

Chapter 2

Kidney Transplantation



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2.1 Introduction

Kidney transplantation has been the definitive treatment for end stage renal disease for the last 70 years. The fundamental principles of vascular anastomoses have been developed over the last one hundred years following the first recorded

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attempt at renal transplantation in 1902 in which a carotid to renal artery anastomosis was successfully accomplished. The use of the iliac vein and artery for renal transplantation, as pioneered by French surgeon Alex Carrel, still provides the foundations of the anastomotic technique utilised today. More recent advances in the field include the use of alternative vessels for anastomosis, variation in implantation site, performing the operation as part of a multi-visceral procedure and the use of suboptimal grafts.

Current research efforts focus on the non-surgical components of organ transplantation: organ procurement, preservation and machine perfusion, development of tolerance-inducing protocols requiring little or no immunosuppression, identification of novel biomarkers to identify recipients at risk of graft loss, and regenerative medicine applications to model disease processes and allow drug testing for therapeutic efficacy as well as to potentially create, engineer or repair organs for transplantation. Continuous improvements in short-term graft patency has led to renal transplantation becoming the optimal treatment for end-stage renal disease, with one-year graft survival rates from living-related and deceased donors approaching 95% and 91% respectively. However, long-term graft survival outcomes remain less impressive, with chronic rejection and death with a functioning graft being the leading causes of late loss of renal allografts (more than 1 year after transplantation), resulting in an annual rate of loss of 3–5%. The ongoing demand for kidney transplantation is therefore exacerbated by graft failure and the need for re-transplantation.

Between 1960 and 1980 the estimated incidence for graft loss from surgical complications was up to 20%. These rates have dropped significantly since then but early detection, diagnosis and management of surgical complications are critical to further reduce patient morbidity, and potentially mortality, through graft loss. This chapter provides an overview of the existing surgical techniques employed in the field of kidney donation and transplantation along with some of the proposed updates to these procedures.

2.2 Pre Operative Work up

2.2.1 *Living Kidney Donation*

The options for live kidney donation in the UK have expanded over the last 10 years. Alongside the known related or unrelated direct and paired donation, altruistic donation, with or without direction, has seen an increase in incidence. The surgical work up for each donor remains the same and it is increasingly apparent that the need for short and long term follow up after donor nephrectomy should be prioritised. Patients are counselled for the risk of hypertension as well as the development of end stage renal disease, which at 0.5%, still remains substantially lower than that of the 3.2% risk of end-stage renal failure in the general population.

Identification of peri-operative risks should commence like with any elective procedure, with the donor health and medical history. Significant comorbidities contraindicate donation. Uncontrolled hypertension and diabetes with their associated risk to kidney function are also contraindicated given the increased risk of end stage diabetic nephropathy at 5 years being in the region of 25%. The associated risk of hypertension not only affects the anaesthetic risk but also the theoretical risk of hyperfiltration following nephrectomy, leading to hyperalbuminuria and progressive glomerulopathy. Malignancy and infection in the history of the donor does not absolutely contraindicate donation, but every effort must be made to exclude recurrent disease, mitigate risk and prevent transmission to the recipient.

Another often considered and subsequently managed risk is obesity. Worldwide rates of obesity are increasing, and the boundaries of acceptability of donor body mass index (BMI) are widening. The almost ubiquitous use of laparoscopic techniques over open surgery has enabled donors with BMIs of up to 35 kg/m² to be routinely considered for donation. That being said there is a greater risk of post-operative morbidity in the obese, and careful pre-operative assessment

to exclude cardiovascular, respiratory and kidney disease is advised. Of note, obesity is now recognised as an independent risk factor for end-stage renal disease. The higher rates of postoperative analgesic requirements, increased atelectasis, pneumonia and venous thrombosis should be considered along with the higher incidence of wound complications. The consequence is a lengthier hospital stay and an increased recovery period. In order to mitigate these risks whilst expanding the potential live donor pool, established robotic donor nephrectomy from urological practise has been performed in both the live donor and the recipient with equivalent outcomes reported to laparoscopic counterparts.

All donors routinely have biochemical assessment of their kidney function, previous or active infections (e.g. serological screening for cytomegalovirus (CMV), Epstein Barr virus (EBV), Herpes Simplex virus (HSV), Hepatitis B (HBV) and C (HCV) viruses, Human Immunodeficiency Virus (HIV), and Human T-cell Leukemia Virus, Toxoplasma and Treponema) and haematology along with an electrocardiogram (ECG). Urinalysis for protein, blood, leucocytes with appropriate culture and microscopy is routinely undertaken. Outside of these tests, other analyses are performed at the discretion of the investigator depending on baseline results.

During the work up of the donor, it is essential to establish not only the anatomy and the vasculature of the donor kidneys, but also an assessment of the function must be made as well. Given serum creatinine can be influenced by muscle mass, dietary intake and nutritional status, measured glomerular filtration rate (GFR) using a reference GFR procedure is considered more accurate. Pre-donation GFR should be such that the predicted post-donation GFR remains within the gender and age-specific normal range within the donor's lifetime. Further to this, a DMSA or MAG 3 scan assessment of function should also be performed which should give an equal split function across the two kidneys. When renal function is

normal but there is a significant (>10%) difference in function between the two kidneys, the kidney with lower function should be used for transplantation.

Anatomical anomalies such as cysts or potential tumours should be interrogated with either serial CT or ultrasound scans supported ideally by a specialist radiologist. Once potential malignant lesions are excluded it is then important to establish the vascular anatomy, which can be complex. This enables surgical planning and the anticipation of potential risks in the donor and the need for reconstruction before recipient implantation.

Most centres prefer to use the left kidney for living kidney donation as the renal vein is longer on this side, which is advantageous during implantation. Nevertheless, a single-centre randomised controlled trial has shown no differences between left- and right-sided donor nephrectomy in hospital stay, quality of life, donor and recipient complication rates, or graft survival. The presence of multiple renal arteries or veins does not increase the risk of thrombosis or impact short and long-term graft survival. Increased rates of urinary leaks have been described in particular when associated with a small polar artery owing to the theoretical supply of ureteric vasculature predominantly from the polar vessel. Multiple renal veins are present in 5–10% of donors. Most of the small calibre accessory renal veins can safely be ligated, but occasionally reconstruction to gain length of a short right renal vein maybe necessary.

2.2.2 *Recipient Assessment*

The initiation of chronic kidney disease and the timing of transplantation can impact on the subsequent patient and graft survival. Pre-emptive (prior to the start of renal replacement therapy), offers a better quality of life for the patient with improved cardiovascular comorbidity risk post

transplantation. Transplantation of the recipient within 6 months of requiring renal replacement therapy is the ideal standard. The relatively shorter cold and warm ischaemia times, coupled with the healthier donor (due to extensive pre-donation work-up), confer both short and long term survival advantage over the deceased donor counterpart. Nevertheless, not all recipients have this option. Waiting times for patients on the deceased waiting list average at 3 years in the UK and vary according to the recipients ABO blood group and calculated HLA antibody reaction frequency (CRF). It is therefore generally agreed that all recipients should have at least a cursory inquiry into the possibility of a potential live donor at the onset of waiting list assessment.

Outcome goals of the assessment of the transplant recipient are listed in Box 2.1.

Box 2.1 Outcome Goals for the Kidney Transplant Recipient. (Adapted from the UK Renal Association Kidney Transplant Guidelines, 5th Edition, 2010)

Goals of the Multidisciplinary Recipient Workup

- Ensure transplantation is technically possible;
- Ensure the recipient's chances of survival are not compromised by transplantation;
- Ensure that graft survival is not limited by premature death (maximum benefit obtained from a limited resource)
- Ensure pre-existing conditions are not exacerbated by transplantation
- Identify measures to be taken to minimise peri- and post-operative complications. Inform patients of likely risks and benefits of transplantation

Even though in most cases, the technical aspects, i.e. the approach and anastomosis of the kidney transplant to the recipient, may be feasible, there are some technical barriers to consider as part of the work up. One of the main considerations is the BMI of the patient. Obesity with a BMI of over 30 kg/m² carries high rates of peri-operative morbidity (seromas, wound dehiscence, infections, hernias) and generally it is thought that the benefit of transplanting a patient with a BMI >40 kg/m² is outweighed by the risks. Other technical considerations include space for implantation which can be an issue in patients with polycystic kidney disease. Vascular considerations need to be addressed especially when encountering heavily calcified arteries in long standing diabetic recipients. Venous outflow is rarely an issue but previous DVT or a propensity for thrombosis in familial conditions should be addressed appropriately and an anticoagulation plan sought where necessary.

As stated in the summary Box 2.1, the medical evaluation of the recipient is a multi-disciplinary process, which focuses on the factors that are likely to influence the safety of the recipient whilst maintaining an optimal outcome for the patient and graft, and thus enables the best utilisation of the donor organ. Identification at the outset of absolute contraindications to transplantation is critical. These include active malignancies, certain active infections, severe unmodifiable non-renal diseases e.g. cardiac impairment, psychiatric disease that will impact ability of the patient to adhere to long-term immunosuppression therapy, and active substance abuse. Since the subsequent lifelong immunosuppression to be taken by the recipient will cause a higher risk of malignancy, the assessment of recurrent disease needs to be evaluated. The status of treatments for cervical, bladder, prostate, colonic and skin cancers should be ascertained although outcomes of transplantation after treatment of early stages of these cancers have shown to have good prognoses on registry data.

As the leading cause of death in patients with end-stage renal disease is cardiovascular related disease, the identification of risk factors that can be modified prior to transplantation is critical. A basic history should cover management of diabetes, hypertension, smoking, hyperlipidaemia and identify family history risk of coronary artery disease. Perioperative risks are increased with myocardial infarction 6 months prior to surgery, unstable angina, congestive heart failure and the onset of arrhythmias. Even though routine screening using stress echocardiography and exercise testing can be time consuming and expensive, their use in high risk or symptomatic recipients such as patients with diabetes can help permit operative prediction of the likely level of care (ward, high dependency or intensive care). Referral to a cardiology department for treatment of severe coronary artery occlusive disease is mandatory prior to transplantation.

All sources of bacterial infection should be identified during routine assessment. Areas to be considered include peritoneal catheter sites, dental abscesses, vascular access grafts along with routine urine dipsticks and cultures. Persistent urological infections should be further investigated with pyelography (CT or fluoroscopy) with ultrasound to ensure complete bladder emptying and where necessary cystoscopy.

Routine serology is common practise and recommended by the UK Renal association. This includes viral studies for IgG and IgM titres of CMV, EBV, HSV and Hepatitis and HIV viruses. The use of pan-genotypic direct antiviral agents is likely to mean that Hepatitis B and C donors are no longer contraindicated to use in non-Hepatitis B and C recipients; at present this practise is not universal.

Assessment of the recipient bladder function can be difficult in the anuric dialysis patient. This is often best left to post-transplantation when kidney function has stabilised. Screening early on in the assessment of elderly (over 60 year old) men for prostate disease with a documented digital rectal examination and a serum prostate specific

antigen is often all that is required to identify those at risk. Diabetic patients often have neurogenic bladders that should be treated post-transplantation if high residual volumes are discovered after removal of the urinary catheter post-surgery. Patients with prior cystectomies that have ileal conduits or augmented bladder should be fully investigated with the aid of CT scanning and cystoscopy to delineate the appropriate anatomy prior to listing for transplantation. In this small subgroup of patients, a clear plan for bladder reconstruction or creation of a neocystoureterotomy should be documented.

2.3 Surgical Technique

2.3.1 *Deceased Donor Procurement*

Deceased kidney procurement occurs in sequence, following the other abdominal organs (namely liver and pancreas) in both donation after brain-death (DBD) and donation after circulatory death (DCD) donors.

There is a distinct warm phase in DBD donors, whereby careful exposure the inferior vena cava (IVC), left renal vein with mobilization of the duodenum in its entirety superiorly and laterally (Cattell-Braasch manoeuvre), is undertaken. Once key vessels are identified, including the superior mesenteric artery (SMA) caudal to the left renal vein crossing the aorta, the infra-renal aorta either proximal to its bifurcation or the common iliac artery can be cannulated to proceed to the cold phase.

The cold phase of procurement is very similar in both DBD and DCD procurement. Unlike DBD, there is no period of warm dissection in DCD and rapid cannulation of the aorta with either IVC or right atrial venting is undertaken through a midline sternotomy and laparotomy. Cross clamping of the aorta in both DBD and DCD procurement can either take place in the supra-coeliac position below the diaphragm, or (as is the authors preference) in the thoracic

descending aorta. It is common to wait for 5 min in DBD procurement whilst an intravenous bolus of heparin 20–30,000 units is given to prevent thrombosis after cross-clamping. In DCD procurement, the cold perfusion fluid is normally heparinised with a similar amount. Optional back table perfusion should be prepared in case once the organs are inspected, perfusion is deemed inadequate.

After cold perfusion of the aorta has commenced, ice slush is applied to both paracolic gutters to commence topical cooling whilst the liver and pancreas are mobilised and removed. It should be noted that the plane between the right lobe of the liver and the right kidney should be dissected through the adrenal gland thus avoiding kidney or liver capsular injury. Similarly, on the left, a plane close to if not upon the left adrenal gland should be maintained to avoid pancreatic capsular or parenchymal injury.

Mobilisation of the colon should be swiftly undertaken commencing from the ileocolic junction to the descending aspect. Transection of the duodenal-jejunal junction should be performed with a linear stapling device which will allow division of the small bowel mesentery (again with multiple linear staples if pancreatic procurement is performed). Once this has been completed, the entire small bowel and colon can be exteriorised completely, allowing full view of the abdominal aorta. The left renal vein is then identified and finger swept underneath to allow a cuff of IVC to be taken when transected. Once the SMA is identified and divided at its base, the remaining aorta can be opened and split in the midline. The authors recommend a clean knife blade (size 10) in order to ensure precision in cutting the Carrel patch and avoiding injury to the renal artery ostia. At this point, the IVC can be divided superior to the right renal vein allowing enough renal vein for the recipient surgeon on both the liver and renal side. This is usually 2 finger breadths (1 cm) above the right renal vein.

The right renal ureter is identified first by encircling the peri-ureteric tissue commencing laterally from the psoas to the midline at the level of the right common iliac artery. Care

should be taken to avoid removing the peri-ureteric tissue and cause “stripping of the ureter.” The ureter should be accompanied by at least 1 cm of the peri-ureteral tissues and also the hilar inferior triangle (e.g. the window between the inferior pole of the graft and the ureteral origin from the renal pelvis) should be maintained intact. Once the ureter has been identified, the aortic patch can be mobilised posteriorly maintaining a close plane to the lumbar spine. The right kidney is mobilised by extending the existing plane of dissection towards the psoas, gently pulling the kidney medially. It is possible to apply a haemostat across the ureter at this point and transect the aortic patch and IVC inferiorly, thus releasing the kidney, although it is the authors’ preference that both the aorta and IVC are transected free leaving the kidney on the ureteric pedicle as the last element to be divided before the organ is placed immediately on ice.

The left kidney is mobilised in a similar manner. The superior plane in the spleno-renal ligament should be carefully transected to avoid traction injury to the pancreas. Mobilisation of the left colon will have already occurred, and excessive traction of the colon, which can lead to inadvertent transection of the left main renal artery or a polar vessel, should be avoided. Retroperitoneal mobilisation is similar to that of the right kidney with transection of the aorta and iliac veins being recommended prior to the ureter.

After placement of the kidneys on ice, the circumferential fat along the lateral aspect of the kidney should be removed as much as possible. This facilitates both cooling of the organ and allows inspection for lesions, the general state of perfusion and any damage that may have occurred. The organ should then be triple bagged in cold storage fluid for transport.

2.3.2 *Live Donor Nephrectomy*

The first successful living donor kidney transplant originated in 1954 at the Peter Bent Brigham Hospital. Subsequently,

due to the convenience of live donor implants over the logistical challenges of deceased donors, expansion of transplantation in non-identical twin pairs and then on to related non-twin siblings were favoured. By the mid 1960's and with the pioneering drive of Thomas Starzl, living donor transplantation in the USA was well established. Developmental progress in tissue typing and immunosuppression regimens was made by Paul Terasaki and colleagues to form the basis of modern protocols. It was not until 40 years after the first successful kidney transplant that a major technical step was made in procuring kidneys from live donors.

First described by Lloyd Ratner in 1995, laparoscopic donor nephrectomy was a major step in the surgical community in driving live-donor kidney transplantation. This has become the preferred method for procuring kidney grafts from living donors and accounts for over 90% of live donor nephrectomies performed in most high-volume transplant centres. Currently the options for laparoscopic donor nephrectomy are numerous, with both hand assisted and total laparoscopy assisting trans- or retro- peritoneal approaches (Box 2.2).

Box 2.2 Techniques in Living Donor Nephrectomy

Surgical techniques for living kidney donation

Open donor nephrectomy technique

Classical flank incision

Muscle-sparing mini-incision donor nephrectomy

Laparoscopic transperitoneal technique (*)

Laparoscopic donor nephrectomy

Hand-assisted laparoscopic donor nephrectomy

Endoscopic retroperitoneal technique (*)

Endoscopic retroperitoneal donor nephrectomy

Hand-assisted Endoscopic retroperitoneal donor nephrectomy

***can also be performed with robotic assistance**

Given the above work up of the live-donor with appropriate investigations, consent is obtained outlining the risks in the immediate, early and late operative phases. Potential injury to visceral structures around the kidney should be outlined necessitating the risk of conversion to an open procedure to repair the injury or control any bleeding. This may or may not impact on donation, in which case any event or injury deemed to impact permanently on the health of the donor may cease the process of donation in its entirety.

Donor nephrectomy is by convention performed in the lateral decubitus position. Therefore, the donor is warned of the risk of deep vein thrombosis, pulmonary embolus, peripheral nerve injury and back pain, with the former requiring the use of prophylactic low molecular weight heparin for up to 2 weeks post-surgery. In addition to this, the risk of hypertension in the donor should be explained along with the remote risk of developing renal failure in the remaining solitary kidney. Other risks commonly outlined to the donor are listed in Box 2.3.

Box 2.3 Common and Important Risks Associated with Laparoscopic Donor Nephrectomy

Potential risks of Laparoscopic Donor Nephrectomy

- Mortality range from 1 in 1600 to 1 in 2400
- Conversion to open procedure up to 2%
- Major risks (up to 5%)
 1. Bleeding
 2. Visceral injury
 3. DVT / PE
 4. Wound infection
 5. Chest complications- atelectasis, pneumonia
 6. Urinary tract infection
 7. Adhesions
 8. Wound pain, collections; incisional hernia

- General Anaesthesia risks
- Risks of living with a solitary kidney
 1. Hypertension
 2. Microscopic Haematuria
 3. End stage renal disease 0.9% plus requiring the need for renal replacement therapy if remaining kidney is removed for cancer or trauma

2.3.2.1 Laparoscopic Hand Assisted Donor Nephrectomy

By definition, the removal of a kidney for the purpose of allograft transplantation using both laparoscopy with the placement of a hand into the peritoneal cavity/retroperitoneum is termed laparoscopic hand assisted donor nephrectomy. The ability of a silicone gel hand port enables the hand to be placed in the abdomen without loss of pneumoperitoneum (set at 12–15 mmHg). Both retroperitoneal and transperitoneal approaches have been described in the literature with excellent outcomes and acceptability to the donor. Ostensibly transperitoneal laparoscopic donor nephrectomy has been widely adopted over the retroperitoneal technique in part because most transplant and general surgeons are familiar with peritoneal insufflation and working within the peritoneal space.

With the patient supine, the first port is marked on the skin as the hand port, with the authors preference for this to be drawn just above the pubic symphysis along the “bikini line”. It is ideal for this should be drawn to the size of the operator’s hand with the patient asleep, fully relaxed and supine, as the midline of the abdomen may shift during repositioning to the lateral decubitus position. Alternative sites for the hand port include a midline supraumbilical, periumbilical or infraumbilical incision. The hand port can be used partly or totally during the operation. A further 2 ports are introduced - a 12 mm port lateral to the umbilicus, and then under vision for the 30° camera, a 5 mm lateral port for the working instrument can be used for an energy device or conventional

diathermy. For the right kidney, an optional peri-xiphoid 5 mm port may be required to help retract the liver. The insufflation pressure is set maximally at 12 mmHg.

In the transperitoneal approach, the left or right colon is mobilised along the avascular white line of Toldt towards the pelvis. Gerota's fascia at this point is generally left in place, so that this does not fall and obscure the operators view. In order to expose the renal vein, the fascia overlying the vein is dissected and the renal vein identified. On the left, the adrenal and gonadal tributary is also identified. Gerota's fascia is divided over the adrenal gland at the upper pole, extending posteriorly and inferiorly to the spleen. Mobilisation of the adrenal gland is preferentially left before complete renal mobilisation as this area can inadvertently bleed.

The ureter and gonadal vein are usually identified inferiorly towards the pelvis and then traced back toward the kidney hilum. Digital sweeping of the tissue laterally with a finger around the gonadal vein and ureter permits mobilisation caudally. With the gonadal vein mobilised at least 2 cm away from the renal vein, it is ligated twice with a clip and then divided. This is then repeated in a similar manner for the adrenal vein approximately 1 cm at least away from the renal vein. Adequate length of the renal vein on the left side can often be attained without this manoeuvre and should not compromise risk of bleeding from an IVC cuff that retracts after ligation. With lumbar vessels draining into the renal vein identified and ligated, the renal artery can then be dissected by releasing the tissue around its base. This can be facilitated by posterior retroperitoneal release of the kidney, enabling anterior and posterior views of the renal artery. Once the kidney is mobile in this back and forth motion, the tissue between the renal artery and vein can be divided adequately to ensure passage of the linear cutting endostapling device. Once the ureter is divided with Hem-o-lok® clips and scissors, the vessels can then be divided. It is the authors preference to use a linear stapler (the authors preference is the Echelon Flex™ angulated stapler, Ethicon US) across the renal artery first and then the vein, although it is recognised that Ligaclips and plastic Hem-o-lok® clips have been utilised in centres outside the UK, with the advantage of millimetres of length gained on the organ

vasculature. The counter to this is the catastrophic effect of a potential slip of clips/ligatures, with the ensuing morbidity or indeed mortality. Once divided, the mobile kidney can be removed via the hand port and handed to the recipient surgeon on ice to be cold perfused.

It is vitally important at this stage to remain focused on the donor, with the camera remaining inside to ensure no immediate bleeding. Both staple lines should be inspected after identification, with judicious haemostasis around the renal bed. The 12 mm port can be closed intracorporally and the Pfannenstiel hand port wound closed in a layered standard fashion with 1 Polydioxanone or Prolene suture. It is sometimes advocated in donors with an elevated BMI a closed suction drain applied to the wound to limit the development of seroma, although this observational practise is not supported with high level evidence.

The advantages of hand-assisted laparoscopic donor nephrectomy over full laparoscopy include the ability to use tactile feedback, less kidney traction, rapid control of bleeding, fast kidney removal, less blood loss and shorter warm ischaemic periods. The hand port provides additional safety to laparoscopic donor nephrectomy, because rapid control of potential massive blood loss from major blood vessels is possible with hand assistance. The disadvantage includes higher costs associated with a hand port, a worse ergonomic position for the surgeon during the operation, and a higher rate of wound infections.

2.3.2.2 Laparoscopic Retroperitoneal Donor Nephrectomy

By far the most common approach to the retroperitoneum for donor nephrectomy is with the use of a hand for assistance (HARS). As previously mentioned, the HARS technique confers the safety advantage by allowing immediate haemostasis should there be a severe sudden bleed. In a pure laparoscopic procedure, sudden severe bleeding from a major vessel is much harder to control and the necessity for open conversion is always prioritised. Other advantages are listed in Box 2.4.

Box 2.4 Advantages of Hand Assisted Retroperitoneal Donor Nephrectomy

Advantages of hand assisted and retroperitoneal nephrectomy over total laparoscopic nephrectomy

1. Port placement- safer with the hand, reduced risk to visceral structures
2. Control of bleeding- immediate with the hand in abdominal cavity
3. Prevention of torsion of the kidney
4. No risk of internal herniation
5. Secure/Rapid placement of staplers
6. Secure/Rapid retrieval of the kidney
7. Reduction in warm ischaemia time
8. Shorter learning curve
9. Reduced risk of bowel obstruction
10. Reduced risk of adhesions and internal hernias

2.3.2.3 Fully Laparoscopic Donor Nephrectomy

Without the tactile sensation of the hand inside the abdomen, the approach to the fully laparoscopic donor nephrectomy is slightly more technically challenging than its hand assisted counterpart and has a steeper learning curve. Dissection of tissues is of critical importance and vigilance must be taken on both the retracting forceps as well as the working energy device dissection.

Port placement is again user dependant, but the authors agree on the common placement of a subxiphoid 5 mm port, a periumbilical 12 port, a lateral 12 mm port and a lower Pfannenstiel incision similar to the hand port of the hand assisted approach, measuring approximately 6–8 cm in diameter and lying approximately 1–2 cm above the pubic symphysis centred over the midline.

Mobilisation of the colon is performed in a similar fashion to that previously stated, with medial visceral rotation carefully performed to identify the ureter whilst separating the mesocolon from the mesoureteral structures in the avascular plane.

Identification of the ureter and dissection laterally over the psoas enables caudal mobilisation towards the renal pelvis and the kidney. In a similar manner to the hand assisted approach, careful identification of the gonadal and adrenal tributaries from the renal vein should be undertaken, with the former being traced from the ureteric pedicle. As previously stated, dissection around the hilum and identification of the renal artery can take place once the vein is in clear view. The adrenal vein tributary at the superior aspect of the renal vein can be isolated with a right-angled dissector, ligated and clipped before being transected.

It is the authors' preference to identify the plane between the adrenal gland and the kidney, and dissect close to the adrenal with electrocautery. Once the adrenal gland is separated, mobilisation towards the spleen can then take place with division of the splenorenal ligament using a Ligasure or similar device. The upper pole of the kidney will be fully mobile now, with the fat between the vessels remaining to be dissected. The latter should be done with great care so as not to cause traction injury to the renal artery. Once the posterior retroperitoneal attachments to the kidney are released and the vessels mobilised, stapling of the renal artery followed by the vein, in a similar manner to the hand assisted approach, can take place. An Endo Catch™ is inserted via the lower abdominal Pfannenstiel incision, with care taken to maintain the pneumoperitoneum by creating a purse string suture in the peritoneum before the instrument enters the abdominal cavity. Once the Endo Catch™ is removed with the kidney, the purse string can be pulled close to enable inspection of the renal bed for haemostasis along with identification of the staple lines.

2.3.2.4 Open Retroperitoneal Nephrectomy

In the era of laparoscopy, the open donor nephrectomy operation in the developed world has become largely historical. Having been the standard from 1954 until the mid 1990s, the operation is still performed in a minimal access

manner in limited numbers, but has largely been replaced with the previously described minimally invasive techniques. Laparoscopic donor nephrectomy is associated with a significantly shorter hospital stay, fewer postoperative analgesic requirements, improved cosmetic appearance and a quicker return to work as compared with open donor nephrectomy and results in similar allograft function. The slight disadvantage of the laparoscopic technique is that it results in a shorter vascular pedicle when compared with the open donor nephrectomy. The warm ischaemia time and operating time for laparoscopic donor nephrectomy is also substantially longer than compared with open donor nephrectomy. A 2008 meta-analysis of 4 randomised control trials comparing laparoscopic with open donor nephrectomy found no significant difference in post-operative complications, although longer warm ischaemia times were noted in with the former.

With the patient positioned in the lateral decubitus position, an incision is conventionally made between the anterior superior iliac spine and the 12th rib anterior to the mid axillary line. Resection of the distal part of the lowest rib can be applied to allow sufficient access to the kidney. Dissection and division of the latissimus dorsi, external oblique, internal oblique and transversus abdominus muscles should occur with exposure of the peritoneum which can then be swept medially to enter into the retroperitoneum. Judicious retraction is required at this point to expose Gerota's fascia which can be divided to enable exposure of the kidney hilum. Once the perinephric fat is divided, the vessels can be easily identified and isolated with a vessel sling. The adrenal gland can be bluntly dissected with a finger with cautious use of electrocautery to ensure minimal bleeding. Once the vessels are isolated and the tributaries ligated, adequate artery and vein length should be obtained in order to pass a haemostat across their respective bases. The vascular pedicles are oversewn with 5-0 Prolene suture. Once divided, the ureter can be identified on its pedicle and transected with adequate length using a Hem-o-lok[®] clip and scissors.

With one of the most common post-operative complications from open nephrectomy being incisional hernias, judicious haemostasis and layered closure should take place in a systematic and precise fashion. Each muscle layer is closed with a 1 Polydioxanone suture and the deep dermal layer approximated with 3-0 Vicryl absorbable suture. It is not the authors preference not to leave a drain unless there is an absolute necessity or the risk of seroma formation e.g. in high BMI ($>35 \text{ kg/m}^2$) patients.

2.3.2.5 Robotic Donor Nephrectomy

Robotic surgery in donor nephrectomy was first reported in 2002. Use of a multi-armed, multi-port instrument with the operating surgeon in a separate operating module is now widely established in urological practise. The application in transplantation not only in donor nephrectomy but also in recipient implantation has gained much momentum over the last decade with leading centres in India and the USA publishing case series. The potential advantages sought over conventional laparoscopy lies in the optics and dexterity the arms of the robotic instruments can provide.

The donor nephrectomy is performed with the patient in a decubitus position. Four trocars are placed in the left or right side of the abdomen to allow placement of three articulated robotic arms, the robotic camera, and the standard laparoscopic instruments used for retraction and dissection during the procedure.

The limitation of laparoscopic instruments is their inability to articulate fine dissection of hilar vessels in a confined space. This is where the use of the small multi-faceted robotic arms excels. Proponents of the technique claim the potential to create vascular exposure and increase length of vessels working in a limited space. There is also the potential reduction in dissection time in the skilled operators hands, although the authors find limited published evidence for this. Whether this level of finesse impacts on graft outcome is again not evidenced. Currently, for many units the high costs of the

machine and consumables makes the technology a non-essential commodity. Nonetheless despite longer operating times and warm ischaemia, post-operative pain requirements are reportedly reduced in donors without impact on immediate function.

2.3.2.6 Donor's Complications

Both laparoscopic and open donor nephrectomy operations potentially have significant operative risks that should be outlined at the time of consenting. Registry data has found that the mean stay after laparoscopic donor nephrectomy to be approximately 2.5 days with the quoted overall complication rate to be between 6–8%, whereas for open nephrectomy the mean length of stay is 5 days with an overall quoted complication rate of 2%. The 90-day mortality rate after laparoscopic and open nephrectomy is 0.03% and 0.04% respectively. The main significant difference is the return to work and normal activity, which is on average 6 weeks after laparoscopy and can be up to 3 months following open donation. Major complications (Clavien grade ≥ 3), are rare, ranging from 3 to 6%, with the overall rate of morbidity significantly higher after open donor nephrectomy compared to laparoscopic nephrectomy.

One of the most important potential risks is the development of end stage renal disease (ESRD) following kidney donation and has been quoted as low as 0.9% over 15 years. Even though this risk remains higher, however, than matched non-donor counterparts, it remains much less than that of the general (unscreened) population. Compared to the general public, kidney donors have equivalent (or better) survival, excellent quality of life, and no increase in ESRD. Certain patient groups (e.g. Afro-Caribbean donors, younger donors, genetically related donors, donors to patients with immunological causes of renal failure, and overweight donors) have a higher risk of ESRD following donation.

For the recipient, the benefits of living, compared to deceased-donor, kidney transplantation are well known

with most donors also enjoying a quality of life that is similar or even better when compared with the general population. These results are linked to the intense medical evaluation of potential donors, resulting in the selection of only healthy and motivated individuals. Several studies have reported a better quality of life of donors after laparoscopic donor nephrectomy than after open donor nephrectomy, and in terms of costs, although laparoscopic donor nephrectomy has the potential to be more expensive due to the use of disposable instruments, better cost-effectiveness has been found compared with open donor nephrectomy.

2.3.3 *Recipient Implantation*

The basic operative methodology for renal transplantation has changed little from the principles of vascular anastomosis described by Alexis Carrel in 1902 and subsequently revised by René Küss and colleagues in 1951. Preparation and preservation of the kidney is essential to maximise early and late graft function after transplantation and is achieved in part through the use of preservation solutions and maintaining the graft in hypothermic conditions.

Three approaches exist with regard to the surgical placement of the renal allograft: (1) extraperitoneal, (2) transperitoneal, and (3) intraperitoneal. Traditionally implantation has been extraperitoneal in the iliac fossa for renal transplantation alone or a simultaneous liver-kidney transplant owing to the superficial position of the external iliac vein and ease of graft assessment by palpation and biopsy. For a simultaneous pancreas-kidney transplant, the left iliac fossa is preferred for the renal allograft as this will allow for implantation of the pancreas the right side, with pancreas exocrine drainage via the small bowel or bladder and endocrine release into the systemic circulatory system via the IVC or common iliac vein. A transperitoneal approach may be used following failed kidney transplants in both iliac fossae and the intra-

peritoneal approach in small children to accommodate the relatively large graft. Morbidity associated with an intraperitoneal approach remains higher than extraperitoneal, with complications such as visceral injury or bowel obstruction and adhesions almost exclusively observed in the former. In the case of dual kidney transplantation (DKT), these are often split for individual implantation either ipsilaterally or bilaterally in the iliac fossae of the recipient via a classic Rutherford Morrison incision and will be discussed in more detail below.

2.3.3.1 Implantation Site

As alluded to above, the classical site for renal transplantation is the right iliac fossa, centred over the external iliac vasculature, as the longer and more horizontal right external iliac vessels facilitate easier vascular anastomoses. However, the advantage of placing the donor kidney in the recipient's contralateral side ensures the renal pelvis and ureter lie anterior and will be easier to access should the need arise for further surgeries (e.g. ureteric reconstruction). Other factors to consider when deciding on the site of surgery include previous surgery (e.g. failed renal transplantation), severe atherosclerotic/calcific disease affecting iliac arteries, and previous pelvic exploration and peritoneal dialysis catheters and are further outlined in Table 2.1. The use of both internal iliac arteries in serial renal transplantations in men is avoided to prevent impotence. Large grafts have historically been implanted within the abdominal cavity so as to prevent potential "kidney compartment" syndrome (over compression of the renal parenchyma limiting venous outflow). However it is the authors preference to still place the large kidney allograft into the iliac fossa but use either a subrectus pouch to position the kidney, a mesh to enable fascial closure without compression or use the right iliac retroperitoneal space to permit distal aortic anastomosis or common iliac artery with venous drainage either to the inferior vena cava or common iliac vein.

TABLE 2.1 Factors to take into consideration for implantation site

Factor	Preferred Site	Explanation
Previous surgeries	Opposite iliac fossa	Prevention of visceral/vessel injury or lymphocele and shorter operative time
Multivisceral operation	Left iliac fossa in the retroperitoneal space Abdominal cavity for en bloc Paediatric transplantation	Prevention of complications spreading from one graft to another
Size/length/number of graft arteries and veins	Iliac fossa	Prevention of postoperative ileus
Size/length/number of ureters	Iliac fossa if recipient ureter not diseased	Prevention of urine leakage or ureteral stricture
Number of kidney grafts	Retroperitoneal space of right iliac fossa	In this case it is better may be better to use the abdominal aorta/common iliac artery and inferior vena cava
Anomalies of donor graft	Abdominal cavity/iliac fossa depending on size of graft	Space consideration for graft and anastomotic sites for graft vessels/ureters

Historically, the three incisions used for renal transplantation are the Gibson incision, the 'hockey stick' incision and the Rutherford Morrison oblique incision. The Gibson incision is the most common approach and involves a relatively atraumatic curvilinear incision that starts two centimetres medially to the anterior superior iliac spine, running 0.5 centimetres above the inguinal fold, and is continued to the lateral border of the rectus muscle. The para-rectus 'hockey stick' incision is prolonged medially to the midline above the

pubic symphysis and can be extended upward to the subcostal margin. One advantage of this approach is that it yields better access to the common iliac vessels and inferior vena cava. Its disadvantages include denervation of the para-rectal groove, lesser strength of abdominal wall closure, and potentially inferior cosmetic appearance due to its direction against the Langer's skin lines. Although shorter in length, the oblique incision may require the division of all the lateral abdominal muscles. Nanni and colleagues compared the 'hockey stick' and oblique incisions for post-operative complications and concluded that the latter was associated with a reduced incidence of incisional hernia and achieved a more favourable cosmetic appearance. Whichever approach is used, it is imperative that all incisions are accompanied by strict haemostasis to avoid wound or peri-graft haematomas that could eventually lead to infection, dehiscence, kidney compartment syndrome from compression of the graft.

Mobilization of a length of the external iliac vessels is subsequently conducted (and common iliac arteries is also needed when the internal iliac artery is considered as the candidate of arterial anastomosis). Exposure of the iliac vessels requires precise technique to avoid peritoneal injury and enteroceles, commonly described as a 'renal paratransplant hernia'. In addition, post-renal transplant lymphoceles resulting from inadequate lymphatic ligation can result in unnecessary patient morbidity. One study that followed up the impact of surgical technique on the incidence of lymphoceles reported that thorough ligation of all lymphatics using silk ties, both during dissection of the recipient vessels and the donor allograft, significantly reduces the incidence of this complication (with only one patient in their series of 273 transplants developing a lymphocele).

Following iliac vessel mobilization, the process of vascular anastomosis begins after choosing suitable points of vascular inflow and outflow along the iliac vessels. The site of each anastomosis and the position of the graft should be specified accurately according to the size and length of the vessels and also the length of the ureter and position of the recipient bladder. The kidney graft is placed in the wound and the renal

vessels stretched to the recipient vessels to determine the best sites for the arterial and venous anastomoses. After confirming the exact length and position of the anastomosis site to prevent donor vessel kinking or rotation, vascular clamps are applied to the recipient vessels. We prefer to use Statinsky clamps for side-clamping of the external iliac vein or inferior vena cava and angled Dardik clamps to the common or external iliac artery.

It is important the anastomosis steps are completed carefully but in a timely manner as the kidney lies outside the body (i.e. out of cold storage) for this process, thus theoretically presenting an opportunity for warm ischaemic graft insult. The classical technique involves end-to-side venous anastomosis first, followed by an end-to-side arterial anastomosis.

2.3.3.2 Venous Anastomoses

Classically, allograft renal vein to the recipient iliac vein is anastomosed in an end-to-side fashion using a continuous monofilament suture (5-0 or 6-0 Prolene). The venous valve site in the external iliac vein should be avoided, if possible, as the wall of the vein is very thin proximal to the venous valves (sinuses of Valsalva) and may be ruptured during the anastomosis. The length of the donor vein of a right kidney can be increased by refashioning the inferior vena cava cuff which may be of particular importance in a short right renal vein (Fig. 2.1). Saphenous, gonadal or superficial femoral vein grafts as well as polytetrafluoroethylene grafts have also been used to successfully elongate short donor veins. It is the authors opinion that venous reconstruction is probably best avoided when using kidneys with prolonged cold ischemic times and from DCD donors to avoid the risk of venous thrombosis. Any reconstructions of the donor vein should take place prior to implantation of the kidney and, as mentioned below, excessive elongation should be avoided to protect against renal vein kinking and thrombosis; this is particular true for the left renal vein which is invariably shortened.

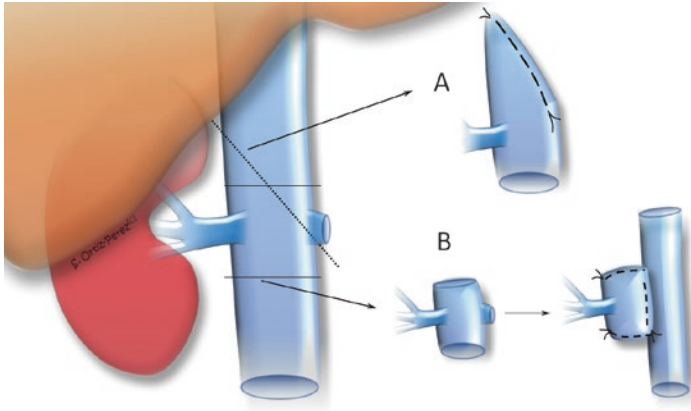


FIGURE 2.1 Venous extension of a right renal vein can be performed either with an oblique transection of the IVC (**A**) or side oversew of the supra- and infra-renal IVC ends (**B**). (IVC inferior vena cava, RRV right renal vein)

Initial sutures are placed either end of the venotomy with an anchor suture sometimes placed at the mid-point of the lateral wall to prevent the anterior or posterior wall being inadvertently caught up in the suture line. The anchoring sutures can prevent posterior wall suturing whilst ensuring end-to-side apposition.

Inaccessible or unsuitable iliac veins in the recipient can be managed by using the infrarenal and infra-hepatic inferior vena cava. In rare cases where both the iliac veins and the inferior vena cava have thrombosed, satisfactory results have been achieved with anastomosis of the renal vein to the portal venous drainage system, inferior and superior mesenteric veins and even large venous collaterals such as the left ovarian vein.

2.3.3.3 Arterial Anastomoses

Most operators would agree that surgical equipoise dictates personal preference over evidence base for the type of technique of renal artery to donor vessel anastomosis. Using a

monofilament suture (5-0, 6-0 or 7-0), the most common vessel for end-to-side anastomosis is the external iliac artery (EIA), which is generally placed at a point more proximally than the vein, and for end-to-end anastomosis the internal iliac artery (IIA) in both living and deceased donor transplants remains the best option.

The external iliac artery is incised longitudinally and the lumen is irrigated with heparinized saline. An opening of a suitably-sized calibre created with an artery puncher is created in the common or external iliac artery and facilitates the anastomosis of renal arteries from live donors in the absence of Carrel patch. An endarterectomy is not needed in most cases, but if it is performed, any intimal flaps must be completely secured to the arterial wall with a tagging U-stitch. Taking full-thickness sutures of the arterial wall, particularly in patients with arteriosclerosis, must be meticulous to complete the anastomosis. The needle should move from inside to outside of the more diseased artery (usually the recipient artery) to tag the intima to the media of the artery and prevent creating of an intimal flap and potential thrombosis.

If a deceased donor graft has multiple vessels, a Carrel patch of aorta line with the graft vessels can be used. The patch technique, however, may result in elongated donor vessels (artery on the right side and vein on the left side) that leaves the graft vulnerable to kinking and could be a site of stenosis, thrombosis or drug-resistant hypertension at a later post-operative follow up. Dual arteries on a single patch to a right-sided kidney often make positioning of the kidney difficult without kinking one or the other artery, and might necessitate dividing the patch and shortening the arteries to fulfil two separate anastomoses. In addition, the Carrel patch may be severely atherosclerotic and might not be suitable for a safe anastomosis.

Multiple renal arteries in a living related donor represent more of a challenge. It is considered acceptable to ligate smaller arteries (less than 1 millimetre) of the upper and middle pole depending on the supply to the renal cortex. This can be judged during back-table perfusion of the kidney via

the main donor vessel immediately after retrieval. Ligation is usually considered acceptable if the dependant area is judged to be less than 10%. Arteries bigger than 1 millimetre can be anastomosed to the EIA or possibly the inferior epigastric artery following reperfusion of the graft, especially in the lower pole to avoid ischaemia of the ureter. Smaller vessels (one to five millimetres) can be anastomosed using an interrupted monofilament (Prolene) suture that ensures an even distribution of tension around the vessel and prevents theoretical stricturing that can be caused with a continuous suture. In the living donor recipient setting, it is also the authors' experience to isolate a section of the distal IIA down towards the first branches and utilise the end for an end-to-end anastomosis with the main renal artery and then an end-to-side of the polar vessel directly onto the conduit (Fig. 2.2) or end-to-end with one of the first-order branches. Once the reconstruc-

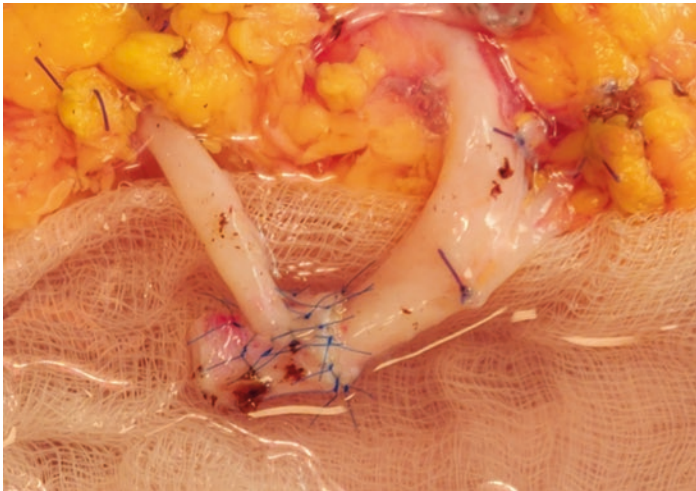


FIGURE 2.2 Use of the internal iliac artery conduit to create an end to end anastomosis of the main renal artery and end to side of the lower polar vessel. Interrupted 6-0 prolene sutures placed. (Picture courtesy of Mr. N Russell, Cambridge)

tion has been performed on the back table, the internal iliac end can be anastomosed back together with interrupted Prolene in an end-to-end fashion to the proximal IIA. The use of the internal iliac saves prolonged clamping of the EIA and leg ischaemia whilst preserving future options for the external iliac to be used.

Variant anatomy with two or more renal arteries may be anastomosed together side-to-side preserving the lumen of each vessel, or anastomosed separately to either the recipient EIA, IIA or one renal branch to each.

Different techniques may be employed if a surgeon attempts to reconstruct arteries before implantation including side-to-side anastomosis of same size arteries or end-to-side anastomosis of a smaller artery to a larger one (Fig. 2.3). In situations where the renal artery is damaged the best approach it is to transect the diseased part and use a small branch of the donor artery (for example, the donor iliac artery) as an elongation conduit of the renal artery. However, this would inevitably prolong the operative time and thus impact the length of warm ischaemia of the kidney.

2.3.3.4 Reperfusion

At the point of completion of the vascular anastomosis, vessel clamps can be removed to aid in reperfusion. It is the authors practise for reperfusion to coincide with a mean arterial pressure (MAP) of at least 65 mmHg with a systolic blood pressure of between 110 to 120 mmHg. At this point, the kidney is inspected for fullness of perfusion and then felt globally to ensure the organ is adequately filled. A soft kidney may be indicative of under filling or even arterial inflow problems, whereas an overly tense kidney could be a sign of venous outflow compromise. It is recommended that constant communication is held with the anaesthetist during the peri-reperfusion period so that changes in cardiovascular status is known and managed appropriately.

Potential challenges can occur with a non-perfused kidney and a pulsatile hilum- indicative of thrombosis or occlusion.

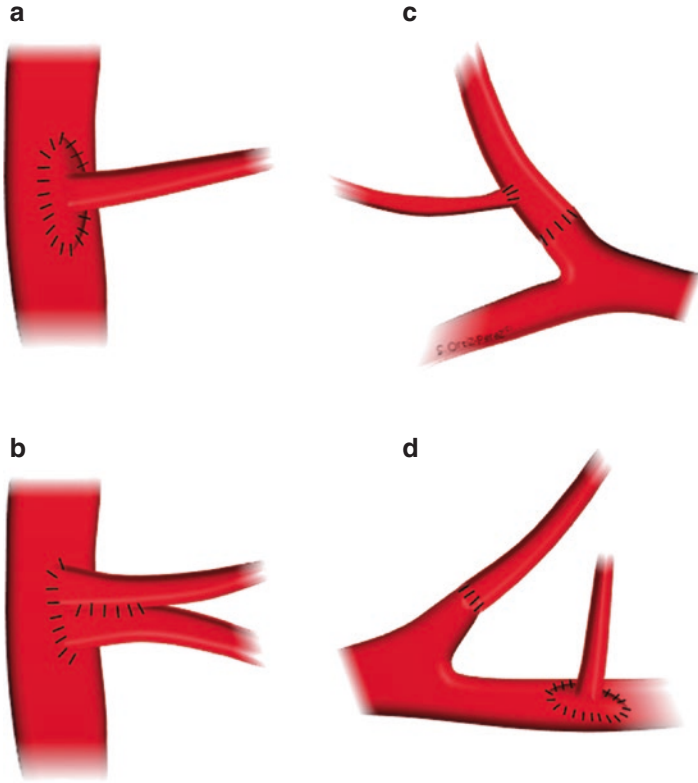


FIGURE 2.3 Some of the variant arterial anastomotic techniques. (a) standard end- to- side anastomosis with Carrel patch, (b) trouser side- to- side of 2 vessels with an end- to- side anastomosis to the external iliac artery, (c) end- to- end of the internal iliac with main artery and an end- to- side of the polar vessel to the artery, (d) use of the inferior epigastric artery for a lower polar artery

Intraoperative ultrasound can also be used to check flow within the artery and vein. At this point, preparation should be made to reclamp the iliac vessels, cold perfuse the organ with preservation solution and refashion the anastomoses. Preparation for blood loss should be made and it may be useful to consider cell salvage of blood.

2.3.3.5 Ureteric Implantation

The most common early post-operative complication in renal allograft transplantation (ranging from quoted rates of 5 to 10%) arises from the vesicoureteric anastomosis. Two major complications are recognised: urinary leak and ureteral stenosis. Prevention of these begins with meticulous attention to the surgical technique at time of implantation.

Urinary tract reconstruction begins following successful reperfusion of the donor kidney, with the type of reconstruction dependent on the position of the graft, condition of the recipient's bladder (or bladder alternative) and the length, condition and number of donor ureters. The most commonly employed technique is the ureteroneocystostomy (UNC) and is often categorised into transvesical or extravesical procedures. It is the authors' preference to keep the ureter as short as is feasible for a comfortable anastomosis to prevent distal ureteric ischaemia. Maintenance of the lower polar triangle of ureteric mesentery is essential given that blood supply to the upper ureter is originated from the lower polar terminal arterial branches.

The Leadbetter-Politano approach (transvesical UNC) utilises one anterior cystostomy to access the interior of the bladder and a posterior cystostomy to recreate a new ureteric orifice in the normal anatomical position, with the ureter subsequently tunnelled in the submucosa to prevent reflux. Murray et al. exploited this method during their first successful human renal transplant in 1954. The Lich-Gregoir technique (extravesical UNC) was first published in 1961, where the aim was to avoid a second cystostomy but maintain comparable antireflux mechanisms. The procedure consists of a suprahialal detrusor myotomy and exposure of the bladder mucosa. Using either continuous or interrupted sutures the ureter is anastomosed to the mucosa with PDS II (polydioxanone) suture and then the detrusor muscle closed over it. Advantages compared to its counterpart procedure involve less bladder dissection, a shorter ureteral length and, overall, a quicker operative time associated with reduced morbidity.

A further variation of the extravesical approach to UNC includes the U-stitch technique, where after creating the anti-reflux tunnel (following dissection of the detrusor muscle and incision of the bladder mucosa), only one U-stitch at the toe or two U-stitches at the toe and the heel of the ureter are used to anchor it before closing with the detrusor muscle. This method can leave the anastomosis vulnerable to leakage, however, especially when there is concern about the distal ureteric blood supply and risk to ischaemia. Alternatively, two parallel incisions in the detrusor muscle may be used: one to transfer the ureter in a submucosal tunnel and the second to anastomose the ureter to the ureteral mucosa. Finally, the ureter may also be anastomosed to the full-thickness wall of the bladder without any antireflux mechanism.

Most surgeons use a ureteral stent to reduce the risk of obstruction in the post-operative period if the ureter or bladder tissue appears marginal. A meta-analysis evaluated five prospective, randomised, controlled trials of routine stenting vs no stenting following renal transplantation and indicated that the collective urinary complication rate following routine stenting was 1.5% compared to 9% without stenting. The markedly lowered incidence of ureteric complications, often a cause of graft loss, appeared to outweigh any increased risk of stent-associated problems such as urinary tract infections or bladder spasms. However, cystoscopic stent removal in the early period post transplantation (between 2 and 6 weeks) is imperative in order to avoid complications such as haematuria, stone formation and infection. Recent technological developments have enabled post-operative stent removal in the outpatient setting, with disposable instruments such as the Isiris™ (Coloplast, Humlebaek, Denmark) endoscope, complete with an incorporated camera module and grasper for the sole purpose of stent extraction. The solitary high cost of the single use camera is offset by the need of theatre space and a day surgery bed with conventional cystoscopy. Another innovation removes the need for cystoscopy altogether, with the ability to connect a magnet incorporated on the stent with that on the tip of a disposable

catheter. The Magnetic Black Star retrieval catheter (Urotech, Achenmühle, Germany) is an introducer catheter smaller than a conventional urinary catheter and is designed for the sole purpose of retrieving the stent with the magnet in a single procedure. Unlike the Isiris system, no prior endoscopic experience is necessary and as such could be performed by a range of healthcare professionals.

In the case of a substandard graft ureter (too short, ischaemic or devascularised), or difficulty mobilising the bladder to enable a sufficient anastomosis, use of the native ureters may be necessary if there is clear lack of evidence for stricture, dilatation, reflux or infection. The surgeon may therefore perform an ureteroureterostomy, pyeloureterostomy or even pyeloneocystostomy. In rare cases where the renal transplant ureter and native ureter are both unsuitable, a pyelovesicostomy may be completed. Ureteral duplication is the most common congenital malformation of the urinary tract but there are few cases in the literature that describe renal transplantation with completely duplicated ureters. Bozkurt and colleagues used a modified extravesical UNC technique on a cadaveric kidney transplant with a completely duplicated ureter. The distal ends of the duplicated ureters were spatulated and their medial ends approximated before the distal parts were anastomosed to form a single cuff and subsequently sutured to the mucosa of the bladder. This approach differed to the previously described procedure involving anastomosis of both distal ends of the ureters to each other followed by the Lich-Gregoir technique for UNC.

2.3.3.6 Wound Closure

Given the potential morbidity associated with wound collections and dehiscence, judicious care should be taken when closing the kidney transplant wound. Mass closure can be adopted, although particular care must be taken in the upper lateral aspects of the external and internal oblique aponeurosis opposition to prevent incisional herniation or inadvertent bowel injury. A medium-sized silicon drain is commonly used

which can be removed in the first few post operative days and this has the added advantage of reducing lymphatic collections immediately post operatively whilst being a safety measure for urinary leak should it occur.

2.3.3.7 Multiple Graft Implantation

In the current climate of growing transplant waiting lists and a shortage of organ donors, the use of extended criteria donors (ECD) is set to gain further momentum in the medium to short term. Extended criteria donors include donors aged 60 years and older or those aged over 50 years with at least two of the following three conditions: cerebrovascular cause of death, serum creatinine greater than 1.5 mg/dL or a history of hypertension.

Outcomes of transplants from ECD kidneys are associated with higher rates of acute rejection episodes and long-term graft dysfunction. However, a benefit of extra life-years is still observed in recipients when compared to dialysis patients on the waiting list. Clinical characteristics that marginalise such donors include age, a history of hypertension or diabetes, the risk of transmitting infection or malignancy, brain death versus cardiac death, the presence of graft abnormalities as well as the morphology and functioning profile of the kidney.

One option for using organs from donors with a suboptimal nephron mass is dual kidney transplantation (DKT). This involves the simultaneous transplantation of two marginal kidneys from donors older than 60 years old or from a solitary paediatric patient younger than 5 years old or less than 21 kilograms in size. When retrieved from paediatric patients, the two kidneys are transplanted en-bloc and the aorta and inferior vena cava anastomosed to the external iliac artery and vein in an end-to-side technique.

Dual kidneys from older donors are mostly split for individual implantation either ipsilaterally or bilaterally in the iliac fossae of the recipient. Outcomes of dual kidneys from standard and extended criteria donors have been reported by a few centres. Remuzzi et al. outlined the use of a pathological

scoring system in which risk was calculated based on histopathological analysis of the donor kidney biopsy. Grade of tubulitis, nephritis and vascular insult was stratified against outcome. This scoring system is now in use in some centres in the UK and a randomised national trial (PITHIA) of using this scoring system to allocate deceased donor kidneys (aged above 60 years) as single or duals is underway. With the availability of a 24 h pathology service that will risk stratify the quality of the donor kidney based on the Remuzzi score, it is predicted that each transplant unit's acceptance of kidneys for transplantation from elderly donors will increase by 10%.

A unilateral DKT is performed via a classic Gibson incision, preferably on the right side. The right kidney is placed superiorly as its renal vein may be lengthened by a segment of inferior vena cava. If necessary, the internal iliac vein can be divided to facilitate anastomosis of the renal vein to it and the renal artery anastomosed to the external iliac artery. Vascular clamps are placed immediately below the arterial and venous anastomoses following revascularisation of the right kidney; the left kidney is then implanted inferomedially and anastomosed also to the external iliac vessels. Extravesical ureteroneocystostomies are then performed separately leaving the ureter of the upper transplanted kidney lateral to the lower one.

2.3.4 Complications of Renal Transplantation

2.3.4.1 Wound Complications

Wound complications post kidney transplantation is by far the most common cause of morbidity with a reported incidence of around 5%. Risk factors associated with the development of wound issues can be categorised into patient related and drug related. Patient related factors include obesity, diabetes, clotting or pre-existing haematological disorders. The most common drug to cause wound problems

in the early post-operative period is Sirolimus which has been associated with lymphocoele accumulation as well as dehiscence. Diagnosis is largely clinical, with local pain, erythema, discharge and dehiscence being common findings. Closure with skin clips enables local drainage of collections and the application of a superficial vacuum assisted closure (VAC) system. Treatment of wound infections with antibiotics should be guided based on positive microbiological cultures. Complete full thickness dehiscence of the wound is rare, but mandates return to theatre, wound washout and vacuum-assisted closure. Repeated exploration of patients for recurrent seromas or haematomas may give rise to the risk of incisional hernias which can be managed with mesh repair in the context of culture negative microbiology.

2.3.4.2 Arterial Complications

Post-transplantation transplant renal artery stenosis (TRAS) is not uncommon, with the varied reported rates of incidence of 0.5–13% in part attributed to lack of standardised definition of haemodynamically significant transplant renal artery stenosis. They can cause significant morbidity with transplant dysfunction and eventual graft failure.

The aetiology is complex with multiple predisposing factors such as pre-existing atherosclerosis, arterial trauma during transplant, cytomegalovirus infection and surgical technique. Transplant renal artery stenosis may arise in the donor renal artery, surgical anastomotic site or in the recipient iliac artery secondary to surgical trauma.

Initial evaluation of TRAS is most commonly performed by colour flow duplex ultrasound, with Magnetic resonance angiography (MRA) reserved for those with potentially complex vascular anatomy. Significant vascular stenosis is suggested by Doppler findings of: (i) peak systolic velocities >200 cm/second, (ii) velocity gradient between stenotic and prestenotic segment of $>2:1$, and (iii) distal turbulence seen as spectral broadening or parvus tardus waveform.

Institutions adopt varying intervention management strategies, with some performing percutaneous angioplasty (PTA) and solely reserving stents for balloon-resistant stenoses as the primary percutaneous intervention. Primary angioplasty is often implemented in those with stenosis affecting the main-stem or first-order segmental arteries, whilst stent placement is performed in case of residual stenosis or dissection.

A meta-analysis reported a higher technical success (98% vs 77%), lower restenosis rate (17% vs 26%) and clinical outcome (20% vs 10% cure rate in hypertension, and 30 vs 38% improvement rate of renal function, $p < 0.001$) in stent placement compared to angioplasty alone.

Conservative management of TRAS has a higher risk of graft failure (65%) with early intervention. Medical management is advocated if the stenosis is considered haemodynamically insignificant or if intervention is deemed to be associated with high risk of graft loss. In a retrospective single centre study of 44 primary angioplasty treated TRAS, 82% demonstrated improvement in graft function, with this cohort being the only one illustrating both significant and sustained improvement in BP blood pressure and serum creatinine, compared to groups treated with surgery or conservative medical management. Surgery is reserved for those refractory or with unfavourable anatomy for PTA. Other indications for surgery include recent transplant, multiple stenoses, long and narrow stenoses.

2.3.4.3 Venous Complications

Venous thrombosis is relatively rare but a clinically devastating post-operative complication (2.9% in one study of 103 renal transplants (41), with rates ranging from 0.5% to 4%). It should be considered in the presence of acute severe supra-pubic swelling or sudden onset frank haematuria and is most common within the first 30 days post-operatively. Even though there are many intrinsic causes of thrombosis, it is more likely that in the immediate post-operative setting the

cause is due to kinking of the renal vein or the onset of sustained hypotension. Of note, numerous retrospective studies have found that intraoperative heparin did not reduce the incidence of graft thrombosis. Despite some solitary case reports of thrombolysis, the usual treatment of choice is graft salvage with a reoperation and thrombectomy and most likely graft nephrectomy. The choice of anticoagulation post-operatively will be balanced against the risk of bleeding or collections, but it is the authors experience that haematomas and collections are easier to manage than thrombotic episodes.

2.3.4.4 Ureteric Complications

Despite the widespread use of intraoperative placement of transplant ureteric stents, the reported ureteric complication rate is widely quoted from 2–4%. Ureteric complications are largely leak related or obstructive (stenosis or external compression from, for example, a lymphocele). Clinical evidence of a leak can be in the form of suprapubic or graft site tenderness in the setting of oliguria or with a differentially high drain creatinine. The cause of this in the immediate post operative setting is either technical or necrosis due to an ischaemic ureter. Management of leaks is almost always drainage of the collection followed by surgical correction, although temporising ureteric stents can be placed in the context of minor leaks.

A longer term complication in the setting of insidious graft dysfunction and sonographic features of hydronephrosis, is ureteric stenosis. This can occur over several weeks to months and can be associated with infection (e.g. BK virus), ischaemia or rejection. Initial management must confirm the absence of infection, temporising urinary drainage with a percutaneous nephrostomy prior to definitive treatment. This is then followed with either balloon ureteroplasty for short segment stenosis or surgical reimplantation of a healthy section of the donor ureter. The latter can be performed directly

back on to the bladder itself or implanting the native ureter onto the transplant pelvic ureteric junction in the case of lengthy stenotic lesions.

2.3.4.5 Lymphocoele Formation

The disruption of lymphatics either during dissection of the iliac vasculature in the recipient or during procurement of the kidney and preparation of the renal hilum, can cause collections of lymph post-operatively. Documented incidence of lymphocoeles range from 0.6 to 18% making it one of the most common causes of early morbidity in the renal transplant recipient. Diagnosis is based on graft dysfunction with the presence of a collection surrounding classically the lower pole of the kidney on sonography. Aspiration of the collection can confirm the lymphocoele, rather than a urinoma, when sent for biochemistry and measurement of creatinine. Management can be either percutaneous or open drainage, with fenestration of the peritoneum under open or laparoscopic vision. This should be performed with judicious balance towards drainage of the lymph in a sizeable window without risking the development of intestinal herniation. Excellent results have been seen with laparoscopic approaches to lymph drainage compared to open. Another option is the injection of a sclerosant such as iodine, tetracycline or fibrin glue, although mixed outcomes in terms of rates of complete resolution have been reported.

2.4 Future Perspectives

Kidney transplantation has become the optimal treatment for patients with end-stage renal disease. Early recognition and management of post-operative complications is key to minimising patient morbidity, and potentially mortality, attributed to graft loss. Variation in surgical implantation site has evolved with the advent of multivisceral procedures and the inclusion of suboptimal grafts. Thoughtful consideration must

be given to the use of kidneys from extended criteria donors (ECD) and the implementation of dual kidney transplantation (DKT) which can be associated with a higher risk of surgical complications when compared to a standard kidney transplant. Finally, a consensus is required regarding intraoperative or post-operative anticoagulation avoid peri- or post-operative graft thrombosis as recent evidence suggests little to no benefit over no anticoagulation.

Of course, not to be overlooked is the development, advancement and clinical integration of robotic technology in renal transplant surgery. The first case report of laparoscopic/robotic kidney transplantation was published in 2010 demonstrating the feasibility of such a procedure; however, operative anastomosis time was slower when compared in other studies with open kidney transplantation. Nevertheless, limited published data report less pain, better cosmetic appearance, fewer wound complications resulting in shorter hospital stay, and equivocal graft function to an open procedure. It is clear that with refinement of laparoscopic devices and technique, this is a strategy that may be widely employed in the near future. The current limitation of high cost with an equivocal outcome measure over conventional open implantation means uptake is likely to be slow, with significant benefits potentially to be seen in sub-group of patients e.g. those with high BMI.

Finally, perfusion machine systems have been one of the most exciting developments in the last decade. The initial cold perfusion machine of the Lifeport™ (Organ Recovery Systems, Brussels, Belgium) that was trialled across the UK and Europe, has been shown to reduce the incidence of delayed graft function and lead to better graft function at 3 years in a recent meta-analysis. More recently, ex-vivo normothermic perfusion (EVNP) of kidneys has been developed by Hosgood and associates and offers the potential to serve as a tool for evaluation of kidney grafts prior to implantation in order to reduce the uncertainty with respect to graft viability often encountered when using marginal kidneys. This has led to a multi-centre clinical trial aimed at establishing whether EVNP can improve early graft function in DCD kidney transplants.

Finally, whilst at the experimental phase, the potential for establishing cellular treatments or repair using the machine perfusion platform, for example by infusion of nanoparticles attached with therapeutic drugs directly into the donor kidney, remains an exciting prospect.

Bibliography

1. Klein AA, Lewis CJ, Madsen JC. Organ transplantation; a clinical guide: Cambridge University Press; 2011.
2. Libby P, Pober JS. Chronic rejection. *Immunity*. 2001;14(4):387–97.
3. Pascual M, Theruvath T, Kawai T, Tolloff-Rubin N, Cosimi AB. Strategies to improve long-term outcomes after renal transplantation. *N Engl J Med*. 2002;346(8):580–90.
4. Heaphy EL, Poggio ED, Flechner SM, Goldfarb DA, Askar M, Fatica R, et al. Risk factors for retransplant kidney recipients: relisting and outcomes from patients' primary transplant. *Am J Transplant*. 2014;14(6):1356–67.
5. Nankivell BJ, Borrows RJ, Fung CL, O'Connell PJ, Allen RD, Chapman JR. The natural history of chronic allograft nephropathy. *N Engl J Med*. 2003;349(24):2326–33.
6. Muzaale AD, Massie AB, Wang MC, Montgomery RA, McBride MA, Wainright JL, et al. Risk of end-stage renal disease following live kidney donation. *JAMA*. 2014;311(6):579–86.
7. Mjoen G, Hallan S, Hartmann A, Foss A, Midtvedt K, Oyen O, et al. Long-term risks for kidney donors. *Kidney Int*. 2014;86(1):162–7.
8. Matas AJ, Wadstrom J, Ibrahim HN. Kidney donation and risk of ESRD. *JAMA*. 2014;312(1):92–3.
9. Heimbach JK, Taler SJ, Prieto M, Cosio FG, Textor SC, Kudva YC, et al. Obesity in living kidney donors: clinical characteristics and outcomes in the era of laparoscopic donor nephrectomy. *Am J Transplant*. 2005;5(5):1057–64.
10. Kalantar-Zadeh K, Kopple JD. Body mass index and risk for end-stage renal disease. *Ann Intern Med*. 2006;144(9):701; author reply 701–2.
11. Vivante A, Golan E, Tzur D, Leiba A, Tirosh A, Skorecki K, et al. Body mass index in 1.2 million adolescents and risk for end-stage renal disease. *Arch Intern Med*. 2012;172(21):1644–50.

12. Yang A, Barman N, Chin E, Herron D, Arvelakis A, LaPointe Rudow D, et al. Robotic-assisted vs. laparoscopic donor nephrectomy: a retrospective comparison of perioperative course and postoperative outcome after 1 year. *J Robot Surg.* 2018;12(2):343–50.
13. Minnee RC, Bemelman WA, Maartense S, Bemelman FJ, Gouma DJ, Idu MM. Left or right kidney in hand-assisted donor nephrectomy? A randomized controlled trial. *Transplantation.* 2008;85(2):203–8.
14. Hsu TH, Su L, Ratner LE, Trock BJ, Kavoussi LR. Impact of renal artery multiplicity on outcomes of renal donors and recipients in laparoscopic donor nephrectomy. *Urology.* 2003;61(2):323–7.
15. Saidi R, Kawai T, Kennealey P, Tsouflas G, Elias N, Hertl M, et al. Living donor kidney transplantation with multiple arteries: recent increase in modern era of laparoscopic donor nephrectomy. *Arch Surg.* 2009;144(5):472–5.
16. Gerstenkorn C, Papalois VE, Thomusch O, Maxwell AP, Hakim N. Surgical management of multiple donor veins in renal transplantation. *Int Surg.* 2006;91(6):345–7.
17. Tran MH, Foster CE, Kalantar-Zadeh K, Ichii H. Kidney transplantation in obese patients. *World J Transplant.* 2016;6(1):135–43.
18. Rahul Koushik BK. Chapter 16: kidney transplantation-the recipient: Mc Graw Hill Medical; 2008.
19. Ratner LE, Ciseck LJ, Moore RG, Cigarroa FG, Kaufman HS, Kavoussi LR. Laparoscopic live donor nephrectomy. *Transplantation.* 1995;60(9):1047–9.
20. Giessing M. Laparoscopic living-donor nephrectomy. *Nephrology Dialysis Transplant* 2004;19:36–40.
21. Kokkinos C, Nanidis T, Antcliffe D, Darzi AW, Tekkis P, Papalois V. Comparison of laparoscopic versus hand-assisted live donor nephrectomy. *Transplantation.* 2007;83(1):41–7.
22. Nanidis TG, Antcliffe D, Kokkinos C, Borysiewicz CA, Darzi AW, Tekkis PP, et al. Laparoscopic versus open live donor nephrectomy in renal transplantation: a meta-analysis. *Ann Surg.* 2008;247(1):58–70.
23. Horgan S, Vanuno D, Sileri P, Cicalese L, Benedetti E. Robotic-assisted laparoscopic donor nephrectomy for kidney transplantation. *Transplantation.* 2002;73(9):1474–9.
24. Giacomoni A, Di Sandro S, Lauterio A, Concione G, Buscemi V, Rossetti O, et al. Robotic nephrectomy for living donation:

- surgical technique and literature systematic review. *Am J Surg.* 2016;211(6):1135–42.
25. Segev DL, Muzaale AD, Caffo BS, Mehta SH, Singer AL, Taranto SE, et al. Perioperative mortality and long-term survival following live kidney donation. *JAMA.* 2010;303(10):959–66.
 26. Patel S, Cassuto J, Orloff M, Tsoulfas G, Zand M, Kashyap R, et al. Minimizing morbidity of organ donation: analysis of factors for perioperative complications after living-donor nephrectomy in the United States. *Transplantation.* 2008;85(4):561–5.
 27. Mjoen G, Oyen O, Holdaas H, Midtvedt K, Line PD. Morbidity and mortality in 1022 consecutive living donor nephrectomies: benefits of a living donor registry. *Transplantation.* 2009;88(11):1273–9.
 28. Hadjianastassiou VG, Johnson RJ, Rudge CJ, Mamode N. 2509 living donor nephrectomies, morbidity and mortality, including the UK introduction of laparoscopic donor surgery. *Am J Transplant.* 2007;7(11):2532–7.
 29. Ibrahim HN, Foley R, Tan L, Rogers T, Bailey RF, Guo H, et al. Long-term consequences of kidney donation. *N Engl J Med.* 2009;360(5):459–69.
 30. Clemens KK, Thiessen-Philbrook H, Parikh CR, Yang RC, Karley ML, Boudville N, et al. Psychosocial health of living kidney donors: a systematic review. *Am J Transplant.* 2006;6(12):2965–77.
 31. Smith GC, Trauer T, Kerr PG, Chadban SJ. Prospective psychosocial monitoring of living kidney donors using the short Form-36 health survey: results at 12 months. *Transplantation.* 2004;78(9):1384–9.
 32. Andersen MH, Mathisen L, Veenstra M, Oyen O, Edwin B, Digernes R, et al. Quality of life after randomization to laparoscopic versus open living donor nephrectomy: long-term follow-up. *Transplantation.* 2007;84(1):64–9.
 33. Perry KT, Freedland SJ, Hu JC, Phelan MW, Kristo B, Gritsch AH, et al. Quality of life, pain and return to normal activities following laparoscopic donor nephrectomy versus open mini-incision donor nephrectomy. *J Urol.* 2003;169(6):2018–21.
 34. Buell JF, Lee L, Martin JE, Dake NA, Cavanaugh TM, Hanaway MJ, et al. Laparoscopic donor nephrectomy vs. open live donor nephrectomy: a quality of life and functional study. *Clin Transpl.* 2005;19(1):102–9.

35. Nicholson ML, Elwell R, Kaushik M, Bagul A, Hosgood SA. Health-related quality of life after living donor nephrectomy: a randomized controlled trial of laparoscopic versus open nephrectomy. *Transplantation*. 2011;91(4):457–61.
36. Morris PJ. Transplantation—a medical miracle of the 20th century. *N Engl J Med*. 2004;23(351(26)):2.
37. Cassini MF, de Andrade MF, Tucci S. Surgical Complications of Renal Transplantation.
38. Gittes RF, Waters WB. Sexual impotence: the overlooked complication of a second renal transplant. *J Urol*. 1979;121(6):719–20.
39. Nanni G, Tondolo V, Citterio F, Romagnoli J, Borgetti M, Boldrini G, et al. Comparison of oblique versus hockey-stick surgical incision for kidney transplantation. *Transplant Proc*. 2005;37(6):2479–81.
40. Khan T. Post kidney transplant lymphoceles: meticulous ligation of lymphatics reduces incidence. 2011.
41. Baston CHM, Preda A, Gener I, Manea I, Voinea S, et al. Comparative urologic complications of ureteroneocystostomy in kidney transplantation: transvesical Leadbetter-Politano versus extravesical lich-Gregoir technique. *Transplant Proc*. 2014;46(1):3.
42. Zilinska ZCM, Trebaticky B, Breza J, Slobodnik L, Breza J, et al. Vascular complications after renal transplantation. *Bratisl Lekárske Listy*. 2010;111(11):3.
43. Mangus RSHB. Stented versus nonstented extravesical ureteroneocystostomy in renal transplantation: a metaanalysis. *Am J Transplant*. 2004;4(11):7.
44. MT. BB. Modified extravesical ureteroneocystostomy in cadaveric kidney transplantation with completely duplicated ureters: a case report. *J Transplant Technol Res*. 2014;04(2).
45. NHSBT. Taking organ transplantation to 2020. In: England N, editor. Bristol: NHSBT; 2018.
46. Aubert O, Kamar N, Vernerey D, Viglietti D, Martinez F, Duong-Van-Huyen JP, et al. Long term outcomes of transplantation using kidneys from expanded criteria donors: prospective, population based cohort study. *BMJ*. 2015;351:h3557.
47. Lucarelli G, Bettocchi C, Battaglia M, Impedovo SV, Vavallo A, Grandaliano G, et al. Extended criteria donor kidney transplantation: comparative outcome analysis between single ver-

- sus double kidney transplantation at 5 years. *Transplant Proc.* 2010;42(4):1104–7.
48. Remuzzi G, Grinyo J, Ruggenti P, Beatini M, Cole EH, Milford EL, et al. Early experience with dual kidney transplantation in adults using expanded donor criteria. Double kidney transplant group (DKG). *J Am Soc Nephrol.* 1999;10(12):2591–8.
 49. Remuzzi G, Ruggenti P. Renal transplantation: single or dual for donors aging > or =60 years? *Transplantation.* 2000;69(10):2000–1.
 50. Schaffer M, Schier R, Napirei M, Michalski S, Traska T, Viebahn R. Sirolimus impairs wound healing. *Langenbeck's Arch Surg.* 2007;392(3):297–303.
 51. Kobayashi KCM, Rossman LL, Kyriakides PN, Kahan BD, Cohen AM. Interventional radiologic management of renal transplant dysfunction: indications, limitations, and technical considerations. *Radiographics.* 2007;27(4).
 52. Ghazanfar ATA, Augustine T, Pararajasingam R, Riad H, Chalmers N. Management of transplant renal artery stenosis and its impact on long-term allograft survival: a single-Centre experience. *Nephrol Dial Transplant.* 2011;26(1):7.
 53. Voiculescu ASM, Hollenbeck M, Braasch S, Luther B, Sandmann W, Jung G, Mödder U, Grabensee B. Management of arterial stenosis affecting kidney graft perfusion: a single-centre study in 53 patients. *Am J Transplant.* 2005;5(7):7.
 54. Leertouwer TCGE, Bosch JL, van Jaarsveld BC, van Dijk LC, Deinum J, Man In 't Veld AJ. Stent placement for renal arterial stenosis: where do we stand? A meta-analysis. *Radiology.* 2000;216(1):7.
 55. Baig MA, Khan T, Mousa D. Post transplant ureteric stenosis causing allograft hydronephrosis and calyceal rupture: salvage side to side ureteroneocystostomy. *Saudi J Kidney Dis Transpl.* 2010;21(3):504–6.
 56. Keller H, Noldge G, Wilms H, Kirste G. Incidence, diagnosis, and treatment of ureteric stenosis in 1298 renal transplant patients. *Transpl Int.* 1994;7(4):253–7.
 57. Golriz M, Klauss M, Zeier M, Mehrabi A. Prevention and management of lymphocele formation following kidney transplantation. *Transplant Rev (Orlando).* 2017;31(2):100–5.
 58. Lucewicz A, Wong G, Lam VW, Hawthorne WJ, Allen R, Craig JC, et al. Management of primary symptomatic lymphocele after

- kidney transplantation: a systematic review. *Transplantation*. 2011;92(6):663–73.
59. Wagenaar S, Nederhoed JH, Hoksbergen AWJ, Bonjer HJ, Wisselink W, van Ramshorst GH. Minimally invasive, laparoscopic, and robotic-assisted techniques versus open techniques for kidney transplant recipients: a systematic review. *Eur Urol*. 2017;72(2):205–17.
 60. Hosgood SA, Yang B, Bagul A, Mohamed IH, Nicholson ML. A comparison of hypothermic machine perfusion versus static cold storage in an experimental model of renal ischemia reperfusion injury. *Transplantation*. 2010;89(7):830–7.
 61. Jochmans I, O’Callaghan JM, Pirenne J, Ploeg RJ. Hypothermic machine perfusion of kidneys retrieved from standard and high-risk donors. *Transplant international: official journal of the European society for. Organ Transplantation*. 2015;28(6):665–76.
 62. Hosgood SA, Barlow AD, Hunter JP, Nicholson ML. Ex vivo normothermic perfusion for quality assessment of marginal donor kidney transplants. *Br J Surg*. 2015;102(11):1433–40.
 63. Chadha R, Hossain MA, Bagul A. Optimising organs for transplantation: is normothermic machine perfusion the answer? *Expert Rev Med Devices*. 2016;13(3):221–3.
 64. Doizi S, Kamphuis G, Giusti G, Palmero JL, Patterson JM, Proietti S, Straub M, De La Rosette J, Traxer O. First clinical evaluation of a new single-use flexible cystoscope dedicated to double-J stent removal (Isiris™): a European prospective multi-center study. *World J Urol*. 2017;35(8):1269–75.
 65. Rassweiler MC, Michel MS, Ritter M, Honeck P. Magnetic ureteral stent removal without cystoscopy: a randomized controlled trial. *J Endourol*. 2017;31(8):762–6.
 66. Mallon DH, Riddiough GE, Summers DM, Butler AJ, Callaghan CJ, Bradbury LL, Bardsley V, Broecker V, Saeb-Parsy K, Torpey N, Bradley JA, Pettigrew GJ. Successful transplantation of kidneys from elderly circulatory death donors by using microscopic and macroscopic characteristics to guide single or dual implantation. *Am J Transplant*. 2015;15(11):2931–9.
 67. Ekser B, Furian L, Broggiato A, Silvestre C, Pierobon ES, Baldan N, Rigotti P. Technical aspects of unilateral dual kidney transplantation from expanded criteria donors: experience of 100 patients. *Am J Transplant*. 2010;10(9):2000–7.

68. Ayorinde JO, Summers DM, Pankhurst L, Laing E, Deary AJ, Hemming K, Wilson ECF, Bardsley V, Neil DA, Pettigrew GJ. PreImplantation Trial of Histopathology In renal Allografts (PITHIA): a stepped-wedge cluster randomised controlled trial protocol. *BMJ Open*. 2019;9(1):e026166.
69. Snanoudj R, Timsit MO, Rabant M, Tinel C, Lazareth H, Lamhaut L, Martinez F, Legendre C. Dual kidney transplantation: is it worth it? *Transplantation*. 2017;101(3):488–97.
70. van den Berg TAJ, Minnee RC, Nieuwenhuijs-Moeke GJ, Bakker SJL, Pol RA. The effect of perioperative antiplatelet/ anticoagulant therapy on the incidence of early postoperative thromboembolic complications and bleeding in kidney transplantation. - a dual center retrospective cohort study of 2000 kidney transplant recipients. *Transplantation*. 2018;102:S186.
71. Eng M, Brock G, Li X, Chen Y, Ravindra KV, Buell JF, Marvin MR. Perioperative anticoagulation and antiplatelet therapy in renal transplant: is there an increase in bleeding complication? *Clin Transpl*. 2011;25(2):292–6.
72. Breda A, Territo A, Gausa L, Tuğcu V, Alcaraz A, Musquera M, Decaestecker K, Desender L, Stockle M, Janssen M, Fornara P, Mohammed N, Siena G, Serni S, Guirado L, Facundo C, Doumerc N. Robot-assisted kidney transplantation: the European experience. *Eur Urol*. 2018;73(2):273–81.
73. Sood A, Ghosh P, Menon M, Jeong W, Bhandari M, Ahlawat R. Robotic renal transplantation: current status. *J Minim Access Surg*. 2015;11(1):35.
74. Peng P, Ding Z, He Y, Zhang J, Wang X, Yang Z. Hypothermic machine perfusion versus static cold storage in deceased donor kidney transplantation: a systematic review and meta-analysis of randomized controlled trials. *Artif Organs*. 2018;43(5):478–89.
75. Hosgood SA, Saeb-Parsy K, Wilson C, Callaghan C, Collett D, Nicholson ML. Protocol of a randomised controlled, open-label trial of ex vivo normothermic perfusion versus static cold storage in donation after circulatory death renal transplantation. *BMJ Open*. 2017;7(1):e012237.
76. Bahmani B, Uehara M, Jiang L, Ordikhani F, Banouni N, Ichimura T, Solhjoui Z, Furtmüller GJ, Brandacher G, Alvarez D, von Andrian UH, Uchimura K, Xu Q, Vohra I, Yilmam OA, Haik Y, Azzi J, Kasinath V, Bromberg JS, McGrath MM,

- Abdi R. Targeted delivery of immune therapeutics to lymph nodes prolongs cardiac allograft survival. *J Clin Investig.* 2018;128(11):4770–86.
77. Hosgood SA, Thompson E, Moore T, Wilson CH, Nicholson ML. Normothermic machine perfusion for the assessment and transplantation of declined human kidneys from donation after circulatory death donors. *Br J Surg.* 2018;105(4):388–94.