance by excreting hydrogen ions. (d) Nociceptive fibres travel with the sympathetic nerves. (e) Pain may be referred to the flank and groin.

Question 2
    (a) True (b) True (c) True (d) False (e) True

(a) Creatinine is freely filtered at the glomerulus and is neither reabsorbed nor secreted; it therefore reflects glomerular function. (d) Serum electrolytes only become deranged in frank renal failure. (e) The ability to produce a concentrated urine indicates good tubular function.

Question 3
(a) False (b) True (c) True (d) True (e) False
(a) Chronic renal failure results in a normocytic, normochromic anaemia of chronic disease. (b) Hypertension occurs due to increased activity of the renin/ angiotensin system and sodium and water retention. (d) Pericarditis may occur in uraemic patients. (e) Patients have accelerated ischaemic heart disease secondary to hypertension.

Question 4
(a) True (b) False (c) False (d) False (e) False
(b) Morphine is not nephrotoxic, however care should be taken in patients with renal impairment as the active metabolite morphine-6-glucuronide is renally excreted and may accumulate. (d) Vecuronium is largely renally excreted and so reduced doses should be used in those with impaired renal function, however it has no nephrotoxic effects.

Question 5
(a) False (b) True (c) True (d) True (e) False
(a) Ventilation is increased to the upper lung and reduced to the lower lung. (c) Venous return is reduced due to compression of the IVC and mediastinal shift. (e) PEEP may be used intra-operatively to overcome hypoxaemia due to ventilation perfusion mismatch.