NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedure overview of robot-assisted kidney transplant

A kidney transplant is an effective treatment for people who have end-stage kidney failure. A robot-assisted kidney transplant is a 'keyhole' technique in which the surgeon uses a robot to assist with transplanting the kidney. The aim is to use smaller cuts (the largest being about 7 cm) and decrease blood loss during surgery, and to reduce recovery time. It may also allow kidney transplantation in some patients with obesity in whom conventional transplant surgery would not be considered.

Contents

Introduction

The National Institute for Health and Care Excellence (NICE) prepared this interventional procedure overview to help members of the interventional procedures advisory committee (IPAC) make recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the

medical literature and specialist opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This overview was prepared in May 2017 and updated in December 2017.

Procedure name

- Robot-assisted kidney transplant

Specialist societies

- British Transplantation Society
- NHS Blood and Transplant
- The Renal Association
- British Association of Urological Surgeons
- Royal College of Surgeons.

Description of the procedure

Indications and current treatment

End-stage renal disease happens when kidney function is insufficient to maintain health without either dialysis or a kidney transplant. This is typically when the glomerular filtration rate is less than 15 ml/min/1.73m^2. End-stage renal disease may be caused by a number of conditions, most commonly diabetes.

The treatments for end-stage renal disease include conservative treatment, dialysis and kidney transplant. Kidney transplant is considered the treatment of choice for many patients but is not always possible.

Kidney transplant, using a kidney from either a deceased or living donor, is usually done by open surgery through an incision in the left or right lower abdomen providing a retroperitoneal approach to the iliac fossa.

What the procedure involves

Robot-assisted kidney transplant may result in decreased blood loss, shorter recovery time, fewer wound complications and improved cosmetic results compared with conventional open surgery.

With the patient under general anaesthesia and placed in supine position, a periumbilical incision of about 7 cm is made to insert a hand-assist device. Then, 4 or 5 small incisions (0.5 cm to 1 cm) are made to insert robotic arms and instruments into the abdomen. After the ports and the hand-assist device are in place, the patient is usually moved to the Trendelenburg position. The external iliac vessels are prepared and the bladder is filled with normal saline to facilitate its dissection. The graft kidney is put into the peritoneum, and the renal vein and artery are anastomosed to the external iliac vessels using the robot. After completion of vascular anastomoses, an ureteroneocystostomy is done robotically. The patient's wounds are then sutured. Intra-operative Doppler imaging may be used to assess graft vascular flow.

Modifications of the techniques used for robot-assisted kidney transplant have been described.

Outcome measures

Re-warming time: time that a graft spends in the recipient before re-perfusion, while continuously surrounded by ice-slush.

Efficacy summary

Patient survival

In a retrospective comparative study of 612 patients with obesity (BMI greater than or equal to 40 kg/m^2) who had robotic kidney transplant (n=67) or open kidney transplant (n=545), patient survival at 1 year was 97% in the robotic group and 98% in the open surgery group. Rates at 3 years were 97% and 95% respectively. The overall main cause of death was infection (2%).[1]

In a case series of 54 patients having robot-assisted kidney transplant, the patient survival rate within a median 13.4 month follow-up was 96% (52/54). One patient died of acute congestive heart failure 45 days after the procedure and another died of myocardial infarction 7 months after the procedure.[2]

In a study of 56 patients with obesity comparing robotic kidney transplant (n=28) and open kidney transplant (n=28), patient survival at 6 months was 100% (28/28) in both groups.[3]

In a case series of 25 patients, survival at 6 months was 96% (24/25).[4,5]

In a case series of 10 patients, survival at a mean 7 month follow-up was 100% (10/10).[7]

Graft survival

In the comparative study of 612 patients, the crude graft survival rates were 95% at 1 year and 90% at 3 years in both treatment groups. In the robotic group, the causes of graft failure were acute rejection in 3% (2/67) of patients, chronic rejection in 1% (1/67), primary failure in 1% (1/67) and other in 1% (1/67). In the open surgery group, the causes of graft failure were acute rejection in 2% (10/545) of patients, chronic rejection in 1% (8/545), graft thrombosis in 1% (7/545), infection in less than 1% (4/545), primary failure in less than 1% (3/545), urological complications in less than 1% (1/545) and other in 2% (12/545).[1]

In the case series of 54 patients, the graft survival rate (death-censored) within a median 13.4 month follow-up period was 100% (52/52). [2]

In the study of 56 patients comparing robotic kidney transplant and open kidney transplant, graft survival at 6 months was 100% (28/28) in both groups. [3]

In the case series of 25 patients, graft survival at 6 months was 100% (24/24).[4,5]

In the case series of 10 patients, graft survival at 7 months was 100% (10/10).[7]

Graft rejection

In the comparative study of 612 patients, there was statistically significantly more in-hospital acute graft rejection in the robotic group than in the open surgery group (9% [6/67] compared with 2% [12/545] respectively, p<0.009). This was attributed to a higher proportion of high immunological risk patients in the robotic kidney group. Graft loss due to acute rejection was not different between the groups.[1]

In the case series of 54 patients, acute graft rejection episodes were reported in 13% (7/54) of patients within a median follow-up of 13.4 months.[2]

In the comparative study of 56 patients, the graft rejection rate was 25% (7/28) in the robotic kidney transplant group and 18% (5/28) in the open kidney transplant group.[3]

In the case series of 25 patients, 1 patient had an acute cellular rejection within 6-month follow-up. [4,5]

In the case series of 10 patients, there was 1 acute humoral rejection (treated by plasmapheresis and intravenous immunoglobulin) and 1 acute cellular rejection.[7]

Need for dialysis

In the case series of 54 patients, 1 patient needed dialysis for renal dysfunction during an episode of acute rejection after discharge from hospital, within a median follow-up period of 13.4 months.[2]

In the case series of 25 patients, no patient needed dialysis after the procedure.[4,5]

In a case series of 17 patients, 1 patient needed dialysis because of delayed graft function which was caused by tacrolimus nephrotoxicity.[6]

Renal function

Serum creatinine

In the comparative study of 612 patients, the mean serum creatinine levels ± standard deviation (SD) 3 years after transplant were similar: 1.91±1.68 mg/dl in the robotic group compared with 1.62±0.95 mg/dl in the open surgery group (p=0.171).[1]

In the case series of 54 patients, the mean serum creatinine level ±SD 6 months after transplantation was 1.2±0.3 mg/dl. [2]

In the comparative study of 56 patients, the mean serum creatinine levels ±SD at 6 months were similar in both groups: 1.5±0.4 mg/dl in the robotic surgery group and 1.6±0.6 mg/dl in the open surgery group (p=0.47).[3]

In the case series of 25 patients, there was a decrease in the mean serum creatinine level ±SD from 8.3±3.0 mg/dl before the procedure to 1.1±0.2 mg/dl at 6 months.[4, 5]

In the case series of 17 patients, there was a decrease in the mean serum creatinine level ±SD from 387.6±162.8 µmol/l before the procedure to 126±35.9 µmol/l at 1 month.[6]

In the case series of 10 patients, the mean serum creatinine level was 1.31±0.31 mg/dl at discharge.[7]

In a comparative study of 80 patients who had robot-assisted kidney transplant or open kidney transplant, the serum creatinine levels were similar in both groups from hospital discharge to 6 months after the procedure (p value not statistically significant for the difference between groups). In the robot-assisted kidney transplant group, the serum creatinine levels decreased from 5.57±1.77 mg/dl before the procedure to 0.95±0.90 mg/dl at 6 months and in the open kidney transplant group, they decreased from 7.1±2.07 mg/ dl to 0.87±0.73 mg/dl (p value not stated for the difference within group). [8]

In a case series of 120 patients, there was a statistically significant decrease in the median creatinine level from 517 µmol/l before the procedure to 120 µmol/l at 1 month (p<0.001).[11]

Glomerular filtration rate

In the comparative study of 612 patients, the estimated glomerular filtration rates 3 years after transplant were similar: 50.89±21.55 ml/min/1.73 m^2 in the robotic group compared with 54.18±21.82 ml/min/1.73m^2 in the open surgery group (p=0.462).[1]

In the case series of 25 patients, there was an increase in the mean estimated glomerular filtration rate from 46.7 ml/min before the procedure to 82.9±11.6 ml/min at 6 months.[4,5]

In the case series of 17 patients, there was an increase in the mean estimated glomerular filtration rate from 12.4 ml/min/1.73 m^2 before the procedure to 69.4 ml/min/1.73 m^2 at 6 months. [6]

In the case series of 10 patients, the mean estimated glomerular filtration rate was 58.2±8.1 ml/min at discharge.[7]

In the case series of 120 patients, there was a statistically significant increase in the median estimated glomerular filtration rate from 10 ml/min/1.73 m^2 before the procedure to 58 ml/min/1.73 m^2 at 1 month (p<0.001).[11]

Conversion to open kidney transplant

In the case series of 120 patients, 2% (2/120) of patients needed conversion to open kidney transplant because of low blood flow at Doppler ultrasound evaluation immediately after skin closure.[11]

In the case series of 54, 25, and 17 patients, there were no conversions to open kidney transplant.[2,4,5,6]

In the case series of 25 patients, no anastomosis had to be revised, and no patient needed re-exploration for anastomotic bleeding.[4,5]

Ischaemia times

In the case series of 54 and 17 patients, the mean re-warming time were 43 minutes and 52 minutes respectively.[2,6]

In the case series of 120 patients, the median re-warming time was 50 minutes.[11]

In the comparative study of 80 patients, the mean (± SD) re-warming time was statistically significantly longer in the robot-assisted kidney transplant group (54.70±17.80 minutes) than in the open kidney transplant group (37.30±4.07 minutes), p<0.001. [8]

Incision length

In the case series of 10, 25 and 54 patients, the mean incision length varied between 6.1 cm and 7.7 cm.[2,4,5,7]

In the comparative study of 80 patients, the mean (± SD) incision length was statistically significantly smaller in the robot-assisted kidney transplant group (5.11±0.67 cm) than in the open kidney transplant group (12.90±1.48 cm), p<0.001. [8]

Hospital length of stay

In the case series of 10, 17, 25 and 54 patients, the mean hospital length of stay varied between 6.0 days and 13.6 days.[2,4,5,6,7]

In the comparative study of 56 patients, the mean hospital length of stay and the mean total number of hospital days over 6 months ±SD were similar in both groups: 8.2±4.5 days and 14.3±10.2 days in the robotic surgery group compared with 8.1±5.3 days and 15.8±17.3 days in the open surgery group (p=0.98 and 0.69).[3]

In the case series of 120 patients, the median hospital length of stay was 7 days (range 4 to 8).[11]

Safety summary

Death

Death caused by acute congestive heart failure secondary to an underlying cardiac condition was reported in 1 patient in a case series of 25 patients, 1.5 months after the procedure.[4,5]

Death was reported in 2 patients in a case series of 136 patients, within 30 days of the procedure.[9]

Delayed graft function

The rate of delayed graft function with a need for dialysis in the first week after transplant was 3% (2/67) in the robotic group compared with 6% (31/545) in the open surgery group (p=0.504) in a retrospective comparative study in 612 patients.[1]

Delayed graft function was reported in 1 patient in the robotic kidney transplant group (n=28) and in none of the patients in the open kidney transplant group (n=28) in a comparative study of 56 patients (no statistically significant difference between groups).[3]

Delayed graft function was reported in 1 patient in a case series of 17 patients. It was caused by tacrolimus nephrotoxicity and treated by dialysis.[6]

Delayed graft function was reported in 1 patient in a case series of 10 patients. It resulted from prolonged warm ischaemia (190 seconds) in the donor nephrectomy. The patient had peritoneal dialysis during the first week and was discharged with a creatinine level of 2.3 mg/dl 20 days after transplantation.[7]

Delayed graft function rate was 7% (4/60) in a case series of 60 patients.[10]

Delayed graft function rate was 4% (5/120) in a prospective case series of 120 patients.[11]

Readmission rate

Readmission rate in the first 6 months after transplant was 45% (30/67) in the robotic group compared with 32% (174/545) in the open surgery group (p value not statistically significant) in the comparative study of 612 patients.[1]

The mean number of readmissions per patient in the first 6 months after transplant was 2 in both groups in the study of 56 patients comparing robotic and open kidney transplant.[3]

Re-exploration

Re-exploration rate in the first 6 months after robotic kidney transplant was 8% (2/25) in the case series of 25 patients. One of these was immediately after skin closure because of low blood flow on Doppler ultrasound and lack of urine production. This was found to be secondary to kinking of vessels during retroperitonealisation. The other re-exploration was done 1 day after the procedure because of increased drain output, to rule out vascular anastomotic complications after a transfusion with plasma, platelets and packed red blood cells was ineffective. At the time of exploration, haemostasis was achieved with topical agents.[4,5]

Blood loss

Mean blood loss during the procedure varied from 54 ml to 152 ml in the case series of 17, 25, 54, 60 and 120 patients.[2,4-6,10,11]

Mean blood loss ± SD during the procedure was 110±75.2 ml in the robotic surgery group compared with 120.8±102.4 ml in the open surgery group in the comparative study of 56 patients (p=0.69). No patients needed a blood transfusion in the robotic surgery group (n=28) compared with 1 in the open kidney transplant group (n=28).[3]

The mean estimated blood loss (± SD) was statistically significantly lower in the robot-assisted kidney transplant group (182±55 ml) than in the open kidney transplant group (211±29 ml) in a comparative study of 80 patients (p=0.005). In the same study, a haemorrhage was reported in 1 patient in the robot-assisted kidney transplant group. The patient was stabilised after 1 dialysis session and had a mean creatinine level of 1.7 mg/dl at discharge.[8]

Bleeding requiring blood transfusion was reported in 3% (3/120) of patients in the case series of 120 patients.[11]

Arterial thrombosis

A massive arterial thrombosis was reported 2 days after the procedure in the case series of 17 patients; it needed a transplant nephrectomy.[6]

Arterial thrombosis needing transplantectomy was reported in 3% (3/120) of patients in the case series of 120 patients.[11]

Haematoma

A subcutaneous haematoma with subsequent superficial wound dehiscence secondary to warfarin treatment was reported in the robotic kidney transplant group in the comparative study of 56 patients.[3]

An intraperitoneal haematoma was reported in 1 patient in the case series of 25 patients.[4,5]

An intraperitoneal haematoma caused by graft bleeding was reported 1 day after the procedure in the case series of 17 patients; it was treated laparoscopically.[6]

Intraperitoneal haematoma needing surgical exploration was reported in 4% (5/120) of patients within 2 to 4 days of the procedure in the case series of 120 patients.[11]

Infection

Wound infection rate was statistically significantly lower in the robotic kidney transplant group than in the open surgery group in the comparative study of 56 patients within 6 months of the procedure (0% [0/28] compared with 29% [8/28], p=0.004).[3]

Surgical site infection rate was 2% (1/60) in the case series of 60 patients.[10]

Polyoma virus infection was reported in 7% (2/28) of patients in the robotic kidney transplant group compared with 4% (1/28) of patients in the open kidney transplant group within 6 months of the procedure in the comparative study of 56 patients (p=0.99).[3]

Cytomegalovirus viremia, fungal pneumonia and septic shock were each reported in 1 patient in the robotic kidney transplant group and in none of the patients in the open kidney transplant group within 6 months of the procedure in the comparative study of 56 patients (no statistically significant difference between groups).[3]

An infection was reported in 1 patient in the case series of 25 patients.[4,5]

Wound infection was reported in 3% (1/40) of patients in the robot-assisted kidney transplant group and in 8% (3/40) of patients in the open kidney transplant group in the comparative study of 80 patients (p=0.615). [8]

Wound infection was reported in 1 patient in the case series of 120 patients.[11]

Drop in body temperature

A significant drop in body temperature (to 34ºC) which was caused by crushed ice was reported in 1 patient in a case series of 4 patients. After the procedure, the patient showed delayed graft function and needed 3 times more haemodialysis treatments. [12]

Oedema

Head and neck oedema were reported in 6% (3/54) of patients in the case series of 54 patients. This resolved within 48 hours.[2]

Pain

Pain scores measured on a visual analogue scale (from 0 meaning no pain to 10 meaning maximum pain) were 3.5±0.5 at 12 hours after the procedure and 0.3±0.5 at 48 hours after the procedure in the case series of 17 patients.[6]

Pain scores measured 12 hours after the procedure were statistically significantly lower in the robot-assisted kidney transplant group (5.65±1.07) than in the open kidney transplant group (7.25±0.95), p<0.001. After 48 hours, the pain scores remained statistically significantly lower in the robot-assisted kidney transplant group at 3.37±1.61 compared to 4.02±1.22 (p=0.046). [8] Median pain scores measured on a visual analogue scale were 5 at 12 hours after the procedure and 2 at 48 hours.[11]

Hypertension

High blood pressure during the procedure was reported in 13% (7/54) of patients and was controlled with nitroglycerine in the case series of 54 patients.[2]

Hypotension

Hypotension was reported in 1 patient in the case series of 54 patients. It was treated with inotropes.[2]

Diabetes

New onset of diabetes within 6 months of the procedure was reported in 11% (3/28) of patients in the robotic kidney transplant group and in none of the patients in the open kidney transplant group in the comparative study of 56 patients (no statistically significant difference between groups).[3]

Pulmonary embolism

Pulmonary embolism was reported in 4% (1/28) of patients in the robotic kidney transplant group compared with 7% (2/28) of patients in the open kidney transplant group within 6 months of the procedure in the comparative study of 56 patients (p=0.99).[3]

Cardiovascular events

Cardiovascular events were reported on 4 occasions within 30 days of the procedure in the case series of 136 patients.[9]

Stroke

Stroke was reported in 4% (1/28) of patients in both groups within 6 months of the procedure in the study of 56 patients comparing robotic kidney transplant with open kidney transplant.[3]

Deep vein thrombosis

Deep vein thrombosis was reported in 1 patient in the case series of 120 patients. This was treated with anticoagulants.[11]

Ileus

Ileus was reported in 5% (2/40) of patients who had a robot-assisted kidney transplant in the comparative study of 80 patients; no ileus was reported in the patients who had an open kidney transplant. The authors reported that it was caused by excessive ice-slush usage.[8]

Ileus was reported in 3% (3/120) of patients in the case series of 120 patients.[11]

Wound collection

Wound collection was reported on 2 occasions within 30 days of the procedure in the case series of 136 patients (no further details provided).[9]

Non-infected seroma was reported in 7% (4/60) of patients in the case series of 60 patients.[10]

Lymphocele was reported in 1 patient in the case series of 120 patients; this was treated by percutaneous drainage.[11]

Urinary leak

Urinary leak was reported on 6 occasions within 30 days of the procedure in the case series of 136 patients.[9]

Urinary leak was reported in 1 patient in the case series of 60 patients. It was treated with robotic surgery.[10]

Evisceration

Evisceration through the epigastric incision was reported in 1 patient in the case series of 60 patients.[10]

Anecdotal and theoretical adverse events

In addition to safety outcomes reported in the literature, specialist advisers are asked about anecdotal adverse events (events which they have heard about) and about theoretical adverse events (events which they think might possibly occur, even if they have never happened). For this procedure, the specialist advisers listed the following anecdotal adverse events: torsion or twisting of the kidney, more difficult biopsy, longer operative time and warm ischaemia time. They considered that the following were theoretical adverse events: equipment failure, and lack of haptic feedback preventing selection of optimal position for clamping the recipient artery and siting anastomosis.

The evidence assessed

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to robot-assisted kidney transplant. The following databases were searched, covering the period from their start to 18 December 2017: MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the Internet were also searched. No language restriction was applied to the searches (see appendix C for details of search strategy). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The following selection criteria (table 1) were applied to the abstracts identified by the literature search. Where selection criteria could not be determined from the abstracts the full paper was retrieved.

Table 1 Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	Clinical studies were included. Emphasis was placed on identifying good quality studies. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, or a laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising study methodology, unless they reported specific adverse events that were not available in the published literature.
Patient	Patients with end-stage kidney disease.
Intervention/test	Robot-assisted kidney transplant.
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

List of studies included in the IP overview

This IP overview is based on 1,174 patients from 3 comparative studies[1, 3, 8], 4 case series[2,4,5,6,7] (one of which was reported in 2 separate phases), data provided by the ERUS RAKT registry[11], and safety data from 3 conference abstracts[9,10,12].

Other studies that were considered to be relevant to the procedure but were not included in the main extraction table (table 2) have been listed in appendix A.

Table 2 Summary of key efficacy and safety findings on robot-assisted kidney transplant

Study 1 Garcia-Roca R (2017)

Details

Study type	**Retrospective comparative study**
Country	USA
Recruitment period	2009-14
Study population and number	n= **612 (67 robotic kidney transplant [from the University of Illinois] versus 545 open kidney transplant [from the United Network of Organ Sharing registry])** recipients with BMI ≥ 40 kg/m^2
Age and sex	RKT: Mean 46 years; 48% (32/67) male OKT: Mean 48 years; 52% (281/545) male
Patient selection criteria	Inclusion criteria: adult living donor kidney transplant recipients with BMI≥40 kg/m^2.
Technique	Robotic kidney transplantation using the DaVinci robot and the Giulianotti et al. technique. Open kidney transplantation.
Follow-up	**3 years**
Conflict of interest/source of funding	None

Analysis

Follow-up issues: Not reported.

Study design issues:

- The robotic kidney transplants (RKTs) were done in a single centre.
- The reasons for readmission were not indicated in the United Network of Organ Sharing database.

Study population issues:

- Donor demographics: Donors were statistically significantly younger in the RKT group (mean 36 years versus 42 years, p<0.0001), with a higher mean BMI (30 kg/m^2 versus 28 kg/m^2, p=0.002) compared with the open kidney tansplant (OKT) group. There were also statistically significantly more African American patients in the RKT donor group than in the OKT group. In the OKT group, there was a statistically significantly higher proportion of white patients than in the RKT group (p<0.0001).
- Recipient demographics: Subgroup analysis of the patients with BMI≥45 kg/m^2 presented statistically significantly higher mean BMI in RKT than OKT group (p<0.0001). The ethnicity distribution was predominantly African American in the RKT group compared with white patients in the OKT group (p<0.0001). The mean waiting time was statistically significantly shorter for patients in the RKT group (p=0.037).
- Induction therapy included steroids in all the patients in the RKT group compared with 74% of patients in OKT (p < 0.0001). Robotic kidney transplantation group received predominantly thymoglobulin (55%) and basiliximab (42%) for induction. The OKT group had more diverse induction therapy, including thymoglobulin (41%), Campath (26%), basiliximab (16%), or other combinations including rituximab and OKT3 (p<0.0001).
- Maintenance immunosuppression was mostly steroid-free in RKT (75%) compared with OKT that was predominantly using steroid for maintenance therapy (51%) (p < 0.0001).

Other issues: There is probably an overlap of patients with the Oberholzer (2013) paper.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **612 (67 RKT versus 545 OKT)**

Survival

	RKT	OKT	p
Patient survival at 1 year	97%	98%	
Patient survival at 3 years	97%	95%	NS
1-year crude graft survival	95%	95%	NS
3-year crude graft survival	90%	90%	NS

The overall main cause of death was **infection (**2.4%). **Cardiovascular death** was the second most common reason (1.9%), but none of the patients in the RKT group died due to cardiovascular disease. Other reasons included haemorrhage, malignancy, anoxic brain injury, and cerebrovascular disease.

Graft rejection

In-hospital acute rejection: 9% (6/67) RKT versus 2% (12/545) OKT; p<0.009

This was attributed to a higher proportion of high immunological risk patients in the robotic kidney group. Graft loss due to acute rejection was not different between the groups.

Graft failure

Causes of graft failure

	RKT	OKT
Acute rejection	3% (2/67)	2% (10/545)
Chronic rejection	1% (1/67)	1% (8/545)
Graft thrombosis	0	1% (7/545)
Infection	0	<1% (4/545)
Primary failure	1% (1/67)	<1% (3/545)
Urological complications	0	<1% (1/545)
Other	1% (1/67)	2% (12/545)

Renal function (mean±SD)

	RKT	OKT	p
Serum creatinine (mg/dL)			
6 months	1.47 ± 0.37	1.49 ± 0.63	0.833
1 year	1.42 ± 0.38	1.5 ± 1.0	0.585
2 years	1.37 ± 0.41	1.51 ± 0.69	0.231
3 years	1.91 ± 1.68	1.62 ± 0.95	0.171
eGFR (MDRD formula, ml/min per 1.73 m^2)			
6 months	55.27 ± 15.35	54.44 ± 17.13	0.714
1 year	58.47 ± 15.77	55.37 ± 18.22	0.221
2 years	59.29 ± 18.81	55.63 ± 20.84	0.306
3 years	50.89 ± 21.55	54.18 ± 21.82	0.462

Safety

Delayed graft function (need for dialysis in the first week):
3% (2/67) RKT versus 6% (31/545) OKT, p=0.504.

Readmission rates in the first 6 months:
45% (30/67) versus 32% (174/545), p=NS.

Abbreviations used: BMI, body mass index; eGFR, estimated glomerular filtration rate; MDRD, modification of diet in renal disease; NS, not statistically significant; OKT, open kidney transplant; RKT, robotic kidney transplant; SD, standard deviation.

Study 2 Sood A (2015)

Details

Study type	**Case series**
Country	India
Recruitment period	2013-14
Study population and number	n= **54** patients with irreversible renal disease
Age and sex	Mean 37 years; 76% (41/54) male Mean BMI: 23.5 kg/m^2
Patient selection criteria	Inclusion criteria: • Irreversible renal disease defined as: (a) ESRD, defined as (I) CKD with GFR <20 ml/min (II) CKD with symptomatic uraemia (III) CKD requiring dialysis (b) Anticipated ESRD, as defined above, within the next 12 months • Matched living donor Exclusion criteria: previous major abdominal surgery with high suspicion for intra-abdominal adhesions, significant atherosclerotic disease of the iliac vessels (>30% blockage), immunologically high-risk transplant, second transplant, simultaneous dual/ multiple organ transplant.
Technique	Robotic kidney transplant using the Menon et al technique. Postoperative pain was managed by continuous infusion of Fentanyl (0.5 µg/kg/hour) with morphine as rescue (patient-controlled analgesia).
Follow-up	**Minimum 6 months**
Conflict of interest/source of funding	The authors declared no conflicts of interest. Vattikuti Foundation supported the initial studies.

Analysis

Follow-up issues:

- After discharge, patients were followed up twice weekly during the first month, once weekly during the second month, once every 2 weeks during the third month, monthly thereafter till the end of first year, and every 2 to 3 months subsequently.

- All recipients with postoperative renal dysfunction underwent ultrasound-guided percutaneous biopsy for histopathological diagnosis to aid guide therapy. The ureteral stent was removed 3 weeks after the surgery.

Study design issues: The RKT were done in a single centre.

Study population issues:

- Triple immunosuppression therapy was: tacrolimus (0.1 mg/kg) and mycophenolate mofetil/sodium (1 g/720 mg twice daily) were started on the day before the surgery, and prednisone (40mg/ day) was started on the day of operation. An induction agent, basiliximab or thymoglobulin, was administered after discussion with the patient regarding human leukocyte antigen match status and affordability.

- Diabetes and hypertension were the 2 most common causes of ESRD (65%). Mean pre-operative creatinine was 9.1 mg/dL (SD = 3.6 mg/dL). Eight (15%) patients underwent pre-emptive transplantation. Basiliximab induction, in addition to triple immunosuppression, was used in 41 patients (76%). Mean Charlson comorbidity score was 3.7 (range = 3–10). All grafts were harvested laparoscopically; 11 grafts (20%) had multiple renal arteries.

- Donor characteristics: 100% living donor, 100% laparoscopic donor nephrectomy.

Other issues: There is probably on overlap of patients with the Menon (2014) study.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **54**

Conversion to open kidney transplantation: none.

Operative outcomes

Operative time: incision-closure (min, mean±SD)	201.1±33.8
Console time: console start-finish (min, mean±SD)	130.8±23.2
Ischaemia times (min, mean±SD)	
Warm Ischaemia time	2.3±0.8
Cold Ischaemia time	27.7±15.8
Re-warming time (with Ice-slush)	42.9±7.6
Total	73.1±18.4
Intra-corporeal kidney cooling	
Surface temp. (before unclamping; °C, mean±SD)	19.2±2.5
Amount of ice-slush used (ml, mean±SD)	289.4±71.6
Drop in core body temperature (°C, mean±SD)	0.7±0.4
Incision length (cm, mean±SD)	6.1±0.5

All anastomoses, including anastomosis of polar graft vessels to recipient inferior epigastric artery (n = 6), could be accomplished robotically.

Postoperative outcomes

Overall need for dialysis at latest follow-up[a, b]	2% (1/54)
Delayed graft function (number)	0
Creatinine (mg/dL, mean±SD)	
At time of discharge	1.4±0.7
At 6 months	1.2±0.3
Graft adverse events[a]	
Graft biopsy	20% (11/54)
Acute rejection episodes	13% (7/54)
Length of stay (days, mean±SD)[c]	8.3±1.1
Patient survival at latest follow-up[a,d]	96% (52/54)
Graft survival (death-censored) at latest follow-up[a]	100% (52/52)

[a]Follow-up between 6 and 18 months with a median follow-up of 13.4 months.

[b]Single haemodialysis needed in a patient after discharge for renal dysfunction during an episode of acute rejection.

[c]Length of stay was fixed at 8 days as part of the renal transplant package unless a complication arose or alternatively a patient felt fine and expressed the desire to leave early.

[d]One patient died after 45 days with acute congestive heart failure and another died of myocardial infarction after 7 months.

Safety

Intraoperative adverse events

Outcomes	% (n/N)
Intraoperative NTG use for BP control	13% (7/54)
Postoperative facial oedema*	6% (3/54)
Blood loss (ml, mean±SD)	146.7±89.5

*Observed head and neck oedema in the 3 patients subsided within 48 hours.

Postoperative outcomes

- Adverse cardiac event within 30 days (number): 0
- All patients, except one, remained hemodynamically stable. **Hypotension** was successfully managed with inotropes in that patient.

Abbreviations used: BMI, body mass index, BP, blood pressure; CKD, chronic kidney disease; ESRD, end-stage renal disease; GFR, glomerular filtration rate; NTG, nitroglycerine; RKT, robotic kidney transplant; SD, standard deviation.

Study 3 Oberholzer J (2013)

Details

Study type	**Comparative study**
Country	USA (University of Illinois Hospital & Health Sciences System,)
Recruitment period	RKT: 2009-11 OKT: 2004-09
Study population and number	n= **56 (28 RKT versus 28 frequency-matched OKT)** obese patients with ESRD
Age and sex	RKT: Mean 48 years; 46% (13/28) male OKT: Mean 50 years; 39% (11/28) male
Patient selection criteria	RKT: patients with ESRD who had robotic kidney transplantation at the University of Illinois Hospital & Health Sciences System and who completed a follow-up of 6 months minimum. OKT: obese patients undergoing OKT prior to June 2009 at the University of Illinois Hospital & Health Sciences System, also with at least 6 months of follow-up.
Technique	RKT using the Giulianotti technique. Living donations were done robotically.
Follow-up	**6 months**
Conflict of interest/source of funding	None

Analysis
Follow-up issues: In the RKT group, the 28 patients were selected from a prospective cohort of 39 obese patients with ESRD who had RKT.
Study design issues:

- Patients were frequency-matched to the robotic surgery group on the following variables, listed in order of priority: BMI (30 kg/m2 ≤ BMI < 35 kg/m2 [obese], or BMI ≥35 kg/m2 [morbidly obese]); race (patient reported Non-Hispanic white, Hispanic, African-American); ABO incompatibility (yes/no); cross-match positivity (yes/no); gender (male/female); age; living/deceased donation; underlying disease; and pre-transplant dialysis (yes/no).
- The established criteria by the Center for Disease Control and Prevention were used to define surgical site infection (SSI). This includes a surgeon diagnosis of infection, a positive fluid culture from the wound, and purulent exudate drainage from the surgical site. The wounds were classified as incisional superficial or incisional deep according to the soft tissue involvement.
- The primary outcomes of interest were wound complications and SSIs.
- Two of the 28 patients in both groups underwent deceased donor kidney transplantation; the remaining patients had a suitable living donor.

Study population issues:

- Kidney transplantation was offered to pre-sensitised patients, patients undergoing desensitisation in the presence of a positive cross-match or ABO incompatibility to their prospective living donors, and patients with a history of previous kidney transplantation.
- The OKT group had a statistically significantly lower average BMI than the robotic transplant group (38.1±5.4 kg/m^2 compared with 42.6±7.8 kg/m^2, respectively; p=0.02), but the proportion of patients who were obese/morbidly obese was comparable between the 2 groups.
- The leading causes of kidney failure were hypertension, diabetes, or the combination in the robotic (61%) and control group (82%).
- The RKT group had a statistically significantly lower rate of patients with diabetes and hypertension than the OKT group (7% versus 36%, p=0.009).

Other issues: There is probably an overlap of patients with the Garcia-Roca (2017) paper.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **56 (28 RKT versus 28 OKT)**

Intraoperative outcomes

	RKT (n=28)	OKT (n=28)	p value
Cold ischaemia time (hours; n=28/18, mean±SD)	2.8±3.6	2.0±4.5	0.48
Warm ischaemia time (minutes; n=28/19, mean±SD)	47.7±7.8	49.2±25.2	0.77

Surgical outcomes

	RKT (n=28)	OKT (n=28)	p value
Delayed graft function	4% (1/28)	0	0.99
Surgical biopsy*	25% (7/28)	0	0.01
Graft rejection	25% (7/28)	18% (5/28)	
Creatinine pre-transplant (mg/dl, mean±SD)	7.6±3.5	6.3±2.5	0.11
Creatinine at discharge (mg/dl, mean±SD)	2.0±1.4	1.4±0.5	0.04
Creatinine at 6 months (mg/dl, mean±SD)	1.5±0.4	1.6±0.6	0.47
Graft survival at 6 months	100% (28/28)	100% (28/28)	
Patient survival at 6 months	100% (28/28)	100% (28/28)	

*Surgical biopsies were done by laparoscopic technique and 1 was converted to open procedure by a mini McBurney incision directly over the graft.

Hospital length of stay

	RKT (n=28)	OKT (n=28)	p value
Hospital days for transplant, mean±SD	8.2±4.5	8.1±5.3	0.98
Total hospital days over 6 months, mean±SD	14.3±10.2	15.8±17.3	0.69

Safety

Intraoperative complications

	RKT (n=28)	OKT (n=28)	p value
Blood loss (mls; n=27/20, mean±SD)	110.2 ±75.2	120.8 ±102.4	0.69
Intraoperative blood transfusion	0	4% (1/28)	0.99
Intraoperative vascular complication	0	7% (2/28)	0.49

The presence of donor vascular anomalies required a vascular reconstruction during the graft bench preparation for two (7.1%) and five (23.8%) patients in the robotic and control group (p=0.12), respectively.

Surgical complications

	RKT (n=28)	OKT (n=28)	p value
Wound complications	4% (1/28)*	29% (8/28)	0.02
Wound infections	0	29% (8/28)	0.004

* The wound complication was a small subcutaneous haematoma with subsequent superficial wound dehiscence secondary to Coumadin treatment.

Readmission/ reoperation

	RKT (n=28)	OKT (n=28)	p value
Readmission over 6 months, mean±SD (per patient)	1.6±2.0	1.5±1.5	0.82
Reoperation over 6 months	0	4% (1/28)	0.99

Complications during 6-month follow-up

	RKT (n=28)	OKT (n=28)	p value
Incident diabetes mellitus	11% (3/28)	0	0.24
Polyoma virus infection	7% (2/28)	4% (1/28)	0.99
Pulmonary embolism	4% (1/28)	7% (2/28)	0.99
Stroke	4% (1/28)	4% (1/28)	
CMV viremia	4% (1/28)	0	0.99
Fungal pneumonia	4% (1/28)	0	0.99
Septic shock	4% (1/28)	0	0.99

Notable issues that occurred in the other 11 patients not included in the current analysis due to less than 6-month follow-up:

- 1 **death** from fulminant line sepsis on POD 9, after a complication-free surgery and immediate graft function.
- Another patient with a BMI of 54.5 kg/m2 developed a median incisional **hernia** 1.5 months after transplantation and required an abdominoplastic hernia repair.
- Two of the 39 patients (5.1%) initially started robotically were converted to the open procedure. In both cases, **conversion** to open surgery was indicated by the presence of severe adhesions. One of them developed a wound haematoma that needed drainage and wound healing by secondary intention.

Abbreviations used: CMV, cytomegalovirus; ESRD, end-stage renal disease; OKT, open kidney transplant; RKT, robotic kidney transplant; SSI, surgical site infection.

Studies 4 and 5 Menon M (2014) a and b

Details

Study type	**Prospective case series**
Country	India (Medanta hospital)
Recruitment period	2013
Study population and number	n= **25** patients with end-stage renal disease
Age and sex	Mean 37 years; 68% (17/25) male Mean BMI: 24 kg/m^2
Patient selection criteria	Inclusion criteria: 6-month follow-up completed, patient with irreversible renal disease defined as ESRD, defined as CKD with a glomerular filtration rate <20 ml/min, symptomatic uraemia and requiring dialysis; anticipated ESRD, within the next 12 months (pre-emptive transplant) and matched living donor. Exclusion criteria: previous major abdominal surgery with high suspicion for intra-abdominal adhesions, significant atherosclerotic disease of the Iliac vessels (>30% blockage), immunologically high-risk transplant, second transplant and simultaneous dual or multiple organ transplant.
Technique	RKT using ice-slush and gel-point device. All grafts were harvested from healthy live donors via laparoscopic donor nephrectomy.
Follow-up	**6 months**
Conflict of interest/source of funding	None.

Analysis

Follow-up issues:

- During the study period, 50 patients with ESRD had RK. Of these, 25 completed a 6-month follow-up.

Study design issues:

- There were 2 phases in this study and 2 papers were published. The first phase comprised 7 patients and the second phase comprised the following 43 patients.
- The primary outcome was post-transplant graft function as measured by serum creatinine level, estimated glomerular filtration rate, and the need for postoperative dialysis.
- Secondary outcomes were technical, including the need for anastomoses revision; operative, ischaemic, and anastomoses times; graft surface temperature; and episodes of conversion to open surgery.

Study population issues:

- The major causes of kidney failure were diabetes and hypertension (64% of patients).
- Most grafts were left-sided (88%) and had a single renal artery (80%).

Other issues: There is probably on overlap of patients with the Sood (2015) study.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **25**

Operative outcomes

Operative parameters, mean±SD	RKT (n = 25)
Operative time: Incision to closure, min	214.1±39.8
Console time: Console start to finish, min	135.4±31.2
Ischaemia times	
Warm ischaemia time, min	2.4±1.1
Re-warming time (with ice-slush), min	46.6±9.3
Total, min	75.3±19.2
Incision length, cm	6.1±0.5
Conversion to open surgery, no. (%) *	0
Need for anastomotic revision (vascular or ureterovesical) *	0
Vascular anastomoses times	
Arterial anastomosis, min	12.0±2.6
Venous anastomosis, min	13.4±3.4
Ureterovesical anastomosis time, min	17.4±5.8

* Though the data are presented for the initial 25 patients (as they had completed 6-mo follow-up), there were no intraoperative injuries, anastomoses revisions, or conversions to open surgery in any of the 50 patients.

Peri- and postoperative outcomes (≥6-mo follow-up)

Peri- and postoperative parameters	RKT (n = 25)
Need for dialysis, no. (%)	0
Serum creatinine level, mg/dl, mean±SD	
Pre-operative	8.3±3.0
At time of discharge	1.3±0.6
6 months	1.1±0.2
Estimated glomerular filtration rate *, ml/min, mean±SD	
Pre-operative	46.7
At time of discharge	70.2±29.6
6 months	82.9±11.6
Rejection episodes, % (n/N)	
ACR	4% (1/25)
AMR	0
ACR+AMR	0
Hospital length of stay, d, mean±SD**	8.4±1.1
Mild pelvicalyceal dilation	39% (7/25)
Graft survival at 6 months	100% (24/24)
Patient survival at 6 months	96% (24/25)

*Using the Modified Diet in Renal Disease equation for patients aged >18 yr and the Schwartz equation for patients aged <18 yr.

**Length of stay as such was fixed from the outset (8-d package) unless a complication arose during the postoperative period.

Safety

Blood loss, ml: 151.7±103.5

Complications

Complications	% (n/N)
Death[b]	4% (1/25)
Graft biopsy	16% (4/25)
Intraperitoneal haematoma	4% (1/25)
Infection	4% (1/25)
Immunosuppressive drug toxicity	4% (1/25)
Re-explorations[a]	8% (2/25)

[a]Although the data are presented for the initial 25 patients (as they had completed 6-month follow-up), there were no other re-explorations in the further 25 patients until the latest follow-up.

- One of the re-explorations was immediately after skin closure because of low blood flow on Doppler ultrasound and lack of urine production. This was found to be secondary to kinking of vessels during retroperitonealisation.
- The other re-exploration was done 1 day after the procedure because of increased drain output. No discrete bleeding source was identified, and both vascular anastomoses were intact. This patient was taking clopidogrel and aspirin because of a recent coronary angioplasty. This same generalized bleeding was noted during the RKT, but exploration was felt prudent to rule out vascular anastomotic complications after a transfusion with plasma, platelets, and packed red blood cells was ineffective. At the time of exploration, haemostasis was achieved with topical agents.

[b]There was one patient death at 1.5 months due to acute congestive heart failure secondary to an underlying cardiac condition.

Abbreviations used: ACR, acute cellular rejection; AMR, antibody-mediated rejection; BMI, body mass index; CKD, chronic kidney disease; ESRD, end-stage renal disease; RKT, robotic kidney transplant: SD, standard deviation.

Study 6 Breda A (2017a)

Details

Study type	**Prospective case series**
Country	Spain (Fundacio Puigvert, Barcelona)
Recruitment period	2015-16
Study population and number	n= **17** patients with end-stage kidney disease
Age and sex	Mean 46 years; 59% (10/17) male Mean BMI: 26kg/m^2
Patient selection criteria	Inclusion criteria: age>20, recipient from living donor nephrectomy, no atherosclerosis on external iliac vessels on CT scan, BMI between 18 and 35, no cardiovascular, pulmonary or hepatic comorbidity, no tumour, no metastasis or any positive virology, no complex vascular anatomy. Exclusion criteria: multiple abdominal surgeries, polycystic kidney disease, general contraindication to laparoscopically abdominal surgery, deceased kidney.
Technique	RAKT using gel-point device and ice-slush.
Follow-up	**1 month**
Conflict of interest/source of funding	None

Analysis

Follow-up issues: Not reported.

Study design issues: Not reported.

Study population issues: The donor nephrectomy was always done laparoscopically.

Other issues: There is a probable overlap of patients with the Breda (2017b) paper also included in table 2.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **17**

Operative outcomes

	RAKT
Operative time, incision to closure, min, mean±SD	356±68
Console time, start, min, mean±SD	180.8±17.5
Ischaemia times, min, mean±SD	
Warm ischaemia time	4±0.5
Cold ischaemia time	43.3±22.2
Re-warming time	51.5±3.5
Total	98.9±22.1
Vascular anastomoses time, min, mean±SD	
Arterial	20.1±2.7
Venous	21.6±3.4
Total	41.7±5.2
Diuresis observed on table	In 16 patients
Ureterovesical anastomosis, min, mean±SD	21.5±2.3

There was no conversion to open transplantation.

Peri- and post-operative results

	RAKT
Need for dialysis	6% (1/17)
Serum creatinine level, µmol/L, mean±SD	
Before the procedure	387.6**±**162.8
1 day	282.5±111.2
3 days	211.9±116.6
7 days	160±104.1
1 month	126±35.9
Estimated GFR, ml/min/1.73m^2, mean±SD	
Before the procedure	12.4±7
1 day	17.7±6.3
3 days	31.3±16.7
7 days	45±18.3
1 month	69.4±12.0
Hb level, g/L, mean±SD	
Before the procedure	113.2±12.1
1 day	104.6±13.1
3 days	99.3±9.3
7 days	98.1±9.3
1 month	115.1±9.9

Hospital length of stay (mean±SD): 6±1 days

Removal of ureteral sent (mean±SD): 15±0.7 days

Safety

Blood loss during the procedure (ml, mean±SD): 54±8.4

Pain scores (VAS, mean±SD)

Time	Pain scores
12h	3.5±0.5
24h	3.0±0.5
36h	1.1±0.6
48h	0.3±0.5

Complications: 17% (3/17)

Safety event	% (n/N)
Delayed graft function*	6% (1/17)
Post-operative bleeding***	6% (1/17)
Graft vascular thrombosis**	6% (1/17)

*The delayed graft function was caused by tacrolimus nephrotoxicity. It needed haemodialysis.

**The massive arterial thrombosis occurred 2 days after the procedure and required transplantectomy.

***An intraperitoneal haematoma because of graft bleeding occurred 1 day after the procedure. It was treated laparoscopically.

Abbreviations used: BMI, body mass index; CT, computed tomography; GFR, glomerular filtration rate; RAKT, robot-assisted kidney transplant.; SD, standard deviation; VAS, visual analogueic scale.

Study 7 Tsai M-K (2014)

Details

Study type	**Case series**
Country	Taiwan
Recruitment period	2012-13
Study population and number	n= **10** patients
Age and sex	Mean 44 years; 50% (5/10) male Mean BMI: 23kg/m^2
Patient selection criteria	Not reported
Technique	RAKT in the retroperitoneum using the daVinci system.
Follow-up	**Mean 7 months**
Conflict of interest/source of funding	This work was supported by the National Taiwan University Hospital.

Analysis

Follow-up issues: One patient was excluded without the robotic system applied for reasons of severe adhesion around the femoral vessels, probably caused by repeated cannulation and infection.

Study design issues: Not reported.

Study population issues:

- Nine of the renal allografts were from the left side: 6 from living donors undergoing laparoscopic donor nephrectomy and 3 from brain-dead deceased donors; one graft was from the right side of a deceased donor.
- The kidney allografts were preferentially transplanted into the right iliac fossae except in 2 patients; one patient with a temporary dialysis catheter in the right femoral vein and the other with a peritoneal catheter in the right side had their renal transplants in the left side.

Other issues: Not reported.

Key efficacy and safety findings

Efficacy	Safety
Number of patients analysed: **10** Average **skin incision (length**): 7.7±1.04 cm Average **anastomosis time**: 67.4 ± 22.3 min Average **operation time** of 257.8 ± 52.7 min Linear regression analyses demonstrated that for every unit increase in BMI, there was an increase in the mean anastomosis time of 1.84 min (p = 0.4243) and operation time of 10.74 min (p= 0.0234). **Average ischaemic time**: • 283.3 ± 51.9 min for living donor transplantation • 630.7±76.6 min for transplants from deceased donors **Average creatinine at discharge**: 1.31 ± 0.31 mg/dl **eGFR at discharge**: 58.2 ± 8.1 ml/min **Average post-transplant hospital stay:** 13.6 ± 3.5 days The **hospital length of stay** was within 14 days for all the patients but three: one with delayed graft function and the other two with overshooting tacrolimus levels taking 4 more days in the hospital to adjust. **Graft and patient survival**: 100% (10/10) All the 10 transplants were functioning at mean 6.9 ± 3.9 months (range: 1–12 months) after surgery.	**Delayed graft function**: 1/10 It resulted from prolonged warm ischaemia (190 s) in the donor nephrectomy. The patient received peritoneal dialysis during the first week and was discharged with a creatinine level of 2.3 mg/dl 20 days after transplantation. **Acute humoral rejection**: 1/10 The humoral rejection was proved by renal biopsy with positive C4d staining. The patient was treated by plasmapheresis and intravenous immunoglobulin. **Acute cellular rejection**: 1/10
Abbreviations used: BMI, body mass index; eGFR, estimated glomerular filtration rate; RAKT, robot-assisted kidney transplant	

Study 8 Tugcu V (2018)

Details

Study type	**Retrospective comparative study**
Country	Turkey (single centre)
Recruitment period	RAKT: 2016-17 OKT: 2010-15
Study population and number	n= **80 (40 RAKT versus 40 OKT)** patients
Age and sex	RAKT: Mean 38 years; 63% (25/40) male, BMI 23 kg/m^2 OKT: Mean 42 years; 70% (28/40) male, BMI 25 kg/m^2
Patient selection criteria	RAKT: First 40 patients treated with RAKT in a single centre. OKT: First 40 patients treated with OKT in the same centre. No patients were excluded from the study but those with a history of abdominal surgery, peritoneal dialysis or autosomal dominant polycystic kidney disease did not receive RAKT.
Technique	RKT using the same technique as Sood et al. Robotic operations were performed using the Da Vinci Xi Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). Irrespective of the method used for the kidney transplant, all the patients received 1000 mg of intravenous paracetamol after induction of anaesthesia. After the procedure was completed, a local anaesthetic (prilocaine) was administered at wound closure. Patients were given intravenous. paracetamol infusions only on demand.
Follow-up	**Maximum 3 months**
Conflict of interest/source of funding	None

Analysis
Follow-up issues: Only 5 patients were followed up for 3 months.
Study design issues:
- Before transplantation, urinary ultrasonography and colour Doppler ultrasonography of the iliac artery were done on all patients.
- The first 3 patients, who had either OKT or RAKT, were operated upon under the guidance of a mentor. After the third patient in either group, all the kidney transplants were performed by the primary transplant surgeon. This was his first experience in either field. He began performing OKT after being trained in a high volume transplant centre for 6 months in 2010. In 2016, he started to do RAKTs.
- Comparisons were made using one-way analysis of variance or the Kruskal–Wallis test for continuous variables, and the chi-squared or Fisher's exact test for categorical variables.

Study population issues:
- All the donor kidneys were retrieved from live donors via laparoscopy.
- There was a statistically significant difference in the BMI and in the pre-transplantation creatinine levels between the RAKT and the OKT groups ($p<0.01$).

Other issues: There is a probable overlap of patients with the Breda (2017b) paper also included in table 2.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **80 (40 RAKT versus 40 OKT)**

Operative outcomes mean (SD)

Variable	RAKT	OKT	p value
Operative time, min	265.37 (46.6)	250.25 (41.3)	0.129
Total ischaemia time, min	96.7 (30.02)	71.32 (8.38)	<0.001
Warm ischaemia time, min	1.86 (0.49)	1.70 (0.73)	0.265
Cold ischaemia time, min	40.47 (13.38)	32.76 (7.45)	0.002
Re-warming time, min	54.70 (17.80)	37.30 (4.07)	<0.001
Arterial anastomosis time, min	18.45 (5.73)	14.97 (2.59)	0.001
Venous anastomosis time, min	20.92 (6.57)	16.02 (2.30)	<0.001
Uretero-vesical anastomosis time, min	21.30 (4.73)	14.95 (1.56)	<0.001
Incision length, cm	5.11 (0.67)	12.90 (1.48)	<0.001

Serum creatinine (mean (SD), mg/dL)

	RAKT	OKT	p value
Pre-operative	5.57 (1.77)	7.1 (2.07)	< 0.01
At discharge	1.40 (0.53)	1.66 (1.34)	0.257
After 1 month	1.59 (1.48)	1.56 (1.40)	0.940
After 3 months	1.04 (1.03)	1.35 (1.62)	0.312
After 6 months	0.95 (0.90)	0.87 (0.73)	0.638

Drain removal time (days): 3.45 (0.93) versus 7.67 (2.11), p<0.001

Safety

Estimated blood loss (ml): 182.25 (55.26) versus 210.75 (28.96), p= 0.005

Complications according to the modified Clavien–Dindo Grading System

Grade	RAKT	OKT	p value
I	1 wound infection	3 wound infections	0.615
II	0	4; 1 orchitis, 3 haemorrhages requiring transfusion	0.116
IIIa	0	0	NA
IIIb	2 exploratory laparotomy: ileus**	3; 2 lymphocoeles, 2 graft thrombosis	0.500
IVa	1 temporary dialysis due to haemorrhage*	0	0.500
IVb	0	0	NA
V	0	2 deaths: sepsis	0.152

*The patient was stabilised after 1 dialysis session and had a mean creatinine level of 1.7 mg/dl at discharge.

**The first 2 patients operated upon in the RAKT group had to undergo exploratory surgery for ileus, which was caused by excessive ice-slush usage. Subsequently, the amount of ice-slush was decreased and a gauze covered with a drape was used to prevent ice-slush contact with the bowels and this problem did not recur.

Pain score (mean (SD))

	RAKT	OKT	p value
After 12 hours	5.65 (1.07)	7.25 (0.95)	< 0.001
After 24 hours	4.85 (1.21)	6.30 (0.93)	<0.001
After 36 hours	4.35 (1.27)	5.00 (1.26)	0.024
After 48 hours	3.37 (1.61)	4.02 (1.22)	0.046

The pain scores were similar within 12 h of surgery.

Abbreviations used: BMI, body mass index; NA, not applicable; OKT, open kidney transplant; RAKT, robot-assisted kidney transplant; SD, standard deviation.

Study 9 Garcia-Roca R (2015) – *Conference abstract only*

Details

Study type	**Retrospective case series**
Country	USA
Recruitment period	2009-14
Study population and number	n= **136** patients with end-stage renal disease and with a BMI≥30
Age and sex	Not reported
Patient selection criteria	Not reported
Technique	RKT
Follow-up	**30 days**
Conflict of interest/source of funding	Not reported

Analysis
Study design issues:

- This is a retrospective analysis of the 30-day complication rate after RKT.
- The surgery complications were classified using the Clavien-Dindo 2009 and the comprehensive complication index (from 0 – no complication to 100 – death) was calculated. Graft dysfunction requiring dialysis after surgery was classified as Grade IVA (single organ failure). Splenectomy after transplant for rescue of rejection was not considered a complication.

Key efficacy and safety findings

Efficacy	Safety
Efficacy findings from conference abstracts are not normally considered adequate to support decisions on efficacy and are not generally selected for presentation in the overview.	117 complications were recorded in 70 patients.

Surgery 30-day complication	**% (n/N) complications**
Grade 1 (mostly related to **wound seroma** and caused by dehydration)	26.5%
Grade 2	54.7%
Rejection	20%
UTI	% not given
Grade 3 A	4.3%
Grade 3 B	5.1% (6/117)
Collection	1.7% (2/117)
Urinary leak	5.1% (6/117)
Grade 4 A	6.8% (8/117)
Cardiovascular events	3.4 % (4/117)
Graft dysfunction requiring dialysis	3.4% (4/117)
Grade 5 (**death**)	1.7% (2/117)

Mean comprehensive complication index: 14.4/100

Abbreviations used: BMI, body mass index; RKT, robotic kidney transplant; UTI, urinary tract infection.

Study 10 Garcia-Roca R (2014) – *Conference abstract only*

Details

Study type	**Retrospective case series**
Country	USA
Recruitment period	2009-13
Study population and number	n= **60** patients with end-stage renal disease and with a BMI≥40 kg/m^2
Age and sex	Mean 47 years; gender not reported Mean BMI: 47 kg/m^2
Patient selection criteria	Suitable KT candidate with a BMI≥40 kg/m$^{2.}$
Technique	RKT
Follow-up	**Mean 17 months**
Conflict of interest/source of funding	Not reported

Analysis
Follow-up issues: Not reported.
Study design issues: The primary outcomes were intraoperative and post-operative data, and short-term outcomes.
Study population issues: Most transplants were from a living donor (88%).
Other issues: Not reported.

Key efficacy and safety findings

Efficacy	Safety
Efficacy findings from conference abstracts are not normally considered adequate to support decisions on efficacy and are not generally selected for presentation in the overview.	**Intraoperative outcomes** • **Blood loss**: 127.2±109.0 mL **Post-operative outcomes** • **SSI rate**: 2% (1/60) • **Non-infected seroma**: 7% (4/60) • **Evisceration through the epigastric incision:** 1/60 • **Urinary leak**: 1/60 It was treated with robotic surgery. • **Delayed graft function rate**: 7% (4/60) **1-year patient survival rate**: 98%
Abbreviations used: BMI, body mass index; KT, kidney transplant; RKT, robotic kidney transplant: SSI, surgical site infection.	

Study 11 Breda A (2017b) – *ERUS RAKT registry*

Details

Study type	**Prospective case series**
Country	Spain, Turkey, France, Germany, Belgium, Italy (8 centres)
Recruitment period	2015-2017
Study population and number	n= **120** patients with end-stage renal disease
Age and sex	Median 43 years; 63% (75/120) male Median BMI: 25.2 kg/m^2
Patient selection criteria	Inclusion criteria: patients with ESRD (considered as a GFR <20 ml/min and/or symptomatic uraemia and/or need for dialysis), matched living or deceased donor, >18 years and BMI ≤ 40. Exclusion criteria: iliac artery atherosclerosis, malignancy, positive virology, severe comorbidity (cardiovascular, pulmonary or hepatic), highly complex vascular anatomy, multiple previous abdominal surgeries, previous transplant (second transplant) or simultaneous dual or multiple organ transplant.
Technique	Robot-assisted kidney transplant using the da Vinci robot. The robot-assisted surgical steps were transperitoneal dissection of the external iliac vessels, venous/arterial anastomosis, graft retroperitonealisation, and ureterovesical anastomosis.
Follow-up	**Minimum 1 month**
Conflict of interest/source of funding	None

Analysis
Follow-up issues: not reported.
Study design issues:
- The surgical outcomes evaluated included cold and warm ischaemia time and re-warming time. Other surgical data analysed were overall operative time, console time, vascular anastomosis time, ureteral re-implantation time and estimated blood loss. Intraoperative complications included intraoperative vascular injuries, the need for vascular anastomosis revision and conversion to open surgery in the event of massive bleeding or low blood flow at the Doppler ultrasound evaluation. The early (30 day) post-operative complication rate was reported according to the classification of Clavien-Dindo.
- The functional outcomes considered were serum creatinine and eGFR on postoperative day 1, 3, 7, 30. The eGFR was calculated using the Modified Diet in Renal Disease equation (patient >18 years old). Delayed graft function was considered as the need for dialysis in the first post-operative week. Among the functional outcomes, were also included post-operative haemoglobin, evaluation of postoperative pain using the Visual Analogue Scale, the postoperative days of hospitalisation and the days to double J removal.
- All surgical teams involved in this study had a thorough expertise in the field of robot-assisted surgery and open kidney transplant with several hundred procedures performed respectively.
- The study did not report on patient cosmetic satisfaction.

Study population issues:
- Patients had previously been on dialysis for a median of 365 days.
- Donor characteristics: 98% (118/120) living donor.
- In 97% (116/120) of patients, the graft was introduced transabdominally and in 4 patients it was introduced transvaginally.

Other issues: There is probably an overlap of patients with the Breda (2017a) paper and the Tugcu (2017) paper also included in table 2.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **120**

Conversion to open kidney transplantation: 2% (2/120)

The cause for conversion was low blood flow at Doppler ultrasound evaluation immediately after skin closure.

Operative outcomes (median [IQR])

Operative time (min)	250.0 (80.0)
Console time (min)	160.0 (60.0)
Ischaemia times (min)	
Warm Ischaemia time	2.0 (2.0)
Cold Ischaemia time	34.0 (11.0)
Re-warming time	50.0 (11.5)
Total	89.5 (21.5)
Arterial Anastomoses time (min)	19.0 (6.5)
Venous Anastomosis time (min)	20.0 (6.5)
Vascular Anastomosis time (min)	38.0 (12.5)
Ureterovesical Anastomoses time (min))	21.0 (7.0)

Postoperative outcomes

Creatinine (µmol/L, median [IQR])	
Pre-operative	517.0 (230.4)
At 1 month	130.0 (59.3)
eGFR (ml/min/1.73m^2, median [IQR])	
Pre-operative	10.0 (6.0)
At 1 month	58.0 (27.8)
Hospital length of stay (days, median [range])	7 (4 to 8)
Delayed graft function	4% (5/120)

Statistically significant difference for the comparisons pre-operative versus 1 month (p<0.001).

Safety

Intraoperative adverse events

- **Blood loss (ml, median [IQR]):** 150 (113)

Pain score (using median VAS score)

- 12 h post-surgery: 5
- 48 h post-surgery: 2

Postoperative complications graded according to the Clavien-Dindo classification

Complication	Patients, % (n/120)
GRADE 1	
Wound infection	1% (1/120)
Ileus	3% (3/120)
Bleeding (observation)	1% (1/120)
GRADE 2	
Deep venous thrombosis*	1% (1/120)
Bleeding requiring blood transfusion	3% (3/120)
GRADE 3a	
Lymphocele**	1% (1/120)
GRADE 3b	
Arterial thrombosis***	3% (3/120)
Bleeding requiring surgical exploration (intraperitoneal haematoma) within 2 to 4 days of surgery	4% (5/120)

*This was treated with anticoagulants.

** This was treated by percutaneous drainage.

***The patients needed transplantectomy.

Abbreviations used: BMI, body mass index; eGFR, estimated glomerular filtration rate; ESRD, end-stage renal disease; GFR, glomerular filtration rate; IQR, interquartile range, VAS, visual analogue scale.

Study 12 Janssen (2017) – *Conference abstract only*

Details

Study type	**Case series**
Country	Germany
Recruitment period	Not reported
Study population and number	n= **4** patients with end-stage renal disease
Age and sex	Not reported
Patient selection criteria	Patients with end-stage renal disease.
Technique	RKT
Follow-up	**5 days**
Conflict of interest/source of funding	Not reported

Analysis
Follow-up issues: Not reported.
Study design issues: Not reported.
Study population issues:
- In 2 patients, the robotic-assisted living kidney transplantation was done for right kidneys and in 2 patients for left kidneys.
- The patients were on dialysis treatment for 1 to 13 months until the transplantation.

Other issues: Not reported.

Key efficacy and safety findings

Efficacy	Safety
Efficacy findings from conference abstracts are not normally considered adequate to support decisions on efficacy and are not generally selected for presentation in the overview.	• **Blood loss**< 250 ml • **Significant drop in body temperature (34ºC) due to crushed ice** in 1 patient. After the procedure, the patient showed a delayed graft function and needed 3 times additional haemodialysis treatment. • **Haemolytic uremic syndrome** in 1 patient. The patient needed additional plasmapheresis.
Abbreviations used: RKT, robotic kidney transplant.	

Validity and generalisability of the studies

- There were no randomised controlled trials in the evidence base.
- There was probably some overlap of patients between the Garcia-Roca (2017)[1] and the Oberholzer (2013)[3] papers, between the Sood (2015)[2] and the Menon (2014) papers[4,5], and between the Breda (2017b)[11] paper and the Breda (2017a)[6] and the Tugcu (2018)[8] papers.
- In the studies included in table 2, different techniques for robotic kidney transplant were used; for example for the patient's position, graft placement and use of regional hypothermia may have varied.
- Some of the papers included only obese patients.[1,3,9,10]
- In the studies included in table 2, the grafts were from living donors or from deceased donors or from both.
- The longest follow-up was 3 years.
- Three conference abstracts were included in table 2 for the safety events.[9-10, 12]
- None of the evidence was from patients treated in the UK.
- One of the studies included in table 2 was done in 2 phases and 2 papers were published.[4,5]

Existing assessments of this procedure

There were no published assessments from other organisations identified at the time of the literature search.

Related NICE guidance

There is currently no NICE guidance related to this procedure.

Additional information considered by IPAC

Specialist advisers' opinions

Specialist advice was sought from consultants who have been nominated or ratified by their Specialist Society or Royal College. The advice received is their

individual opinion and is not intended to represent the view of the society. The advice provided by Specialist Advisers, in the form of the completed questionnaires, is normally published in full on the NICE website during public consultation, except in circumstances but not limited to, where comments are considered voluminous, or publication would be unlawful or inappropriate. Four Specialist Advisor Questionnaires for robot-assisted kidney transplant were submitted and can be found on the NICE website.

Patient commentators' opinions

NICE's Public Involvement Programme was unable to gather patient commentary for this procedure.

Company engagement

A structured information request was sent to 1 company who manufactures a potentially relevant device for use in this procedure. NICE received 1 completed submission. This was considered by the IP team and any relevant points have been taken into consideration when preparing this overview.

Issues for consideration by IPAC

- There is a European registry for this procedure and a paper about the latest results has just been published (study 11). This is probably the largest series published.

References

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2. Sood A, Ghosh P, Jeong W et al. (2015) Minimally invasive kidney transplantation: perioperative considerations and key 6-month outcomes. Transplantation;99(2):316-23.
3. Oberholzer J, Giulianotti P, Danielson K K et al. (2013) Minimally invasive robotic kidney transplantation for obese patients previously denied access to transplantation. American Journal of Transplantation 13, 721-8
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12. Janssen M, Breda A, Guasa L, Sester U et al. (2017) First robotic kidney transplantations after robotic kidney living donation in Germany. Transplant International Conference, 26th Annual Meeting of the German Transplantation. Poster Abstracts. Transpl Int, 30: 28–46. doi:10.1111/tri.13065

Appendix A - Additional relevant papers

The following table outlines the studies that are considered potentially relevant to the IP overview but were not included in the main data extraction table (table 2). It is by no means an exhaustive list of potentially relevant studies.

Article	Number of patients/follow-up	Direction of conclusions	Reasons for non-inclusion in table 2
Abaza R, Ghani KR, Sood A et al. (2014) Robotic kidney transplantation with intraoperative regional hypothermia. BJU International;113(4):679-81	Technique paper n=39 FU=3 months	At a mean follow-up of 3 months all of the grafts functioned. There was a marked reduction in pain and analgesic requirement compared with patients undergoing open KT, with a propensity towards quicker graft recovery and lower complication rate.	There are no clinical outcomes reported in this paper. The paper describes the robotic kidney transplantation technique.
Ayloo S M, D'Amico G, West-Thielke P et al. (2015) Combined Robot-assisted Kidney Transplantation and Sleeve Gastrectomy in a Morbidly Obese Recipient. Transplantation 99, 1495-8	Case report n=1 FU= 2 years	• Total operative time: 318 minutes • Estimated blood loss of 125 ml • 24 months after transplantation: -patient's weight: 81.9 kg -BMI: 35.1 kg/m^2 -creatinine: 0.79 mg/dl -estimated glomerular filtration rate: 81.2 ml/min per 1.73 m. Combined robot-assisted kidney transplant and sleeve gastrectomy is feasible in morbidly obese patients and adds little additional operative time.	Studies with more patients or longer follow-up are included.
Boggi U, Vistoli F, Signori S et al. (2011) Robotic renal transplantation: first European case. Transplant International;24(2):213-8.	Case report n=1 FU= 3 months	Surgery lasted 154 min, including 51 min of warm ischaemia of the graft. Urine production started immediately after graft re-perfusion. Renal function remains optimal at the longest follow-up of 3 months.	Studies with more patients or longer follow-up are included.
Frongia M, Cadoni R, Solinas A. (2015) First Robotic-Assisted Dual Kidney Transplant: Surgical Technique and Report of a Case With 24-month Follow-up. Transplant Direct;1(9):e34.	Case report n=1 FU= 2 years	Total operative time was 400 minutes and blood loss was 120 ml. Both grafts immediately began functioning. There were no intraoperative or postoperative complications. The patient was discharged on the 7th postoperative day with normal renal function. At 24 months, he was well and did not require haemodialysis.	Studies with more patients or longer follow-up are included.
Giulianotti P, Gorodner V, Sbrana F et al. (2010)	Case report	The operative time was 223 min, and the blood loss was less than 50	Studies with more patients or longer

Robotic transabdominal kidney transplantation in a morbidly obese patient. American Journal of Transplantation 10, 1478-1482	n=1 FU= 5 days	cc. The kidney had immediate graft function. No perioperative complications were observed, and the patient was discharged on postoperative day 5 with normal kidney function. Minimally invasive access and robotic technology facilitated the safe performance of a successful kidney transplant in a morbidly obese patient.	follow-up are included.
Hoznek A, Zaki SK, Samadi DB et al. (2002) Robotic-assisted kidney transplantation: an initial experience. The Journal of Urology. 167(4):1604-6	Case report n=1 FU=2 months	Operative time was 178 minutes. Robotic assistance made anastomosis possible by its unique ability of stereoscopic magnification and ultra-precise suturing techniques due to the flexibility of the robotic wristed instruments. Renal perfusion was excellent with immediate diuresis. Postoperative acute tubular necrosis started to resolve after 1 week.	Studies with more patients or longer follow-up are included.
Michiels C, Rouffilange J, Comat V, et al. (2017) Total Preperitoneal Robot-Assisted Kidney Transplantation. Journal of Endourology Case Reports 3(1), 169-172	Single case report FU=10 days	The postoperative sequences were usual with the resumption of function on day 7. The patient was hospitalised for 10 days. The postoperative day 1 and day 5 ultrasound and Doppler examinations did not show any anomaly. Postoperative day 7 creatinine level was at 2.64 mg/dl and at 2.36 mg/dl on postoperative day 10. The patient did not need postoperative haemodialysis.	Studies with more patients or longer follow-up are included.
Sankaran V and Sinha S (2017) Robotic Kidney Transplantation-an Update. Curr Urol Rep.;18(6):45.	Narrative review	Robotic kidney transplantation is a procedure that has been developed over the last decade and could have applicability in kidney transplantation in the obese. Its main benefit is in enabling surgery in less accessible spaces due to body habitus, combined with those of using a smaller incision with less associated morbidity, with no inferiority in the reported primary outcomes of graft and patient survival. There are capital costs associated with this procedure, but further studies on the cost-effectiveness of robotic kidney transplantation are needed before it can be adopted widely.	Narrative review.
Sood A, Ghosh P, Menon M et al. (2015) Robotic renal transplantation: Current status. Journal of Minimal Access Surgery;11(1):35-9.	Review 9 studies on RKT were retrieved.	RKT appears to be a safe surgical alternative to the standard open approach of KT. RKT is associated with reduced postoperative pain, analgesic requirement, and better cosmesis. RKT, although in its	The 3 studies retrieved in the review are included in Table 2.

	3 case series reported clinical outcomes.	infancy, appears to be associated with lower complication rates.	
Territo A, Mottrie A, Abaza R et al. (2017) Robotic kidney transplantation: current status and future perspectives. Minerva Urol Nefrol.:69(1):5-13. doi: 10.23736/S0393-2249.16.02856-3.	Systematic review 11 studies	Robotic surgery allows kidney transplantation to be performed under optimal operative conditions, reducing complications while maintaining the functional results achieved by the open approach. The evolution of this technique is in progress.	Narrative review. No new study listed.
Tuğcu V, Şener NC, Şahin S et al. (2016) Robotic kidney transplantation: The Bakırköy experience. Turkish Journal of Urology;42(4):295-298.	Case series n=15 FU= max 3 months	Operative outcomes (mean±SD) • Operative time (min): 300.3±104.2 • Warm ischaemia time (min): 1.9±0.54 • Re-warming time (min): 73.3±30.7 • Incision length: 5.3±0.72 cm • Conversion to open surgery: 0/15 Serum creatinine • Pre-operative: 6.14±2.12 mg/dl • At discharge (n=15): 1.5±1.49 mg/dl • After 3 months (n=5): 0.83±0.06 mg/dl Glomerular filtration rate • At discharge (n=15): 72.07±32.5 mg/dl/min/1.73 m^2 • After 3 months (n=5): 99.4±7.46 mg/dl/min/1.73 m^2 Hospital length of stay: 10.9±2 days. Safety: Blood loss (mean±SD): 189.3±45.7 ml; Ileus: 13% (2/15)	The patients included in this paper are likely to be also included in the Tugcu (2017) paper included in Table 2.
Wagenaar S, Nederhoed JH, Hoksbergen AWJ et al. (2017) Minimally Invasive, Laparoscopic, and Robotic-assisted Techniques Versus Open Techniques for Kidney Transplant Recipients: A Systematic Review. European Urology;72(2):205-217.	Systematic review 5 studies on RKT.	Although the level of evidence was generally low, minimally invasive techniques showed promising results with regard to complications and recovery, and could be considered for use. For open surgery, the smallest possible Gibson incision appeared to yield favourable results.	All the studies on RKT are included in Table 2.

Literature search strategy

Databases	Date searched	Version/files
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	18/12/2017	
HTA database (Cochrane Library)	18/12/2017	
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	18/12/2017	
MEDLINE (Ovid)	18/12/17	1946 to December 18, 2017
MEDLINE In-Process (Ovid)	18/12/17	December 18, 2017
MEDLINE Epubs ahead of print (Ovid)	18/12/2017	December 18, 2017
EMBASE (Ovid)	18/12/2017	1974 to 2017 Week 51

Trial sources searched 7th February 2017

- Clinicaltrials.gov
- ISRCTN
- WHO International Clinical Trials Registry

Websites searched

- National Institute for Health and Care Excellence (NICE)
- NHS England
- Food and Drug Administration (FDA) - MAUDE database
- Australian Safety and Efficacy Register of New Interventional Procedures – Surgical (ASERNIP – S)
- Australia and New Zealand Horizon Scanning Network (ANZHSN)
- EuroScan
- General internet search

The following search strategy was used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

1 exp Kidney Transplantation/

2 exp Renal Insufficiency/

3 Kidney Diseases/

4 Kidney Failure, Chronic/

5 ((Kidney* or renal*) adj4 (disease* or failur* or transplant* or insufficienc* or implant*)).tw.

6 CKD.tw.

7 or/1-6

8 Robotic Surgical Procedures/

9 Robotics/

10 Surgery, Computer-Assisted/

11 ((Comput* assist* or robot*) adj4 (surg* or techni* or treat* or procedure*)).tw.

12 (Keyhole* adj4 (surg* or techni* or treat* or procedure*)).tw.

13 (da Vinci* or daVinci*).tw.

14 or/8-13

15 7 and 14

16 Animals/ not Humans/

17 15 not 16