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Arterial Reconstruction in Kidney Transplantation

Since its introduction into clinical medicine in the 1950s kidney transplantation has become the preferred renal replacement therapy for patients suffering from end-stage renal disease (ESRD). The rising incident of ESRD is causally determined by an increased life expectancy. On the other hand the results of kidney transplantation have improved enormously due to advances in organ harvesting, organ preservation, surgical techniques and last but not least immunosuppressive regimens. Renal transplantation is more cost effective than haemodialysis and provides a better quality of life. This has resulted in a significant demand for organs that is not met by the current supply of deceased donors. Besides augmentation of the number of living kidney donation the lack of organs is partially compensated by extended donor criteria. Therefore the number of marginal organs with severe arteriosclerosis is rising. This makes great demands to the transplant surgeons.
This article provides a review about techniques and pitfalls of arterial reconstruction during renal transplantation. It is based upon our experience in kidney transplantation and upon the published medical data. Despite rising technical difficulties caused by severe arteriosclerosis and the existence of multiple renal arteries kidney transplantation is a safe and highly efficient procedure.

Key words:
kidney transplantation, surgical technique, sequential anastomosis, multiple renal arteries, arteriosclerosis, arterial reconstruction

Technik der arteriellen Rekonstruktion bei Nierentransplantation

Seit der ersten erfolgreichen Durchführung in den fünfziger Jahren ist die Nierentransplantation Therapie der ersten Wahl des chronischen Nierenversagens geworden. Gegenüber der Dialysebehandlung steigert die Transplantation die Lebenserwartung und die Lebensqualität unter Senkung der Therapiekosten. Zunehmende Erfahrungen und die kontinuierliche Verbesserung der Organentnahme, der Lagerung der Organe, der Technik der Nierentransplantation als auch der Immunsuppression und postoperativen Nachsorge führten neben einer Besserung der Ergebnisse auch zu einer Erweiterung der Indikationsstellung zugunsten jüngerer als auch deutlich älterer Transplantatempfänger. Aufgrund des sich weiter verschärfenden Mangels an Spenderorganen wächst neben der Anzahl der durchgeführten Nierenlebendspenden auch die Häufigkeit der Akzeptanz marginaler Spenderorgane zur Transplantation. Somit steigen die Anforderungen an den Transplantationschirurgen

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sowohl von Seiten des Spenderorgans als auch von Seiten des Empfängers.
Eine Analyse der aktuellen Literatur als auch die Auswertung eigener Daten nach Nierenlebendspende zeigen, dass trotz erhöhtem Schwierigkeitsgrad durch ausgeprägte arteriosklerotische Gefäßveränderungen und dem Vorhandensein multipler Nierenarterien eine arterielle Rekonstruktion sicher erfolgen kann.

Schlüsselwörter:
Nierentransplantation, chirurgische Technik, sequentielle Anastomose, multiple Nierenarterien, Arteriosklerose, arterielle Rekonstruktion

Renal Transplantation

End stage renal disease is conventionally treated by renal replacement therapies like hemo- and peritoneal dialysis. W. Kolff was the first to construct a working dialyzer in 1943 (1). This treatment prolongs life efficiently but severely reduces the quality of life. The first successful long term kidney transplantation was performed 1954 as living related kidney transplantation between twins by Murray in Boston, USA (2). Since then kidney transplantation became the preferred renal replacement therapy because of excellent long term results, better life expectancy as well as quality of life (3) and better cost efficiency compared to dialysis. Nowadays more than 2500 kidney transplantations are performed in Germany every year. Improvements in organ preservation, surgical techniques and immunosuppression make it a safe procedure. Perfect results even in paediatric and elderly patients are rising the demand for cadavaric organs continuously (4,5). Today the mean waiting time for kidney transplantation is about seven to eight years while the life expectancy of patients waiting for transplantation amounts only ten years (6). In order to change this disproportion between waiting time and mean survival time the frequency of living kidney donation must be augmented. On the other hand donor criteria are extended to rise the number of potential cadavaric renal organs (7). Inevitably the donor age, number of donor's diseases and frequency of arteriosclerosis is rising. Equally recipient's age, incidence of arteriosclerosis and other diseases of the recipient are increasing. Many patients require second or third kidney transplantation after acute or chronic allograft failure. These changes pose a challenge to every transplant surgeon. In this article we reflect on the different techniques of arterial reconstruction during kidney transplantation including important steps and pitfalls during organ harvesting, preparation, implantation and postoperative care. Finally we present recent data about the living related kidney transplantation performed in the Medical School Hanover with multiple renal arteries versus single renal artery.

Cadavaric Donors

The age of potential cadavaric donors is increasing during the last years. The proportion of brain dead donors over 65 years old has risen from 10 to 25 percent of all donors (Deutsche Stiftung Organtransplantation). While most untreated diseases of the donor like hypertension, diabetes, amyloidosis have no direct impact on surgical difficulties, severe arteriosclerosis does. Dissection of abdominal cadavaric organs for transplantation is usually performed after cold perfusion. A single cannulation of the aorta is done after ligation of the common iliac arteries as well as the proximal aorta above the coeliac trunc. Perfusion itself is then carried out with an increased pressure for around 15 minutes. After perfusion in hypothermia the abdominal organs should be removed rapidly. We separate liver, pancreas and finally kidneys in situ. During harvesting of the kidneys all renal arteries should be preserved and explanted with a common aortic patch. Special attention should be paid to polar arteries which often originate afar from the main renal artery. If a common patch is impossible to preserve we suggest own patches for each artery. Dissection of renal arteries by crude explantation techniques must be avoided (8,9).

Living Donation

In Germany around twenty percent of all transplanted kidneys originate from living donation while in the USA and the Scandinavian countries this number reaches almost fifty percent (10). Cold ischemia time, optimal selection and timing is the great advantage of living donation. Different explantation techniques are described like open lumbal donor nephrectomy and laparoscopic donor nephrectomy (11). We suggest a open mini incision donor nephrectomy using a small vertical paramedian incision. This technique allows optimal control during explantation and to obtain perfect quality of life of the donor (12,13).
No aortic patch can be extracted for technical reasons in living donor nephrectomy. So even more attention must be paid to an exhaustive exposure of all arteries and an adequate length of the explanted vessels. Iatrogenic dissection of the arteries must be avoided just as well as in cadavaric donor harvesting. Cannulation of every single artery and perfusion is performed ex situ immediately.

Organ Preparation

No more preparation is needed after living donor nephrectomy. Vessels should be free from perivascular tissue, small arteries originating from the renal artery are already occluded.
Cadaveric organs require intense preparation prior to transplantation. Renal arteries and veins as well as existing patches must be dissected from perivascular tissue. Arterial branches leaving the renal artery like a lower adrenal gland artery must be ligated or overstitched. Multiple renal transplant arteries or accessory polar arteries must be identified. Preferably all arteries should be located on a single patch. If the distance between the arteries is sufficiently short no further reconstruction is needed. In case of great distance between the arteries the patch can be divided in two for sequential anastomosis or can be shortened by a segment resection with side to side anastomosis (figure 1). Truncated accessory renal arter-

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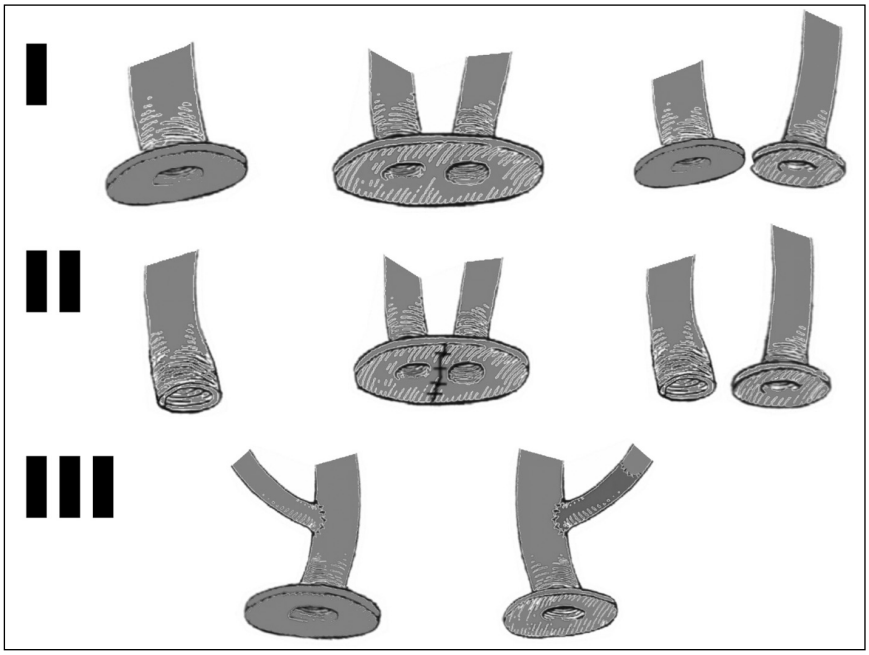

Fig. 1: Preparation of donor kidneys
I) Preferred variations of renal arteries allowing end to side anastomosis with patches. II) Alternative variations: no patch, segment resection of patch in case of distant renal arteries on one patch, one patch in case of two arteries. III) Unfavourable and dangerous reconstruction of renal arteries.

ies or polar arteries should be reconstructed by end-to-end anastomosis whenever possible (figure 3 I). Alternatively the truncated vessel should be used for sequential end-to-side anastomosis to the recipient without patch. We advise not to perform end-to-side anastomosis to the main renal artery because of high risk of vascular obliteration of both vessels leading to graft loss (figure 1 III). Small polar arteries showing a strong backflow while being perfused by the main artery can be closed if sequential anastomosis seems unreasonably difficult or dangerous. Doing this we must take into consideration that a lower polar artery may be crucial for the perfusion of the ureter. Cutting a lower polar artery may lead to distal necrosis of the ureter followed by urinary leakage.

Arteriosclerosis is frequently found in donor organs. While mild occurrence has no effect on the technique severe arteriosclerosis desires special attention. Along with arteriosclerosis the risk of renal dysfunction and vascular occlusion is augmented caused by preexisting renal artery stenosis of the donor and intimal injury. The renal artery should be analysed for proximal stenosis. Intimal desquamation within the patch or proximal artery and stenosis require shortening of the renal artery. If affected areas can not be removed refixation of the intima flap must be performed to avoid ongoing dissection and vascular occlusion. Generally patches with severe arteriosclerosis and intimal lesions should rather be removed. The shortened artery is finally anastomosed end to side without patch.

Implantation Techniques and Sites

Standard renal transplantation is performed to the iliac fossa. The heterotopic approach allows easy access to the iliac vessels without opening the peritoneal cavity and without the need to remove the recipient's kidney. Moreover the proximity to the urinary bladder reduces the required length of the ureter and impairs the risk of distal necrosis. The heterotopic kidney transplantation enables different arterial anastomosis techniques. All techniques require gentle dissection of the recipient's vessels with respect to the lymphatic vessels to avoid lympoceles. All anastomoses are performed using running suture technique. Every anastomosis should be preferably performed in an area free of arteriosclerotic lesions. End to side anastomosis of the renal artery is possible to the common iliac artery as well as the external iliac artery and also to the distal abdominal aorta for example in paediatric patients. End to end anastomosis is commonly performed to the internal iliac artery (8,9,14).

Common Iliac Artery

As a standard procedure in Hannover arterial anastomosis is performed end to side to the common iliac artery while the renal vein is connected to the distal part of the external iliac vein. The advances of the proximal location are evident. Arterial flow within the common iliac artery is higher than in the distal branches. The risk of upstream stenosis by arteriosclerotic lesions is reduced. The distant location of arterial and venous anastomosis stretches the vessels and prevents kinking and torsion (figure 2 I).

External Iliac Artery

Alternatively arterial anastomosis may be carried out to the external iliac artery. Especially in case of a short renal artery, e.g. left donor kidney or living donation, this location is often used. Moreover the external iliac artery provides good opportunity upon existence of accessory renal or polar arteries without a common patch. Common and external artery are used for sequential end to side anastomosis (figure 2 II).

Internal Iliac Artery

Many transplant centres still use the internal iliac artery for end to end anastomosis to the transplant renal artery (figure 2 III). The technique provides good feasibility in case of short transplant renal artery since the internal iliac trunc can be used at different length. Unfortunately incongruity of the lumen often appears making the anastomosis a difficult and complex operation. The luxation of the internal iliac artery bears the risk of kinking leading to vascular occlusion. In addition the internal iliac artery does not provide possibilities for sequential anastomosis in case of multiple renal arteries. Arterial end to end anastomosis was found to have a negative impact on graft survival (15).

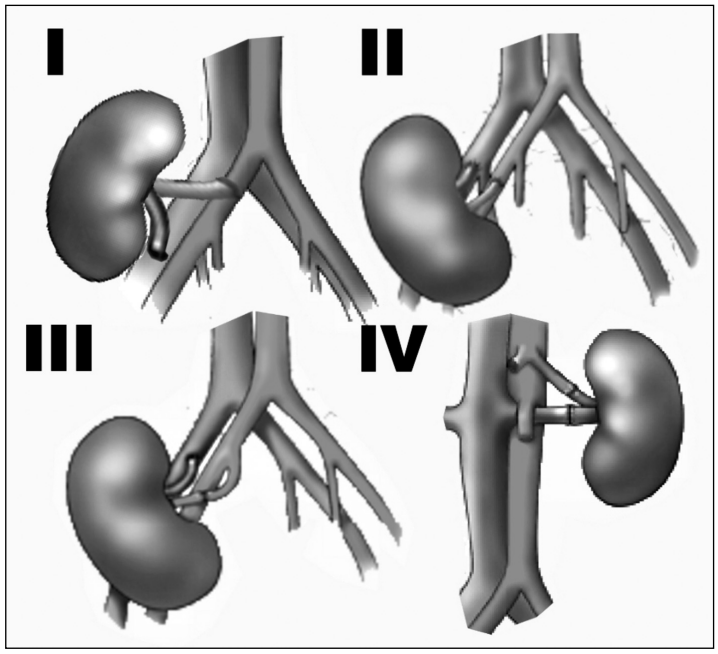

Fig. 2: Arterial reconstruction
I) End to side anastomosis to common iliac artery, preferred technique. II) End to side anastomosis to external iliac artery, alternative technique. III) End to end anastomosis to internal iliac artery, unfavourable technique. IV) Orthotopic renal transplantation.

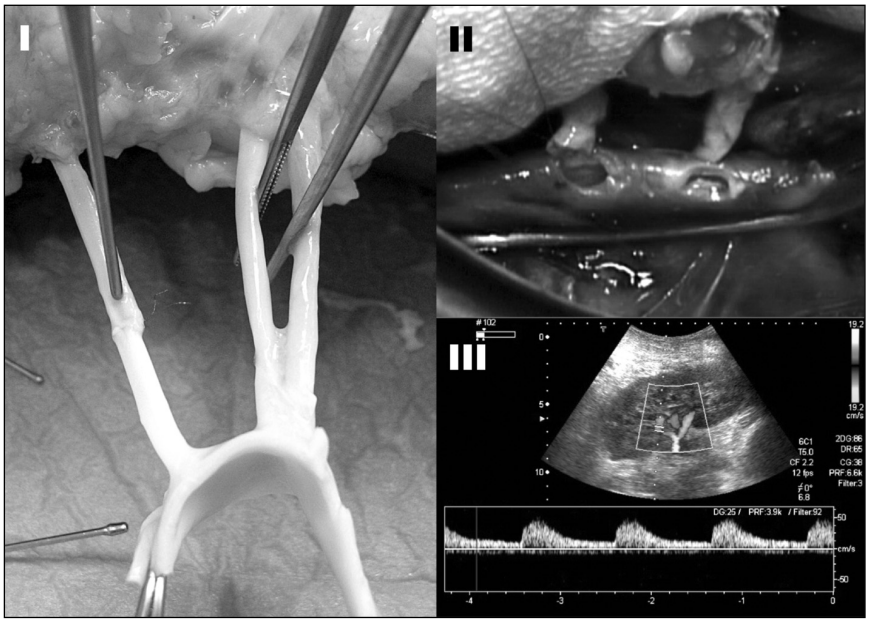

Fig. 3: Arterial reconstruction in kidney transplantation
I) Multiple renal transplant arteries: Renal transplant offering three arteries on one patch. Truncated lower polar artery was reconstructed end to end prior to transplantation. II) Sequential anastomosis technique in case of multiple renal transplant arteries. III) Postoperative management: Frequently performed colour duplex sonography.

The distal part of the internal iliac artery is ligated. Impaired blood flow may have impact on penile vascularity and erectile function (16) in particular after second kidney transplantation to the contra lateral side.

En bloc Transplantation

The basic problem of all developed transplant programs is lack of organs available for transplantation as mentioned above. The kidneys from very young paediatric cadaveric donors, especially up to three years are the typical example of non ideal graft. Technical difficulties and insufficient renal parenchyma makes it a demanding procedure. Transplantation of en bloc removed kidneys from donors under the age of 3 years can be performed with a low rate of technical complications by an interpositional graft of donor aorta and vena cava anastomosed to the recipients aorta and vena cava (17-19).

Orthotopic Renal Transplantation

Orthotopic renal transplantation is an option in case of thrombosis of the iliac veins, severe iliac arteriosclerosis with stenosis or occlusion or retained bilateral heterotopic renal transplantation. In case of need to remove the recipient's kidney, e.g. excessive cystic kidney disease or analgesic nephropathy, orthotopic renal transplantation provides a reasonable opportunity. Orthotopic renal revascularization may be done with native renal artery, splenic artery or end to side anastomosis of the transplant renal artery to the aorta (figure 2 IV). Despite the technical challenges, orthotopic renal transplantation in patients with unsuitable pelvic vessels can result in excellent patient and graft survival (20).

Multiple Renal Arteries

The use of grafts with multiple renal arteries poses a challenge to the transplant surgeon. Multiple renal arteries are unilaterally found in 25% and bilaterally in 10% of the population (21). The existence of multiple arteries has been considered a relative contraindication because of the incidence of vascular and urologic complications. Recently multiple studies have shown that despite technical difficulties grafts with multiple arteries present similar indexes of surgical complications and outcome compared to grafts with single artery (22,23). We suggest to perform sequential anastomosis if one common patch is lacking (figure 3 II). Whenever possible sequential end to side anastomoses are carried out with patches. However a suitable length of the arteries is even more important than the existence of

patches. Common and external iliac arteries may be used for up to three or even more anastomosis. Despite slightly increased incidence of postoperative lymphoceles sequential anastomosis is a safe procedure with excellent short and long term results (23).

Arteriosclerosis

Before being listed to renal transplantation the recipients undergo intensive work up to check the technical feasibility and avoid steal phenomena after transplantation. In case of complicated arteriosclerosis with verified stenosis or aneurysmatic lesions we suggest to cure them prior to transplantation by interventional radiology or vascular surgery. However due to increasing age of the recipients, arteriosclerosis is found frequently at the recipient site. While moderate lesions do not change the recommended proceeding, severe arteriosclerosis may force the surgeon to alternative solutions.
The arterial anastomosis as well as positioning of the vessel clamps should be performed at an area presenting as few arteriosclerosis as possible. Intimal desquamation must be fixed by stitching. To avoid intimal injury we use suture material with a cutting needle. Worst cases of arteriosclerosis with iliac stenosis require aortoiliac reconstruction with allograft and kidney transplantation as a one stage procedure. In the treatment of arterial occlusive disease or abdominal aortic aneurysm simultaneously with renal transplantation the use of arterial allografts is possible and safe (24,25).

Paediatric Renal Transplantation

Early renal transplantation in paediatric patients suffering ESRD enables normal mental and physical development of children. We use a extraperitoneal approach even in small children comparable to the technique in adults. Due to the size of the organ and the reduced blood flow in the recipient's iliac vessels anastomosis is mostly performed to the abdominal aorta and caval vein. This technique allows even adult organs to be transplanted extraperitoneally avoiding postoperative abdominal adhesions (5,26-28).

Postoperative Management

The gold standard for evaluation of the perfusion after renal transplantation is colour duplex sonography (figure 3 III). Routine sonography is performed repeatedly during the early postoperative phase as long as graft function is still lacking. The method is cost effective and can be performed not only on the intensive care unit but also on the regular ward. It is suitable to detect vascular problems as well as allograft rejection by measuring variances in the resistance indices (14,29). Angiography and renal scintigraphy usually are no more needed for exclusion of severe vascular problems. In case of any problems or doubt we perform immediate revision operation.

Living Related Kidney Transplantation with Multiple Renal Arteries

For technical reasons living donor kidneys are procured without an aortal patch for transplantation. Multiple renal arteries are still regarded as a relative contraindication and avoided by many transplant centres. As described above we favour the sequential arterial anastomosis technique in case of multiple renal arteries (figure 3 II). In our own patient population of kidney transplantation we analysed outcome of recipients receiving kidneys from living donors presenting multiple renal arteries in comparison to grafts with singular arteries. Of 216 kidney transplants 36 kidney grafts revealed multiple renal arteries (17%). Of those two arteries were present in 30 cases (14%) and three arteries in 6 cases (3%). All implantations of grafts with multiple renal arteries were performed by sequential anastomosis to the common and or external iliac artery. There was no difference in postoperative hospital stay and operation time for the harvesting procedure for both groups. No significant difference for recipients of kidneys with multiple and single renal arteries were found. There was no significant difference for the rate of surgical complication comparing kidney transplantation using grafts with single and multiple renal arteries (Table 1) (23).

Conclusions

Suboptimal donor organs with multiple renal arteries, missing aortic patches or severe arteriosclerosis challenge the technical skills of every transplant surgeon. End to side anastomosis to the common iliac artery is the standard procedure in Hannover. This approach offers a wide area of potential anastomosis sites in case of arteriosclerosis. Especially compared to end to end anastomosis to the internal iliac artery, end to side anastomosis offers an enormously higher flexibility. Transplantation of donor organs with multiple renal arteries using the sequential anastomosis technique presents similar indexes of surgical and urological complications and outcome. Thus instead of increas-

Tab. 1: Living related kidney transplantation with multiple renal arteries
Outcome of recipients receiving kidneys from living donors presenting multiple renal arteries. Single renal artery (SLA) versus multiple renal arteries (MRA). There was no significant difference for the rate of surgical complication comparing kidney transplantation using grafts with single and multiple renal arteries.

Complication	SRA (180	MRA (36)	p-Value*
Initial Non-Function	5 (3%)	1 (3%)	n.s.
Bleeding	10 (6%)	3 (8%)	n.s.
Vascular Compl.	3 (2%)	0 (0%)	n.s.
Lymphocele	12 (7%)	4 (11%)	n.s.
Urinary Leackage	11 (6%)	2 (6%)	n.s.

ing technical difficulties kidney transplantation is a safe and highly efficient procedure.

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