Multiple Renal Arteries in Kidney Transplantation: Is it a Problem Nowadays?

Artérias Renais Múltiplas na Transplantação Renal: Será um Problema Actualmente?

João Carvalho*, Pedro Nunes, Belmiro Parada, Edgar Tavares-da-Silva, Hugo Antunes, António Roseiro, Carlos Ferreira, Arnaldo Figueiredo

Abstract

Introduction: *Shortage of high quality donors led to an increasing need of compatible organs: grafts with multiple renal arteries (MRA) are one of the solutions, although being a potential risk factor that can impair outcomes. The aim of this study is to provide a view of our experience with multiple renal arteries grafts in renal transplantation and compare the outcome between multiple renal arteries and single renal artery (SRA) groups.*

Material and Methods: *A retrospective study of 2989 kidney transplants was performed in our department between January 1980 and February 2017: demographic characteristics and outcomes were compared between recipients of grafts with multiple renal arteries (648; 21.7%) and single renal artery (2341; 78.3%). Statistical analysis was done using IBM SPSS Statistics 22: chi-square, independent sample t-test and Kaplan Meier tests were used with a p value of 0.05.*

Results: *Grafts from cadaveric donors occurred in 95.8% of the single renal artery group and 97.4% of multiple renal arteries group. The recipients of multiple renal arteries group had a previous higher time on dialysis (50.3 ± 43.1 vs 46.30 ± 37.5 months, p:0.04), a longer operative time (2.43 ± 0.57 vs 2.28 ± 0.49 hours, p<0.001), a higher cold ischemia time (19h08 ± 6h05 vs 18h34 ± 6h17 hours, p:0.04) and more red blood cell transfusions (1.8 ± 0.8 vs 1.7 ± 0.8 packs, p:0.01) than the recipients of single renal artery kidney recipients. In the multiple renal arteries group, ex-vivo bench surgery techniques, in vivo sequential anastomosis and mixed techniques were used. The different options did not affect the outcomes. The rate of delayed graft function, surgical complications, length of hospital stay, acute and chronic rejections, graft loss, death were not statistically different. The follow-up was not statistically different: multiple renal arteries (8 ± 7.3 years) versus single renal artery (7.7 ± 6.6 years) group (p:0.1). The current state of the patient was not dependent on the number of arteries used.*

Resumo

Introdução: A escassez de dadores leva a uma necessidade crescente de órgãos compatíveis: enxertos com múltiplas artérias renais (do inglês *multiple renal arteries* - MRA) são uma das soluções, apesar de ser um fator de risco potencial que pode prejudicar os resultados. O objetivo deste estudo é avaliar os nossos resultados com enxertos com múltiplas artérias renais e compará-los com enxertos com artéria renal única (do inglês *single renal artery* - SRA).

Material e Métodos: Foi realizado um estudo retrospectivo de 2989 transplantes renais realizados na nossa instituição entre janeiro de 1980 e fevereiro de 2017: características demográficas e os resultados foram comparados entre receptores de enxertos com múltiplas artérias renais (648; 21,7%) e artéria renal única (2341; 78,3%). A análise estatística foi efectuada recorrendo ao SPSS *Statistics* 22: teste qui-quadrado, teste t para amostras independentes e teste de Kaplan-Meier com um valor de p de 0,05.

Resultados: Foram utilizados enxertos de dadores cadáver em 95,8% do grupo artéria renal única e 97,4% do grupo múltiplas artérias renais. Os receptores do grupo múltiplas artérias renais estiveram mais tempo em diálise (50,3 ± 43,1 *vs* 46,30 ± 37,5 meses, *p*: 0,04), um tempo cirúrgico maior (2,43 ± 0,57 *vs* 2,28 ± 0,49 horas, *p* <0,001), maior tempo de isquémia fria (19h08 ± 6h05 *vs* 18h34 ± 6h17 horas, *p*: 0,04) e necessitaram de mais transfusões de glóbulos vermelhos (1,8 ± 0,8 *vs* 1,7 ± 0,8 Unidades, *p*: 0,01) do que os receptores de receptores do grupo artéria renal única. No grupo múltiplas artérias renais, foram utilizadas técnicas de cirurgia de banca *ex-vivo*, anastomose sequencial *in vivo* e técnicas mistas. As diferentes opções não tiveram influência nos resultados. A taxa de função tardia do enxerto, complicações cirúrgicas, tempo de internamento, rejeições agudas e crónicas, perda do enxerto e morte não foram estatisticamente diferentes. O seguimento não foi estatisticamente diferente: grupo múltiplas artérias renais (8 ± 7,3 anos) *versus* artéria renal única (7,7 ± 6,6 anos) (*p*: 0,1). O estado actual do doente não dependia do número de artérias utilizadas.

Urology and Renal Transplantation Department of the Coimbra University Hospital Center, Coimbra, Portugal.

Conclusion: *Multiple renal arteries grafts were not a problem in our unit: despite of having a longer operative time, higher cold ischemia time and higher blood transfusions rate, short and long-term outcomes were comparable between groups. At this level, literature results are not consensual: prospective studies are necessary.*

Keywords: *Kidney Transplantation; Renal Artery/abnormalities.*

Conclusão: Apesar do maior tempo cirúrgico, maior tempo de isquemia fria e maior taxa de transfusões de glóbulos vermelhos, os resultados do nosso centro no transplante de rins com múltiplas artérias renais foram idênticos aos de rins com artéria renal única no que diz respeito à função, sobrevida e taxas de complicações cirúrgicas. A este nível os resultados da literatura não são consensuais, sendo necessários estudos prospectivos.

Palavras-chave: Artéria Renal/anomalias congénitas; Transplante Renal.

Introduction

Renal transplantation is considered the preferred treatment in patients with end-stage renal disease, improving the quality of life and survival.[1] Shortage of high quality donors for an increasing rate of end-stage renal disease patients led to an increasing need of compatible organs. Thus, kidneys with anatomical abnormalities, such as multiple renal arteries, multiple ureters, paediatric kidneys and horseshoe kidneys began to be progressively used despite being considered as risk factors for urologic and vascular complications. The most common anatomical anomaly is arterial multiplicity and represents a tricky challenge in the operating room. Novick *et al*[2] showed an incidence of 23% for multiple donor unilateral renal arteries and 10% for multiple bilateral renal arteries. These organs represent a useful opportunity for many recipients. However, the risk of complications also increases with the use of such grafts: longer period of ischemia, higher rate of late graft function and worse prognosis. Surprisingly, the literature reports an excellent prognosis with that vascular multiplicity.[3-4]

The aim of this work is to evaluate our experience with multiple renal artery (MRA) grafts and to compare the prognosis between renal transplants with MRA with single renal artery (SRA) grafts.

Material and Methods

A retrospective observational study was performed in our center (Urology and Renal Transplantation Department, Coimbra University Hospital Center) and included 2989 recipients who underwent renal transplantation in our hospital, between January 1980 and February 2017.

Two groups were created: 648 patients (21.7%) received MRA grafts and 2341 patients (78.3%) received SRA grafts. In the group of MRA grafts, 85.6 had 2 arteries, 12.8% had 3 arteries and 1.6% had 4 arteries.

The age effect and donors and recipients gender effects on prognosis were evaluated. Several variables were compared between groups: type of donor, previous length on dialysis, surgery duration, cold ischemia time, number of red blood cell packs transfused, renal function over time, using serum creatinine and glomerular filtration rate (GFR; using the Cockcroft-Gault equation). Delayed graft function, surgical complications, hospital length of stay, acute and chronic rejection, follow-up, death and its cause were also evaluated. Type of anastomosis chosen in the MRA grafts was also evaluated. Data were evaluated anonymously.

Statistical analysis was performed using IBM SPSS Statistics 20.0 software for Windows (Statistical Package for the Social Sciences, version 20.0, IBM Corp., USA). Categorical variables were compared using the *Pearson chi-square* nonparametric test and the quantitative variables were compared using the independent t-student test and the ANOVA test. Overall patient and graft survival analysis was performed using the Kaplan Meyer method and the log-rank test. These tests were considered statistically significant with a *p*-value of less than 0.05.

Results

Donor and recipient characteristics of both groups are shown in Table 1. The majority of donors were deceased in each group: one important fact is that only 17 living donors' grafts had MRA and no association was seen between the number of renal arteries and donor type. The majority of donors were male in both groups. Both donor age, ventilation time and diuresis at the last hour were nearly the same between groups.

Recipients' demographic characteristics were also similar. Only pretransplantation dialysis time was higher in MRA grafts group (50.3 ± 43.1 *vs* 46.3 ± 37.5 months, *p*: 0.04).

Perioperative data are summarized in Table 2: a slightly higher, but statistically significant, cold ischemia period, longer surgery duration and a higher need for red blood cell transfusion was noticed in MRA grafts transplantation.

Immunosuppression protocols did not differ between groups. The single renal artery was anastomosed to aorta in 0.5%, to the common iliac artery in 73.9%, to the external iliac artery in 23.3%, to the internal iliac artery in 2.1% and to the opposite common iliac artery in 0.2%. The single renal artery

Table 1: Donor and recipients data with SRA (single renal artery) versus MRA (multiple renal artery) grafts

Characteristics	SRA grafts	MRA grafts	*p* value
Deceased donor	2242 (95.8%)	631 (97.4%)	NS (*p*:0.06)
Living donor	99 (4.2%)	17 (2.6%)	
Donor gender ♂ ♀	 1568 (67%) 773 (33%)	 461 (71.2%) 187 (28.8%)	S (*p*:0.04)
Mean donor age (years)	41.9 ± 17.1	41.9 ± 17.6	NS (*p*:0.9)
Donor ventilation time (hours)	55.7 ± 61.9	59.1 ± 65.0	NS (*p*:0.2)
Donor diuresis per hour (mL)	231.8 ± 273.3	233.3 ± 248.7	NS (*p*:0.9)
Donor creatinine serum level (mg/dL)	1.0 ± 0.4	0.9 ± 0.4	NS (*p*:0.2)
Recipient gender ♂ ♀	 1578 (67.4%) 763 (32.6%)	 432 (66.6%) 216 (33.4%)	NS (*p*:0.7)
Recipient age	45.1 ± 14.1	45.6 ± 13.5	NS (*p*:0.4)
Pretransplantation dialysis time (months)	46.3 ± 37.5	50.3 ± 43.1	S (*p*:0.04)
Etiology of end-stage renal disease (%) Glomerular disease Tubulointerstitial disease Cystic congenital disease Systemic disease Undetermined or unknown	 524 (22.4%) 398 (17%) 190 (8.1%) 461 (19.7%) 768 (32.8%)	 161 (24.9%) 97 (15%) 57 (8.8%) 123 (18.8%) 210 (32.5%)	NS (0.6)
Initial imunosupression Aza+P Aza+P+CsA THYMO + Aza + P with or without CsA M/MY+P+CsA THYMO+M/MY+P+CsA M/MY+P+FK SIR + CsA THYMO+M+P+SIR/EVRL THYMO+ M/MY+P+FK M + P + SIR MY + P THYMO + M EVRL+CsA Aza + FK EVRL+FK	 26 (1.1%) 417 (17.8%) 112 (4.8%) 342 (14.7%) 206 (8.9%) 210 (9%) 22 (0.9%) 63 (2.7%) 829 (35.4%) 22 (0.9%) 8 (0.3%) 5 (0.2%) 8 (0.3%) 3 (0.1%) 68 (2.9%)	 11 (1.7%) 117 (18.1%) 36 (5.6%) 95 (14.6%) 66 (10.2%) 54 (8.3%) 7 (1.1%) 16 (2.4%) 214 (33.1%) 2 (0.3%) 2 (0.3%) 0 (0%) 6 (1%) 6 (0.8%) 16 (2.5%)	NS (*p*:0.1)

NS – not significant
Aza – azathioprine; THYMO – thymoglobulin; MY – mycophenolic acid; M – mycophenolate mofetil; P – prednisolone; CsA – cyclosporine; THYMO – thymoglobulin; FK – tacrolimus; SIR – sirolimus; EVRL – everolimus

was anastomosed whenever possible using an aortic donor patch (Carrel technique).

Multiple renal arteries were anastomosed to the aorta in 0.2%, to the common iliac artery in 75%, to the external iliac artery in 22.0%, to the internal iliac artery in 2.4% and to the opposite common iliac artery in 0.3%. The type of arterial anastomosis (Table 3) was sometimes different: *ex-vivo* bench surgery techniques, *in vivo* sequential anastomosis and mixed techniques. *Ex-vivo* bench surgery techniques included end-to-side anastomosis, the use of cadaveric arterial grafts and the creation of a joined patch that could make the *in vivo* anastomosis easier. *In vivo* sequential anastomosis included anastomosis of the multiple renal arteries to one or more recipient arteries. Mixed techniques included both bench and

Table 2: Perioperative data of recipients of SRA and MRA grafts

Perioperative Data	SRA grafts	MRA grafts	*p* value
Kidney Used Left Right	 1180 (50.4%) 1161 (49.6%)	 330 (51.0%) 318 (49.0%)	NS (*p*:0.8)
Renal graft placement side Left Right	 407 (17.4%) 1934 (82.6%)	 126 (19.5%) 522 (80.5%)	NS (*p*:0.2)
Cold ischaemia duration (hh:mm)	18:34 ± 6:17	19:08 ± 6:05	S (*p*:0.04)
CVP on vessel dislodging (cmH_20)	12.9 ± 3.5	12.7 ± 3.5	NS (*p*:0.2)
Systolic blood pressure in reperfusion (mmHg)	125.4 ± 19.5	124.8 ± 20.3	NS (*p*:0.6)
Diastolic blood pressure in reperfusion (mmHg)	73.8 ± 13.6	73.6 ± 14.0	NS (*p*:0.8)
Surgery Duration ≤3 hours >3 hours	 1959 (83.7%) 382 (16.3%)	 479 (74.0%) 169 (26.0%)	S (*p*<0.001)
Surgery duration (hh:mm)	2:28 ± 0:49	2:43 ± 0:57	S (*p*<0.001)
Initial graft function Never-functioning kidney Initial diuresis DGF	 103 (4.4%) 1840 (78.6%) 398 (17.0%)	 30 (4.6%) 516 (79.7%) 102 (15.7%)	NS (*p*:0.7)
Red blood cell transfusion (Units)	1.6 ± 0.9	1.8 ± 0.9	S (*p*:0.01)
Hospital length of stay (days)	12.0 ± 0.8	12.0 ± 118.4	NS (*p*:0.3)

DGF – delayed graft function; NS – not significant; CVP – central venous pressure

sequential anastomosis. There was no statistically significant relationship between the number of arteries and the type of arterial anastomosis ($p = 0.5$).

Surgical complication rate was independent of the number of graft renal arteries (*p*: 0.4), as shown in Table 4. The number of graft renal arteries was also not important for the number of clinical and biopsied acute rejections, for the development of chronic graft nephropathy and for graft loss. There was also no association between the death cause and the number of graft renal arteries (Table 5).

Renal function was assessed by measuring serum creatinine level and by calculation of clearance using the Cockcroft-Gault formula: both did not differ significantly between groups (Table 6).

Renal graft survival was identical [MRA group (6.6 ± 6.7 years) versus SRA group (8.0 ± 3.2 years), *p*: 0.5] as well as the overall follow-up [MRA group (8 ± 7.3 years) versus SRA (7.7 ± 6.6 years), *p*: 0.1] (Fig. 1). Graft survival was not statiscally different at the first year after transplantation, (SRA - 93% vs MRA - 90%, *p*: 0.2), at the fifth year (88% vs 88%, *p*: 0.4), and at tenth year (86 vs 85%, *p*: 0.5). The current state of the patient (alive, dead or on dialysis) was not dependent on the number of renal arteries.

The different types of arterial anastomosis did not have any impact in the graft survival (*p*: 0.07) (Table 7).

Discussion

This study shows that kidney transplantation in Urology and Renal Transplantation Department with multiple renal arteries is a safe procedure with good results either in an early or in a late phase. Only an experienced team with good protocols could have these results: our center has performed 2989 kidney transplants since 1980, with high skills developed through the time. Procurement technique is essential to identify all MRA in grafts in order to have viable grafts for the recipients. Our series showed a prevalence of 21.7% (n = 648): this is a high number for only one center but it is similar to other centers numbers. Typically, MRA is observed in 8% to 30% of donors.[5]

A recent meta-analysis[6] shows that kidney grafts with MRA were associated with higher rate of complications such as delayed graft function, vascular and urological complications. Our data showed no difference: the vascular screening of re-

Table 3: Relationship between the number of renal arteries and the type of arterial anastomosis

Type of arterial anastomosis	Number of renal arteries			Total
	2	3	4	
Ex-vivo bench surgery techniques	403 (62.2)	55 (8.5)	7 (1.1%)	465 (71.8%)
In vivo sequential anastomosis	139 (21.4%)	25 (4.0%)	4 (0.6%)	168 (25.9%)
Mixed techniques	11 (1.7%)	4 (0.6%)	0 (0%)	15 (2.3%)
Total	553 (85.3%)	84 (13.0%)	11 (1.7%)	648 (100%)

Table 4: Surgical complications on recipients of SRA and MRA grafts

Surgical complications	Number of renal arteries		Total	*p* value
	SRA	MRA		
Vascular	105	29	134	NS (*p*:0.5)
Urological	149	38	187	NS (*p*:0.7)
Lymphocele	36	8	44	NS (*p*:0.7)
Bleeding	76	29	105	NS (*p*:0.3)
Wound dehiscence	41	5	46	NS (*p*:0.4)
Surgical Site Infection	8	3	11	NS (*p*:0.8)
Hernia	9	3	12	NS (*p*:0.9)
Total	424	115	539	NS (*p*:0.4)

SRA – single renal artery; MRA – multiple renal artery; NS – not significant

cipients at appointment maybe could explain our success in these fields. The majority of grafts independently of groups had an immediate initial diuresis. However, a higher cold ischaemia time was noticed with multiple renal arteries grafts but it was also lower compared with other series.[5]

Our MRA grafts took more time than SRA grafts but in the majority of cases with no more than three hours. One vies that was not evaluated separately was the time of arterial reconstruction that could have an important role: future studies must have this variable. Arterial reconstruction is one of the keys: the technique adopted was not different when we have more than one artery and didn't have repercussions in graft survival. The *ex-vivo* bench technique was considered the preferred technique. Arterial branches with a diameter larger than 0.5 mm should be preserved if possible.[7] Our center mostly chose the *ex-vivo* bench technique: a single anastomosis is easier to performed with recipient's artery. If the distance between multiple arteries was large enough to prevent a safe reconstruction, a sequential or mixed anastomosis was chosen. When the donor is deceased, we use the aortic patch (of Carrel), technique that cannot be done with living donors.

Another bias of this study is being retrospective: future studies must have this variable into account.

Renal function was not different between groups during the time. In other series,[5,8] it was shown some differences during the time, especially in the first month.

Grafts survival was not influenced by having more than one artery during the time. MRA graft survival at 1 year was 90%, at 5 years was 88% and at 10 years was 85%. Typically, grafts survivals at 1 year varied from 82.8% to 96% and

Table 5: Post-operative complications in recipients of SRA and MRA grafts

Post-operative complications	Number of renal arteries		p value
	SRA	MRA	
cAR	1.1 ± 0.4	1.09 ± 0.3	NS (*p*:0.4)
bAR	1.1 ± 0.6	1.07 ± 0.7	NS (*p*:0.8)
Chronic graft nephropathy	456	131	NS (*p*:0.5)
Graft loss	954	277	NS (*p*:0.6)
Chronic Rejection	401	114	
Vascular/Urological	31	10	
Infectious	32	11	
Renal Disease Relapse	7	0	
Acute Rejection	16	5	
Death with functioning graft	356	107	
Lack of compliance	15	5	
Never-functioning kidney	96	25	
Death cause			NS (*p*:0.9)
Cardiovascular	159	45	
Infectious	134	45	
Hepatic insufficiency	20	7	
Neoplasia	64	20	
Unknown	200	54	

SRA – single renal artery; MRA – multiple renal artery; cAR – clinical acute rejection; bAR – biopsied acute rejection; NS – not significant

Table 6: Creatinine serum value and clearance using the Cockcroft-Gault formula between groups

Time	Variables	Number of renal arteries		*p* value
		SRA	MRA	
1 month	Cr (mg/dL) GFR (mL/min/1.73m²)	1.6 ± 1.0 63.9 ± 24.2	1.6 ± 1.1 63.1 ± 23.1	NS (*p*:0.9) NS (*p*:0.4)
6 months	Cr (mg/dL) GFR (mL/min/1.73m²)	1.6 ± 3.5 65.7 ± 22.6	1.4 ± 0.5 65.6 ± 22.5	NS (*p*:0.4) NS (*p*:0.9)
12 months	Cr (mg/dL) GFR (mL/min/1.73m²)	1.4 ± 0.6 67.4 ± 22.8	1.4 ± 0.7 65.9 ± 22.9	NS (*p*:0.5) NS (*p*:0.1)
5 years	Cr (mg/dL) GFR (mL/min/1.73m²)	1.5 ± 0.7 69.4 ± 24.3	1.5 ± 0.7 68.1 ± 23.1	NS (*p*:0.8) NS (*p*:0.5)
10 years	Cr (mg/dL) GFR (mL/min/1.73m²)	1.9 ± 8.6 74.0 ± 28.8	1.4 ± 0.8 72.7 ± 25.3	NS (*p*:0.4) NS (*p*:0.6)

SRA – single renal artery; MRA – multiple renal artery; Cr – creatinine, GFR – glomerular filtration rate; NS – not significant

at 5 years varied from 70% to 88.6%.[8] Gawish *et al*[9] showed also no differences in graft survival between groups as well as Benedetti *et al.*[10] The most recent meta-analysis[6] showed higher 1-year graft survival (93.2%) but lower 5-year graft survival (81.4%). However, this meta-analysis included studies that could have only 50 patients. So, that fact could introduce some heterogeneity. Nevertheless, like the meta-analysis, long-term outcomes were comparable between groups.

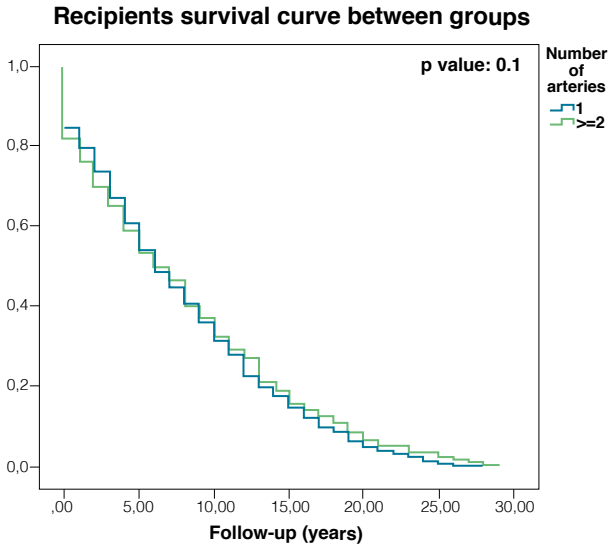

Figure 1: Comparison of recipient's survival curves between groups (Kaplan-Meier curve).

Table 7: Graft Survival time according to the type of arterial anastomosis adopted for multiple renal arteries graft anastomosis

Type of arterial anastomosis	Graft survival time (years)	*p* value
Ex-vivo bench surgery techniques	7.7±7.2	NS (*p*:0.07)
In vivo sequential anastomosis	5.5±5.4	
Mixed Techniques	7.0±4.8	

NS: not significant

Conclusion

Multiple renal artery grafts were not a problem in our unit: despite needing a longer operative time, higher cold ischemia time and higher blood transfusions rate, the short and long-term outcomes were comparable between groups, allowing to be used safely and with results similar to single renal artery grafts. ●

Ethical Disclosures

Conflicts of Interest: The authors report no conflict of interest.

Funding Sources: No subsidies or grants contributed to this work.

Confidentiality of Data: The authors declare that they have followed the protocols of their work center on the publication of patient data.

Protection of Human and Animal Subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Responsabilidades Éticas

Conflitos de Interesse: Os autores declaram a inexistência de conflitos de interesse na realização do presente trabalho.

Fontes de Financiamento: Não existiram fontes externas de financiamento para a realização deste artigo.

Proteção de Pessoas e Animais: Os autores declaram que os procedimentos seguidos estavam de acordo com os regulamentos estabelecidos pelos responsáveis da Comissão de Investigação Clínica e Ética e de acordo com a Declaração de Helsínquia da Associação Médica Mundial.

Confidencialidade dos Dados: Os autores declaram ter seguido os protocolos do seu centro de trabalho acerca da publicação dos dados de doentes.

*Corresponding author/*Autor Correspondente:
João André Mendes Carvalho
Address: Rua Paulo Quintela, Lote 6, 7º B, 3030-393 Coimbra
E-mail: joao.andre.mendes.carvalho@gmail.com

Recebido/Received: 2018-03-22

Aceite/Accepted: 2018-06-04

REFERENCES

1. Tonelli M, Wiebe N, Knoll G, Bello A, Browne S, Jadhav D, et al. Systematic review: kidney transplantation compared with dialysis in clinically relevant outcomes. Am J Transplant. 2011; 11: 2093–109. doi: 10.1111/j.1600-6143.2011.03686.x.
2. Novick AC, Magnusson M, Braun WE. Multiple-artery renal transplantation; emphasis on extracorporeal methods of donor arterial reconstruction. J Urol. 1979; 122:731.
3. Paragi PR, Klaassen Z, Fletcher HS, Tichauer M, Chamberlain RS, Wellen JR, et al. Vascular constraints in laparoscopic renal allograft: comparative analysis of multiple and single renal arteries in 976 laparoscopic donor nephrectomies. World J Surg. 2011; 35: 2159–66. doi: 10.1007/s00268-011-1168-6.
4. Hsu TH, Hsu THS, Su L, Trock BJ, Kavoussi LR. Impact of renal artery multiplicity on outcomes of renal donors and recipients in laparoscopic donor nephrectomy. Urology. 2003; 61:323–7.
5. Taghizadeh Afshari A, Mohammadi Fallah MR, Alizadeh M, Alizadeh M, Makhdoomi K, Rahimi E, et al. Outcome of kidney transplantation from living donors with multiple renal arteries versus single renal artery. Iran J Kidney Dis. 2016;10:85-90.
6. Zorgdrager M, Krikke C, Hofker SH, Leuvenink HG, Pol RA. Multiple renal arteries in kidney transplantation: a systematic review and meta-analysis. Ann Transplant. 2016;21:469-78.
7. Shapiro R, Simmons RL, Starzl TE. In: Shapiro R, editor. The transplant procedure: Renal transplantation. Stamford: Appleton & Lange; 1997. p. 103-40.
8. Chabchoub K, Mhiri MN, Bahloul A, Fakhfakh S, Ben Hmida I, Hadj Slimen M, et al. Does kidney transplantation with multiple arteries affect graft survival? Transplant Proc. 2011; 43:3423-5. doi: 10.1016/j.transproceed.2011.09.027.
9. Gawish AE, Donia F, Samhan M, Halim MA, Al-Mousawi M. Outcome of renal allografts with multiple arteries. Transplant Proc. 2007; 39:1116-7. doi: 10.1016/j.transproceed.2007.03.067
10. Benedetti E, Troppmann C, Gillingham K, Sutherland DE, Payne WD, Dunn DL,et al. Short- and long-term outcomes of kidney transplants with multiple renal arteries. Ann Surg. 1995; 221:406-414