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REVIEW ARTICLE

Laparoscopic procurement of single versus multiple artery kidney allografts: Meta-analysis of comparative studies

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Summary Laparoscopic donor nephrectomy has become the standard procedure to procure kidney graft. Transplantation using multiple arteries allograft is technically more challenging and still controversial with respect to renal transplantation outcomes. The objective of this study was to examine the transplantation outcome in both donor and recipient outcome of multiple arteries allograft kidney compared with single renal artery kidney. Eligible studies were identified from electronic databases: PubMed, Cochrane CENTRAL, Science Direct, and CINAHL as of October 2016. Relevant parameters explored using Review Manager V5.2 included donor and recipient outcomes. Twenty-four studies were included in this meta-analysis. Compared with SA, MA kidneys were associated with a longer donor operative time. There was no difference between donor length of stay, intraoperative blood loss, hospital stay, first warm ischemic time (WIT-I), and donor surgical complications in donors with multiple arteries compared with single. There was an increased risk of one-year graft loss (OR 1.57, 95% CI 1.09 to 2.26, $p = 0.016$), recipient vascular complications and recipient ureteral complications in multiple arteries compared with single artery allografts. Kidney transplantation with multiple arteries is relatively as safe as single artery in terms of donor outcomes. However, transplantation with multiple arteries allograft had several potential negative impacts on the recipient outcomes.

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1. Introduction

Worldwide, the incidence of end-stage renal disease (ESRD) is rapidly increasing. In 2010, approximately 2.618 million people received renal replacement therapy (RRT) due to ESRD, with 78% of patients (2.050 million people) received dialysis and the reminder received renal transplantation. The estimated number of patients who need RRT is approximately 4.9 million people; it has been suggested that 2.2 million people cannot access RRT. The largest treatment gap is found in low-income countries, particularly in Asia.[1]

Patients with ESRD have two options for RRT: renal transplantation or dialysis. Renal transplantation is generally accepted as the best option since it is associated with a better quality of life and longer life span, and is also more cost-effective than dialysis.[2] Although there are an increasing number of patients in need of renal transplantation, the number of donors in the donor pool is still limited.[3] Hence, renal transplantation using difficult grafts such as grafts with anatomical variations, including multiple arteries, veins, and ureters are acceptable.[4]

The anatomical variations in renal arteries consist of supernumerary, aberrant, supplementary, and accessory. The presence of multiple arteries is the most common anatomical variation during kidney transplantation. The incidence of multiple arteries has been reported in 25% of cadaveric analysis.[5] Using a donor graft with multiple arteries is a challenge for the surgeon. The use of laparoscopy to procure the kidney extends the procurement of kidney, especially kidney with multiple arteries.[6] However, usage of multiple arteries as graft is still controversial with respect to donor and recipient outcomes.

To the best of our knowledge, there have been several studies that evaluated the safety and efficacy of using multiple arteries grafts compared with single artery grafts. However, many published studies were using data from a single center included relatively few subjects and presented variable results.[7–9] Thus, we performed meta-analysis to evaluate the overall effect of multiple arteries grafts procured by laparoscopy in terms of donor and recipient outcomes.

2. Methods

2.1. Study design

The design of this systematic review was based on Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines.[10] We searched multiple databases for articles that compared safety and efficacy using kidney donors with multiple renal arteries, published between January 1970 and October 2016. Titles and abstracts were independently assessed by two researchers (A.A and N.R). All comparative studies of kidney transplantation using single artery and multiple arteries grafts were reviewed systematically. There was no restriction in terms of language; articles in languages other than English were translated before performing data extraction. This study just included articles with laparoscopy technique to procure the graft. If the same group of patients was used in multiple publications or in different years, only the most recent one was used for the meta-analysis. The reference lists of the obtained articles were also checked for relevant articles. The Newcastle-Ottawa Scale for cohorts was used for the quality assessment of the included studies in this meta-analysis.[11] This review evaluated donor and recipient outcomes based on the presence of multiple arteries. The donor outcomes were operative time, first warm ischemic time (WIT-I), intraoperative blood loss, hospital stay, and surgical complications. Surgical complication was categorized into: Clavien-Dindo I–II and Clavien-Dindo III–IV. Subgroup analysis was performed based on the type of laparoscopy nephrectomy. The recipient outcomes were vascular complications (stenosis or thrombosis), ureteral complications (ureteral stenosis or leakage), second WIT (WIT-II), cold ischemic time (CIT), delayed graft function (DGF), and one-year graft loss.

2.2. Search strategy

An extensive literature search was performed using the databases PubMed, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL), and ScienceDirect databases. The search terms used were ("multiple arteries" OR "vessel") AND ("renal allograft" OR "kidney transplant" OR "kidney donor" OR "transplantation"). We conducted a secondary search throughout conferences abstracts and reference list of included studies. If the full text article were not sufficient, the authors were contacted. Reviewers independently selected the article, assessed the study quality, and extracted data from the article. We used EndNote Reference Manager version X7 by Thomson Reuters as a reference manager to facilitate the identification and elimination of duplicate records from multiple databases.

2.3. Study selection criteria

The reviewers extracted data from each study onto a standardized form and reviewed the studies. The inclusion criteria were (i) published comparative studies, which included prospective or retrospective cohorts, assessing the donor and recipient outcome of using multiple arteries compared with single artery grafts in renal transplantation, (ii) with a living kidney donor, and (iii) using laparoscopic techniques (transperitoneal or retroperitoneal approach) for kidney extraction. We excluded the study if (i) it included a pediatric population, (ii) it was a case report or case series, or (iii) if the study did not present the outcome that we considered.

2.4. Statistical analysis

The meta-analysis was performed using the Cochrane Collaboration Review Manager Software (Rev-Man version 5.2). For dichotomous data (donor complications, recipient one-year graft loss, recipient DGF, and recipient ureteric and vascular complications), data were analyzed using pooled odds ratios (ORs) and associated 95% confidence intervals (CI). For continuous data (donor operative time, donor blood loss, WIT-I, donor hospital stay, and WIT-II), we calculated the mean difference (MD) and associated 95% CIs. Heterogeneity between studies was assessed using the χ^2 and the I^2 statistics. The study was considered heterogeneous with an I^2 value $> 50\%$ or a p value of $\chi^2 < 0.1$. When significant heterogeneity was found, a random-effects model was used to estimate the overall effect. A publication bias was evaluated using a funnel plot analysis for the most important outcome, with asymmetry of plot was evaluated by Egger's regression test. A significant publication bias was considered if the p value less than 0.1.

3. Result

3.1. Literature search and characteristics of eligible studies

According to the search strategy determined previously, we included 24 comparative studies in this meta-analysis. The detailed literature search and article screening strategy are shown in Fig. 1. All publications were full-text articles. The majority of studies were cohort studies; four studies[12–15] were prospective cohorts and 17 studies[8,16–31] were retrospective cohort. Another three studies[32–34] were comparative cross-sectional studies. Nine studies[8,14,16,18,20,21,23,25,34] used data from transplant centers in Asia and 13 studies[12,13,15,17,19,22,24,26,28–31,33] used data from United States of America (USA) and Canada. Just one studied used laparoscopy in Europe[32] and Latin America.[27] Most of the included studies were using pure transperitoneal laparoscopy for kidney extraction. Hand assisted transperitoneal laparoscopy was used in three studies.[15,18,19] Three studies used retroperitoneoscopy approach for kidney procurement.[8,12,14] The detailed characteristics of the included studies in this meta-analysis are presented in (Table 1).

Nine studies discussed about the site of donor nephrectomy.[8,12,13,15,17,19,22,25,27,29] All of the studies prefer left kidney to be used as a donor kidney, especially when the multiple arteries was found. In the single artery donor, the use of right kidney was more tolerable (Supplementary Table 1). Eighteen studies were presented the method of vascular reconstruction for multiple arteries graft. Majority of the studies were using back-table reconstruction of the kidney included as side to side or end to side arterial reconstruction, or ligation of the smaller artery. Two studies did not using back-table reconstruction and using separate anastomosis of the arteries[28,29] (Supplementary Table 2).

3.2. Methodological quality of included studies

Overall, the methodological quality of the included studies in this review was relatively good (Table 1). All of the studies were of good quality based on the selection criteria (presented with four stars). The intervention cohort (multiple arteries graft) in all studies was representative of patients who undergo renal transplantation. In addition, data regarding the intervention group, i.e. an allograft with multiple arteries graft, was recorded in the medical records. However, in terms of comparability criteria, three studies[14,24,26] were included as non-comparable cohorts (presented with zero stars) because there was no adjustment or matching between the intervention and non-intervention cohorts. In terms of the outcome criteria, we determined that two studies[14,35] had poor methodology for evaluating the outcome of the study. In those studies, there was no statement regarding lost to follow-up or the follow-up period was not adequate.

3.3. Donor outcomes

3.3.1. Operative time

This meta-analysis of 20 studies[8,13–15,17–23,25–30,32–34] found that the pooled mean operative time was 188 min in single artery donor and 214 min in multiple arteries donor. There was significant difference in operative time between multiple arteries and single artery grafts (MD 15.22 min, 95% CI 8.35 to 22.09, $p < 0.001$). Longer operative time in multiple arteries donor was found in the pure transperitoneal laparoscopy, hand assisted laparoscopy, and retroperitoneoscopy donor nephrectomy. The forest plot had significant heterogeneity with I^2 of 80% (Supplementary Fig. 1).

3.3.2. Hospital stay

Analysis of donor hospital stay as an outcome was encountered in 12 studies[8,13,17,18,20,22,23,28–30,33,34] with no significant differences between multiple arteries and single artery grafts (MD 0.23 days, 95% CI −0.05 to 0.50, $p = 0.10$) (Supplementary Fig. 2).

3.3.3. First warm ischemic time

The WIT-I outcome were available in 20 studies.[8,13,14,17–28,30–34] The mean WIT-I in single arteries donor was 265 s and in multiple arteries donor was 238 s. The pooled analysis showed no significant differences between multiple arteries and single artery donor kidney (MD 14.13 s; 95% CI −9.02 to 37.18; $p = 0.23$) (Supplementary Fig. 3).

3.3.4. Blood loss

No significant difference was observed regarding blood loss between multiple arteries and single artery grafts (MD -1.41 mL, 95% CI −20.73 to 17.91, $p = 0.69$) in 10 studies[8,15,17–19,22,23,27,29,33] (Supplementary Fig. 4).

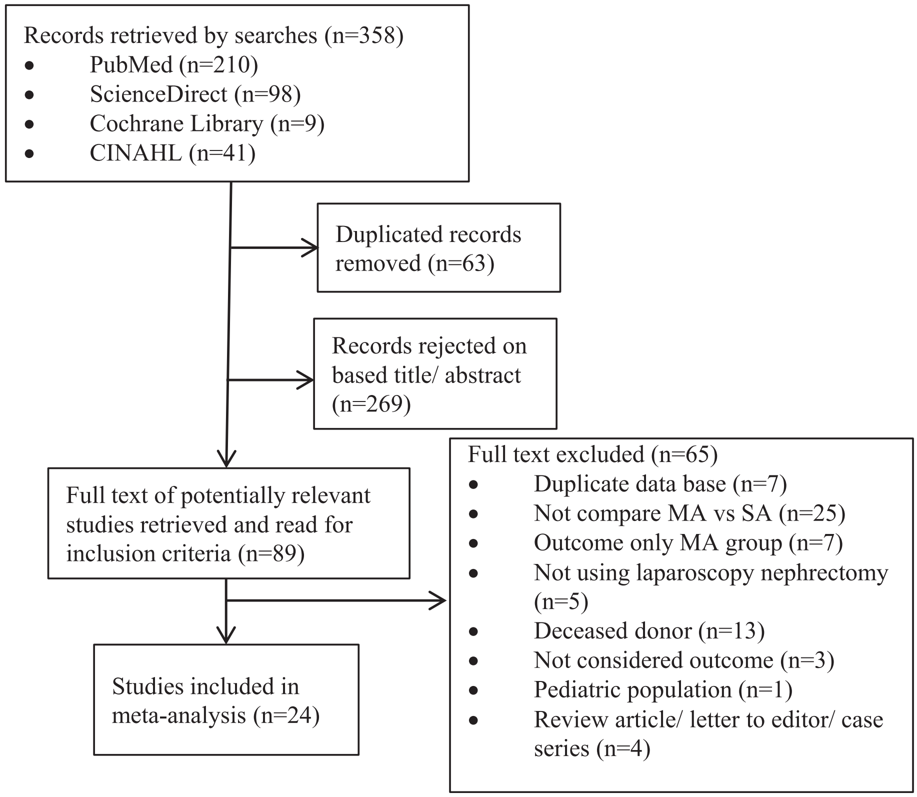

Figure 1 Flowchart showing the search strategy of the identification of studies included in this meta-analysis.

3.3.5. Donor complications

Nine studies[8,17–20,22,26,30,32] assessed overall donor complications in 3112 patients and reported no significant differences between multiple arteries and single artery grafts (OR = 0.95, 95% CI 0.60 to 1.52, $p = 0.84$). Multiple arteries showed 6.4% and single artery showed 6.3% of overall complications. Sub group analysis found no differences in MA and SA graft in all of the laparoscopic technique that used to procure the kidney (Fig. 2). The differences analysis using Clavien-Dindo classification showed that either in outcome Clavien-Dindo I–II or Clavien-Dindo III–IV, multiple arteries and single artery grafts showed no significant different of donor complications (Supplementary Fig. 5). No publication bias was found based on Egger's regression test ($p = 0.431$).

3.4. Recipient outcomes

3.4.1. Second warm ischemic time

Seven studies[14–17,30,32,34] analyzed the effect of multiple arteries allograft in WIT-II. Meta analysis of these studies found no statistically difference of WIT-II between multiple arteries and single artery allograft (MD = 1.45 min, 95% CI −0.38 to 3.29, $p = 0.12$). Mean WIT-II in multiple arteries group was 30 min compared with 28 min in single artery group (Supplementary Fig. 6).

3.4.2. Cold ischemic time

Nine studies analyzed the difference of CIT between multiple arteries and single artery allografts.[8,15,29,30,16,24,27,32,34] Majority of studies using back table reconstruction of the multiple arteries and just one study not performed back table arterial reconstruction. The pooled effect showed longer CIT in multiple arteries allograft compared with single artery allograft (MD = 14.22 min, 95% CI 6.42–21.91, $p < 0.01$). Cold ischemic time in multiple arteries allograft was 79 min and single artery allograft was 67 min. Sub analysis of non backtable arterial reconstruction group found that multiple arteries allograft had same CIT as single artery allograft (Supplementary Fig. 7).

3.4.3. Vascular complications

Vascular complications were reported within 14 studies[12–18,20,22,25,26,32,34] including 3933 recipients. Overall vascular complication rate in multiple arteries was 2.6% and in single artery was 1.3%. The meta-analysis of these studies showed significant differences in vascular complications between multiple arteries and single artery grafts (OR = 2.12, 95% CI 1.24 to 3.61, $p < 0.001$) (Fig. 3).

3.4.4. Ureteral complication

The meta-analysis of 5533 recipients from 16 studies[8,12,14–18,20,22,23,25,29–31,34] showed significant differences in ureteral complications between multiple arteries and single artery grafts (OR = 1.49, 95% CI 1.03 to 2.16, $p = 0.03$). Pooled ureteral complications rate in the multiple arteries group was 3.5% and in the single artery group was 2.7% (Fig. 4).

Table 1 Characteristics of study included in meta-analysis.

No	Study, First Name	Year	City, Country of Transplant Center	Study Type	Type of laparoscopy	N (MA/SA)	Sex, %, MA/SA (M:F)	Donor Age, yr (MA/SA)	Recipient Age, yr (MA/SA)	Study Quality		
										Selection	Comparability	Outcome
Transplant Center in Asia												
1	Abbaszadeh[16]	2009	Taheran, Iran	RC	PTL	90/230	57:43/65:35	38/40	NC	☆☆☆☆	☆☆	☆☆☆
2	Cho[18]	2012	Seoul, Korea	RC	HATL	86/239	59:41/53:47	38.4/38.5	NC	☆☆☆☆	☆☆	☆☆☆
3	Desai[20]	2007	Gujarat, India	RC	PTL	27/245	NC	44.0/45.3	NC	☆☆☆☆	☆☆	☆☆☆
4	Genc[21]	2011	Ankara, Turkey	RC	PTL	13/85	23:77/33:67	48.4/44.1	41.9/34.8	☆☆☆☆	☆	☆☆☆
5	Hung[23]	2012	Tainan, Taiwan	RC	PTL	11/89	45:55/33:77	46.1/43.2	NC	☆☆☆☆	☆☆	☆☆☆
6	Kacar[25]	2005	Izmir, Turkey	RC	PTL	7/23	57:43/35:65	47.4/46.3	NC	☆☆☆☆	☆	☆☆☆
7	Kitada[14]	2010	Fukuoka, Japan	PC	HARP	18/40	NC	53.1	38.4	☆☆☆☆	–	☆
8	Kuo[34]	2010	Singapore & Hong Kong	CS	PTL	8/42	0:100/42:58	44.0/40.2	NC	☆☆☆☆	☆	☆☆☆
9	Omoto[8]	2014	Tokyo, Japan	RC	PRP	127/406	36:64/34:66	54.8/54.1	NC	☆☆☆☆	☆☆	☆☆☆
Transplant Center in USA and Canada												
10	Carter[17]	2005	California, USA	RC	PTL	49/312	51:49/41:59	42.7/39.7	NC	☆☆☆☆	☆☆	☆☆
11	Chedid[12]	2013	Minnesota, USA	PC	HARP	210/923	43:57/43:57	44/44	51/52	☆☆☆☆	☆☆	☆☆☆
12	Cooper[19]	2013	Maryland, USA	RC	HATL	235/997	58:42/40:60	40.3/40.4	NC	☆☆☆☆	☆☆	☆☆☆
13	Hsu[22]	2003	Baltimore, USA	RC	PTL	76/277	42:58/41:59	40.1/41.4	NC	☆☆☆☆	☆☆	☆☆☆
14	Husted[24]	2005	Ohio, USA	RC	PTL	37/203	NC	NC	NC	☆☆☆☆	–	☆☆☆
15	Johnston[13]	2001	Kentucky, USA	PC	PTL	8/16	75:25/37:63	38/37	NC	☆☆☆☆	☆☆	☆☆☆
16	Kapoor[26]	2011	Ontario, Canada	RC	PTL	12/150	52:48/54:46	NC	NC	☆☆☆☆	–	☆☆☆
17	Keller[33]	2009	North Carolina, USA	CS	PTL	37/193	NC	NC	NC	☆☆☆☆	☆☆	☆☆
18	Oh[28]	2003	Detroit, USA	RC	PTL	11/62	47:53/63:37	42/42	NC	☆☆☆☆	☆☆	☆☆☆
19	Paragi[29]	2011	Livingstone, USA	RC	PTL	177/799	NC	40.6/41.1	45.3/44.7	☆☆☆☆	☆☆	☆☆☆
20	Paramesh[15]	2009	Loss Angles, USA	PC	HATL	60/218	NC	37.8/37.6	41.8/37.8	☆☆☆☆	☆☆	☆☆☆
21	Troppmann[30]	2001	California, USA	RC	PTL	21/58	62:38/48:52	39/42	44/42	☆☆☆☆	☆☆	☆☆☆
22	Tyson[31]	2011	Minnesota, USA	RC	PTL	117/393	NC	NC	48.2/50.4	☆☆☆☆	☆☆	☆☆☆
Transplant Center in Europe												
23	Giessing[32]	2003	Berlin, Germany	CS	PTL	18/45	61:39/49:51	36/37	NC	☆☆☆☆	☆	☆
Transplant Center in Latin America												
24	Meyer[27]	2012	Curitaba, Brazil	RC	PTL	22/108	27:73/40:60	36/39	NC	☆☆☆☆	☆	☆☆

RC = retrospective cohort; PC = prospective cohort; CS = cross sectional study; PTL = pure transperitoneal laparoscoy; HATL = hand assisted transperitoneal laparoscopy; PRP = pure retroperitoneoscopic; HARP = hand assisted retroperitoneoscopic; NC = not clear; MA = multiple renal arteries; SA = single renal artery; yr = year.

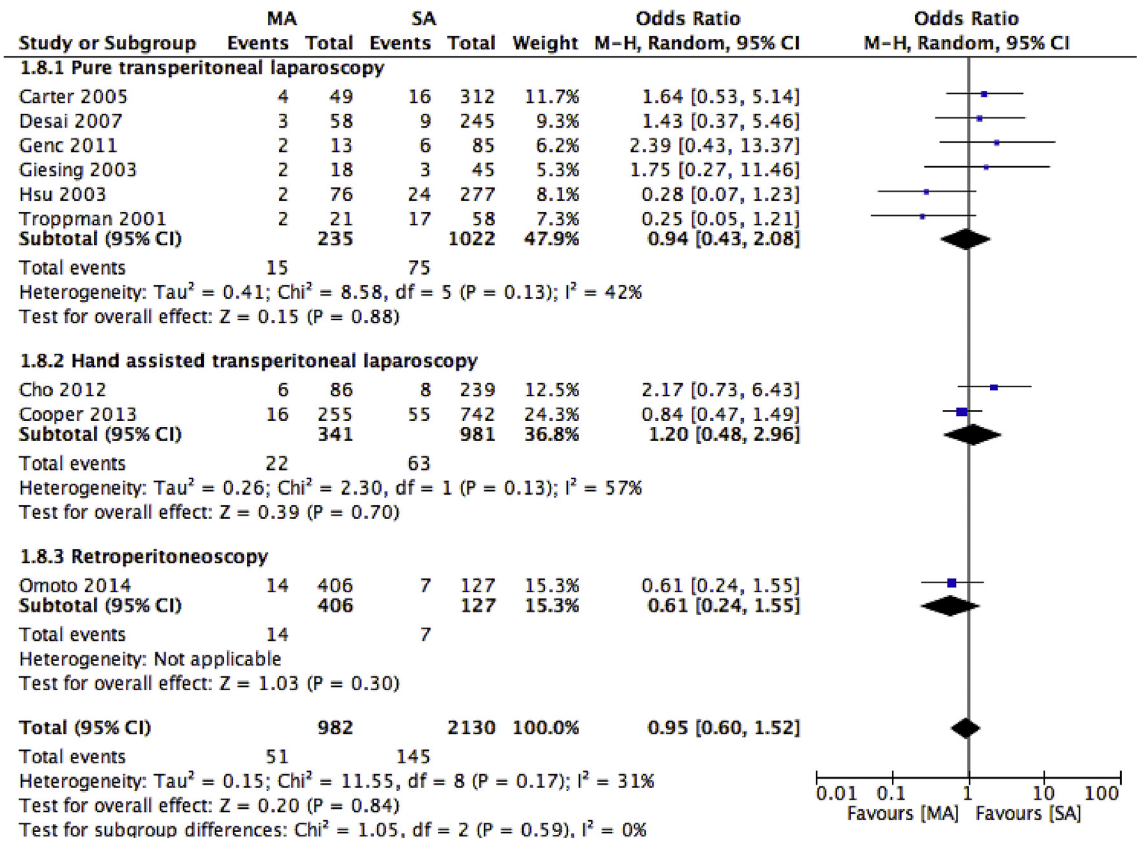

Figure 2 Forest plot of overall donor surgical complications rate based on the donor procurement techniques in single renal artery and multiple renal arteries allograft. The donor complication rate was not significant different in the multiple arteries group compared with single artery group. The complications rate between multiple arteries and single artery was the same based on the donor operations technique.

3.4.5. Delayed graft function

Delayed graft functions were reported in 12 studies[8,15,17–19,23,25,27,30,31,33,34] studies including 3623 recipients. Overall DGF in multiple arteries allograft was 5.1% and in single artery allograft was 5.2%. There was no significant difference in delayed graft function between multiple arteries and single artery grafts (OR 1.05, 95% CI 0.73 to 1.49, p = 0.81) (Supplementary Fig. 8).

3.4.6. One-year graft loss

One-year graft loss was assessed in 14 studies[13,15,16,18–20,22–25,28,29,34] and was significantly higher

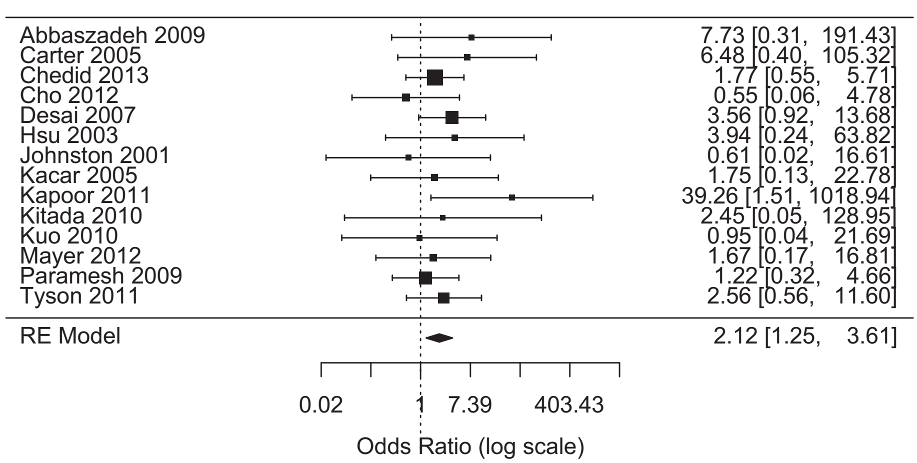

Figure 3 Forrest plots of the vascular complication rate in single renal artery and multiple renal arteries allograft. The complication rate was significantly higher in the multiple arteries group compared with single artery (OR 2.12, p = 0.006). Heterogeneity of vascular complication rate: I^2 = 0%, p = 0.76.

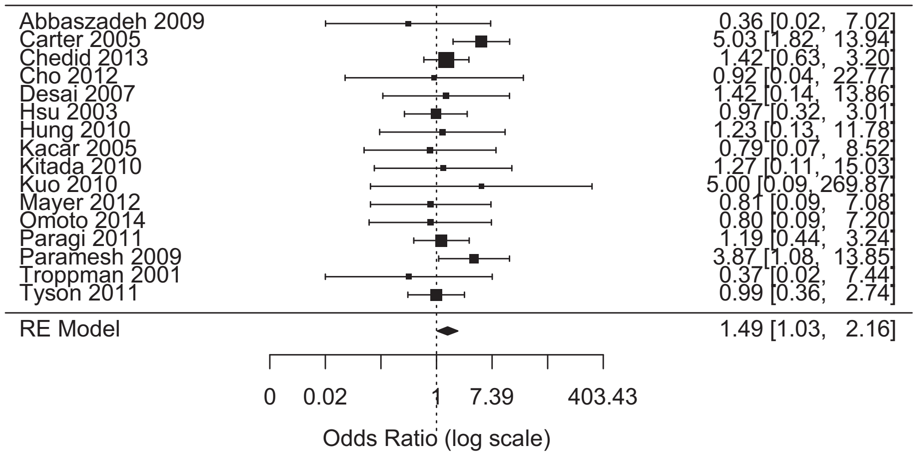

Figure 4 Forrest plots of the ureteral complication rate in single renal artery and multiple renal arteries allograft. The complication rate was significantly higher in the multiple arteries group compared with single artery (OR 1.49, $p = 0.03$). Heterogeneity of ureteral complication rate: $I^2 = 0\%$, $p = 0.671$.

with multiple arteries than with single artery grafts (OR 1.57, 95% CI 1.09 to 2.26, $p = 0.016$) (Fig. 5). A pooled one-year graft survival was 95.3% in the single artery graft and 93.0% in multiple arteries graft. A funnel plot (Supplementary Fig. 9) and Egger's regression test revealed no publication bias ($p = 0.500$).

4. Discussion

In the past, the selection of donors for kidney transplantation was very selective; however, because of the increasing demand for kidney donors, the use of difficult donor sources has rapidly increased, such as using MA donor kidneys. A survey in Europe demonstrated that the most common reason why transplant centers perform right-sided donor nephrectomy is the prevalence of multiple vessels on left-sided kidneys.[36] The left kidney is more preferable especially in the laparoscopy donor nephrectomy. In the United States, the right living donor nephrectomy continues to be lower rates. One right donor nephrectomy is performed for every eight donor nephrectomy in the United States.[37] In Europe, 12 transplantation centers restrict laparoscopy donor nephrectomy just for the left kidney.[36] Left kidney donor nephrectomy is technically easier to performed due to longer renal vein, which is advantageous during the implantation. In addition, performing transperitoneal approach of the laparoscopy nephrectomy in the right kidney is more difficult due to the presence of the liver that complicates dissection.[4] Theoretically, renal transplantation with MA kidneys prolongs the ischemic period and the need for anastomoses more than a single vessel, resulting in higher complication and rejection rates.

Our meta-analysis found that there were no significant differences between multiple arteries and single artery in terms of donor hospital stay, donor blood loss, and surgical

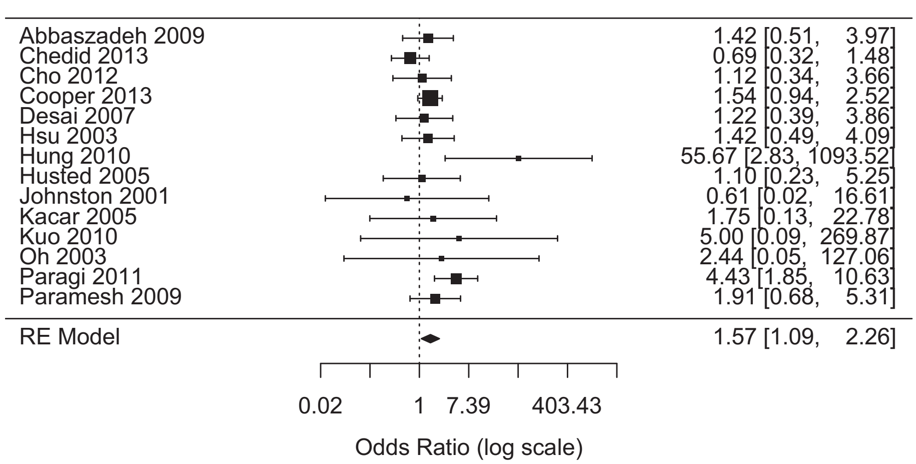

Figure 5 Forrest plots of the one-year graft loss in single renal artery and multiple renal arteries allograft. The one-year graft loss was significantly higher in the multiple arteries group compared with single artery (OR 1.57, $p = 0.016$). Heterogeneity of ureteral complication rate: $I^2 = 23\%$, $p = 0.202$.

complications. These findings suggest that performing laparoscopic donor nephrectomy in a patient with multiple arteries is relatively safe. Several studies showed that pure laparoscopic donor nephrectomy had similar donor outcome (WIT, blood loss, transfusion rate, analgesic requirement, and hospitalized period) as hand assisted laparoscopy donor nephrectomy. In addition, the recipient's graft function was also comparable.[38–40] In a previous study, the presence of multiple arteries in laparoscopic partial nephrectomy was not associated with a higher surgical complication rate or increased blood loss.[41] We found that the overall effect in laparoscopic living donor nephrectomy with an multiple arteries donor was a longer operative time, by approximately 15 min, compared with donor nephrectomy with an single artery donor. The longer donor operative times with MA might have been caused by technical difficulties during donor nephrectomy, but a longer duration of operative time has no negative impact on outcomes in the donor after nephrectomy.[42] The multiple arteries group had same WIT-I as a single artery group. A previous study showed that prolonged (5–10 min) warm ischemic time was not associated with graft survival or recipient serum creatinine at two years of follow-up.[43]

In terms of recipient outcomes, recipients of multiple arteries grafts had the same delayed graft function compared with single artery graft recipients. The risk factors for delayed graft function can be divided into immunologic and non-immunologic causes. With a deceased donor, delayed graft function is caused by ischemic reperfusion injury; this leads to acute tubular necrosis of the transplanted kidney and requires time to recover into normal function.[44] Delayed graft function is also associated with longer cold ischemic time and, theoretically, transplantation with multiple renal arteries prolongs the ischemic time. However, Basaran et al. found that there was no statistically significant difference in cold ischemic time between multiple arteries and single artery grafts.[45]

Most of the studies in this meta-analysis were using back-table arterial reconstruction. Just two studies did not perform arterial reconstruction when multiple arteries found. The ex vivo preparation of MA made a longer CIT in multiple arteries allografts. The finding was difference in the sub group analysis of the non back-table arterial reconstruction group, which showed same CIT in single artery and multiple arteries allografts. There was no significant different of WIT-II in MA and SA allograft. Preparation of kidney ex vivo before vascular anastomosis makes no differences of WIT-II. In addition, MA allografts had a higher rate of vascular complications, ureteral complications, and one-year graft loss, by 2.2-, 1.5-, 1.6-fold, respectively, compared with single artery grafts. The vascular reconstruction of multiple arteries graft might include (1) end-side re-implantation of smaller accessory artery into the main artery; (ii) side to side anastomosis if the artery had equal caliber; or (iii) ligation of small polar artery.[30] The three most troublesome vascular complications that affect graft survival are thrombosis, stenosis of the renal artery, and hemorrhage.[35] Several mechanisms cause vascular complications in multiple arteries allograft, including defective vascular sutures with an incomplete approximation of the tunica intima, resulting in secondary fibrosis, discrepancies in vessel caliber, and arterial trauma during reperfusion. Using an allograft from a cadaveric donor is associated with more frequent vascular complications than grafts from a living donor because living donors are completely evaluated for evidence of any vascular derangement, such as atherosclerosis or any degenerative or vascular impediments.[46] In this meta-analysis we found increasing ureteral complication in multiple arteries allograft. It may be caused by the insufficient of inferior pole kidney perfusion producing ischemia in the ureter. Deterioration of the inferior polar arteries during anastomosis may cause infarction of the calyces or ureter, resulting fistulas or necrosis of the ureter.[47]

This meta-analysis has several strengths. To the best of our knowledge, this is the most comprehensive meta-analysis assessing the outcome of using multiple arteries in renal transplantation, especially using laparoscopy for kidney procurement. Considering that most included studies were retrospective, this might introduce bias due to loss to follow-up, although in the quality assessment, we found that the majority of the retrospective cohorts had complete follow-up of the patients included in the cohort.

This study has several of limitations. First, all of the included studies were obviously not randomized, as a randomized study would not be feasible nor ethically acceptable. Second, we included three studies that were cross-sectional studies because these studies analyzed only donor outcomes, so it was not necessary to perform a follow-up assessment. Third, there were substantial heterogeneities in the five continuous outcomes (e.g. donor operative time, donor blood loss). We had to use the random effect model to increase the weight of the small studies. In addition, this study cannot sub-analyze the effect of arterial reconstruction in multiple arteries to the outcome of recipient because insufficient data of several studies to do that analysis.

In conclusion, laparoscopic donor procurement of kidneys with multiple arteries are relatively as safe as single artery kidneys in terms of donor outcomes. However, using multiple arteries allografts in transplant recipients has several potential negative impacts on recipient outcomes, e.g. an increased risk of vascular complications, ureteral complications, and one-year graft loss compared with single artery allografts.

Conflict of interest

The authors have no conflict of interest to declare.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.asjsur.2018.06.001.

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