

Segmental artery clamping versus main renal artery clamping in nephron-sparing surgery: Updated meta-analysis

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Abstract

Objectives Ischemia–reperfusion injury is harmful in partial nephrectomy (PN) in renal cell carcinoma. Choosing an appropriate surgical method is important to reduce ischemia–reperfusion injury. This study aimed to compare the effect of segmental artery clamping (SAC) and main renal artery clamping (MAC) on patients who underwent PN.

Methods: Studies from January 2008 to November 2019 were identified by an electronic search of English and Chinese databases, including PubMed, Excerpt Medica Database, Cochrane Library, Wanfang, VIP, and Chinese National Knowledge Internet, without language restriction. Two reviewers were involved in the trial. The effects on operation time (OT), warm ischemia time (WIT), length of hospital stay (LOS), blood transfusion rate, postoperative complication rate, Clavien classification (≥ 3), and positive surgery margin (PSM) were evaluated using Stata software. Standardized mean difference (SMD, for continuous data) and pooled odds ratios (for count data) with 95% confidence interval (CI) were used as effect indicators.

Results: Thirty-two studies were included. SAC decreased the 1-week (SMD=-0.973; 95% CI=-1.414, -0.532; $P=0.000$), 1-month (SMD=-0.411; 95% CI=-0.769, -0.053; $P=0.025$), and 3-month (affected kidney: SMD=-0.914; 95% CI=-1.662, -0.617; $P=0.000$) percentages of postoperative changes in renal function (estimated glomerular filtration rate) between the SAC and MAC groups. Sub-group analysis showed that the SAC group had longer OT (SMD=0.562; 95% CI=0.252, 0.871; $P=0.000$) than the MAC group. However, no differences were observed in the OT, WIT, LOS, blood transfusion rate, postoperative complication rate, Clavien classification (≥ 3), and PSM between the two groups.

Conclusions: SAC is superior to MAC in terms of short-term postoperative renal function recovery. The use of SAC or MAC depends on tumor size, location, surgical modality, and surgeon's judgments.

Introduction

Renal cell carcinoma (RCC) is the most lethal malignancy of urinary system tumors ranking the second in the incidence with a higher incidence than prostate cancer and a slightly lower incidence than bladder cancer in North America and Europe[1]. It was reported that there was a significant increase of asymptomatic small renal cell carcinoma (SRMs) and micro renal cell carcinoma with increasing use of imaging for other medical indications by incidental detection[2].

Surgical resection was once the preferred treatment for renal tumors. Radical nephrectomy (RN) and partial nephrectomy (PN) which was firstly performed by Winfield in 1992 are the main two important treatment options[3]. PN is appropriate in carefully selected patients with RCC with the advantages of reducing CKD risk, decreasing the overall and tumor-specific mortality, and improving long-term renal function compared with RN [4-6]. The limitation is that renal artery occlusion is often required and the accompanying thermal ischemic injury is an important cause of postoperative acute renal failure or long-term chronic kidney disease[7]. It is worth noting that main renal artery occlusion adopts the extensive renal blood flow occlusion, which blocks the blood supply of tumor and healthy nephrons at the same time, and the postoperative recovery of blood flow is bound to lead to the ischemia/reperfusion injury of healthy nephrons[8]. It was reported that blocking renal artery branch supplying tumor blood as far as possible in operation with high selective blockade technology and even not blocking the renal artery trunk was safe and feasible in PN because it can maintain normal blood supply of

residual kidney tissues, and no significant difference in total kidney[9]. Trehan reported that Off-clamp PN was associated with a significantly lower reduction in eGFR than on-clamp PN[10]. RPN with sequential SRA clamping, represents a good alternative for selected patients with Multiple ipsilateral renal tumors (MIRTs). The precise segmental artery clamping technique with the guidance of dual-source computed tomography (DSCT) can maximize renal function preservation[11]. Some studies in China have reported that SRAC is associated with decreasing warm ischemia appears promising in terms of reserving postoperative function [12, 13]. SAC was preferred by many surgical doctors. Li and Zhang[12] showed that SAC was safer and had a better renal function preservation compared with MAC in PN by reviewing the previous literatures [13]. However, Taweemonkongsap showed that clamping techniques does not impact on renal functions and complication rate was low even in small-volume center[14]. Therefore, So far, there is a lack of some systematic elaborations on the advantages and disadvantages of the SAC and MAC. The indicators for MAC and SAC are not clear. Therefore, it is necessary to constantly track and analyze the newest researches in the world for more powerful and more systematic evidence.

In this study, we conducted a retrieval and systematic analysis of the latest literature using case-control studies associated with comparing the features of SAC and MAC. In this way, it can provide more convincing evidence-based medicine basis for doctors and supply better services for clinical diagnosis and treatment.

Methods

Search strategy and selection criterion

This Meta analysis complied with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). We selected relevant literatures published from January 2008 to November 2019 by searching the English and Chinese databases including Cochrane Library, PubMed, Excerpt Medica Database (EMBASE) and Web of Science, CNKI, VIP and WanFang database with the following text words and Medical Subject Heading (MeSH) terms:(Kidney Neoplasms [Mesh] OR Renal tumor OR Kidney Neoplasm OR Neoplasm, Kidney OR Renal Neoplasms OR Neoplasm, Renal OR Neoplasms, Renal OR Renal Neoplasm OR Neoplasms, Kidney OR Cancer of Kidney OR Kidney Cancers OR Renal Cancer OR Cancer, Renal OR Cancers, Renal OR Renal Cancers OR Cancer of the Kidney OR Kidney Cancer OR Cancer, Kidney OR Cancers, Kidney) AND (Partial nephrectomy OR Nephrons paring nephrectomy) OR Nephron sparing surgery OR Nephron sparing surgery OR NSS) AND(Selective arterial clamping OR SAC OR Selective clamp OR Super-selective clamp OR Segmental artery clamp OR Zero ischemia) AND (Main arterial clamping) OR MAC) AND (Comparative Study OR Comparative Studies [Mesh]). All eligible tests are considered for review regardless of language.

Inclusion and exclusion criteria

The patients diagnosed as patients with renal tumors including benign and malignant tumors. And the above patients were subjected to SAC and MAC. The review literature and the studies which were not control-case studies were not included in this study. Documents without necessary and incomplete basic information are excluded. Low-quality studies were excluded.

Two researchers (Xu and Zhang) reviewed the related articles separately and extracted the data using a uniform standardized table including made with EXCEL 2010. They preliminary screened the article titles and abstracts independently. Then the studies that meet the criteria were included in this meta analysis. When disagreements

arise, another researcher (SX Xu) will enroll in a discussion until agreement was reached. Interested outcome measures are as follows: operating time(OT), estimated blood loss(EBL), warm ischemia time (WIT), bleeding requiring transfusion, length of hospital stay(LOS), postoperative complication rate, post-operative estimated glomerular filtration rate (eGFR) change value and percentage decrease in eGFR. In the process of data extraction, the continuous variables expressed using median and quartile spacing were converted to approximate mean and standard deviation according to the methods proposed by Luo and Wan, respectively.

Quality evaluation

The quality of each eligible article was assessed using the Newcastle-Ottawa Quality Assessment Scale (NOS). The papers scores above 8 points are considered as being of high quality. The papers scoring 6 to 8 points were considered methodologically sound. The studies scoring under 5 points are considered as being of low quality and were excluded from the final meta-analysis.

Statistical analyses

Statistical analysis was performed with Stata software version 12.0 (2011) (Stata Corp, Colledge Station, TX, USA). The heterogeneity was assessed using the Cochran's Q -test and the inconsistency index value (I^2). I^2 was more than 50%, which indicated that there was obvious heterogeneity. A random-effects model was used. A fixed-effects model was used when I^2 was less than 50%. Otherwise, Descriptive evaluation was adopted for outcome indicators that cannot be quantitatively evaluated. *Egger's* linear regression test was used to judged publication bias when the number of studies was more than 10.

Results

Baseline characteristics of the eligible studies

A total of 429 studies were identified from a search of the aforementioned databases. After carefully reviewing, 140 duplicate publications were eliminated. Finally, 32 studies with 19 references in English and 13 references in Chinese were included in this meta-analysis with 3098 cases cumulative sample size, 1289 cases in the SAC group and 1809 cases in the MAC group. Literature research phase flow chart was shown in figure 1. The basic information and NOS score results: The NOS scores of 9 articles were 6 marks. 11 articles were 7 marks, 12 articles were 8 marks. The basic information and NOS score of the included literature are shown in table 1. All data retrieved from the reviewed studies were recorded in an electronic database as follows: geographics characteristics: age, sex, body mass index (BMI), preoperative estimated glomerular filtration rate (eGFR), tumor size (maximum diameter), and RENAL marks. And the analysis was conducted about geographics which was shown in table 2. No significant difference in geographics was shown between the two groups

Sensitivity analysis

It showed that OT, EBL, 1 week postoperative change percentage of eGFR, 1 month postoperative change percentage of eGFR, 3 months postoperative change percentage of eGFR, 6 months postoperative change percentage of eGFR, PSM, Blood transfusion rate, Clavien classification ≥ 3 , Postoperative complications (hemorrhage, hematuria, Urine leak). The result difference of two models was not significant, which illustrated

the result was stable and reliable. About WIT, LOS, the results were not very reliable. The results are shown in table 3.

Publication bias

Publication bias was assessed for OT, LOS, 1 week postoperative change percentage of eGFR, 1 month postoperative change percentage of eGFR, 3 months postoperative change percentage of eGFR, 6 months postoperative change percentage of eGFR, PSM%, Blood transfusion rate, Clavien classification ≥ 3 , Postoperative complications (hemorrhage, hematuria, urine leak) using *Egger* linear regression. And *Egger* linear regression test showed that the *P* value of OT \square EBL, LOS was less than 0.05, suggesting that there might be publication bias. The *P* values of other studies were all greater than 0.05 indicating that there was not possibility of publication bias. The results are shown in table 4.

OT: 30 articles [12-41] were included in the literature. Heterogeneity results showed $I^2=92.3\%$, $P=0.000$, there was heterogeneity among the studies. Therefore, subgroup analysis was made according to different operation methods LPN and RPN. The heterogeneity changed very little in different groups indicating that operation method was not the main source of heterogeneity. Therefore, a random-effect model was used to pool the effectors. The result showed that OT is more in SAC group than in MAC group [SMD:0.56, 95% CI (0.25, 0.87), $I^2=92.3\%$, $P=0.000$]. No difference in OT was observed between SAC and MAC in RPN group [SMD:0.00, 95% CI (-0.38, 0.38), $I^2=90.3\%$, $P=0.000$]. See Figure 2.

WIT: 25 articles [12-23, 26-29, 31-34, 37, 39, 42, 43] were included in the literature. Heterogeneity results show $I^2=86.4\%$ $P=0.000$, there was heterogeneity among the studies. Therefore, subgroup analysis was made according to different operation methods LPN and RPN. The heterogeneity changed very little in different groups indicating that operation method was not the main source of heterogeneity. Therefore, a random-effect model was used to pool the effectors. The result showed there was no significant difference in WIT between SAC group and MAC group overall [SMD:0.04, 95% CI (-0.21, 0.28), $I^2=86.4\%$, $P=0.000$]. See Figure 3.

EBL: 30 articles [12-40, 43, 44] were included. Heterogeneity results show $I^2=84.3\%$, $P=0.000$. There was severe heterogeneity among the studies. Therefore, subgroup analysis was made according to different operation methods LPN and RPN. The heterogeneity changed very little in different groups indicating that operation method was not the main source of heterogeneity. Therefore, a random-effect model was used to pool the effectors. The result showed that EBL is more in SAC group than in MAC group [SMD: 0.55, 95% CI (0.34, 0.75), $I^2=84.3\%$, $P=0.000$]. See Figure 4.

Blood transfusion rate: Total 12 articles [12-14, 24, 26, 29, 30, 33, 35, 37, 43, 44] were included. Heterogeneity showed that there is no heterogeneity among the studies ($I^2=0$, $P=0.922$). Therefore, a fixed-effect model was used. The result showed there was no significant difference in blood transfusion rate between SAC group and MAC group [OR:1.065, 95% CI (0.610, 1.860), $I^2=0$, $P=0.922$]. See Figure 5.

LOS: Total 15 articles [16, 18, 20, 24, 26, 30, 31, 33-35, 38, 42, 43] were included. Heterogeneity showed that there was mild heterogeneity among the studies ($I^2=39.1\%$, $P=0.060$). Subgroup analysis was performed according to the operation methods LPN and RPN. And I^2 value was reduced to some extent in the subgroups. Therefore, operation method was the part of the heterogeneity resource but not the complete resource. The result showed

there was no significant difference in LOS between SAC group and MAC group in LPN group [SMD:-0.006, 95% CI (-0.166, 0.154), $I^2=39.1\%$, $P=0.060$]. No difference in OT was observed between SAC and MAC group in RPN Group [SMD: 0.152, 95% CI (-0.019, 0.322), $I^2=15.2\%$, $P=0.317$]. See Figure 6

Postoperative complications (hemorrhage, hematuria, urine leak): Total 24 articles[12, 13, 15, 18-22, 24, 26-35, 37, 38, 42-45]were included. Heterogeneity showed that there is no heterogeneity among the studies ($I^2=0$, $P=1.00$). Therefore, a fixed-effect model was used. The result showed there was no significant difference in Postoperative complications (hemorrhage, hematuria, urine leak) between SAC group and MAC group [OR:0.82, 95%CI (0.60, 1.11), $P=0.191$] . See Figure 7.

Clavien ≥ 3 : Total 15 articles[13, 14, 19, 27-31, 33-35, 37, 38, 44, 45] were included. Heterogeneity showed that there is no heterogeneity among the studies ($I^2=0$, $P=0.983$). Therefore, a fixed-effect model was used. The result showed there was no significant difference in Clavien ≥ 3 between SAC group and MAC group[OR: 0.89, 95% CI (0.51, 1.56), $I^2=0$, $P=0.983$] . See Figure 8.

PSM%:Total 23 articles[14-17, 20-22, 24, 26, 27, 29-35, 37, 38, 43-45]were included. Heterogeneity showed that there is no heterogeneity among the studies ($I^2=0$, $P=0.908$) . Therefore, a fixed-effect model was used. The result showed there was no significant difference in PSM% between SAC group and MAC group [OR: 1.17, 95% CI (0.55, 2.52), $P=0.908$]. See Figure 9.

1 week postoperative change percentage of eGFR: Total 8 articles [15, 28-30, 32, 33, 35, 42] were included. Heterogeneity showed that there was severe heterogeneity among the studies ($I^2=80.7\%$, $P=0.000$). Subgroup analysis was performed according to the operation methods LPN and RPN. And I^2 value was reduced to some extent in the subgroups. Therefore, operation method was the part of the heterogeneity resource but not the complete resource. The result showed SAC group had a less change than MAC group in LPN group in 1 week postoperative change percentage of eGFR [SMD:-1.95, 95% CI (-2.90, -1.01), $I^2=62.5\%$, $P=0.103$] . Similarly, SAC group had a less change than MAC group in RPN group [SMD:-0.69, 95% CI (-1.00, -0.38), $I^2=56.7\%$, $P=0.041$]. See Figure 10.

1 month postoperative change percentage of eGFR: Total 6 articles[27-29, 32, 33, 45] were included. Heterogeneity showed that there was moderate heterogeneity among the studies ($I^2=62.7\%$, $P=0.020$). Therefore, random-effect model was used. The result showed SAC group had a less change than MAC group in 1 month postoperative change percentage of eGFR [SMD:-0.41, 95% CI (-0.77, -0.05), $P=0.025$]. See Figure 11.

3 months postoperative change percentage of eGFR of the total kidney: Total 6 articles[19, 27, 29, 30, 33, 42] were included. Heterogeneity showed that there was severe heterogeneity among the studies ($I^2=72.0\%$, $P=0.003$). Subgroup analysis was performed according to the operation methods LPN and RPN. And I^2 value was changed to some extent in the subgroups. Therefore, operation method was the heterogeneity resource in LPN group but not in the RPN group. Therefore, random-effect model was used. The result showed that there was no significant difference in 3 months postoperative change percentage of eGFR between SAC group and MAC group [SMD:-0.35, 95% CI (-0.72, 0.03)]. See Figure 12.

3 months postoperative change percentage of eGFR of the affected kidney: Total 3 articles [12, 13, 34] compared the 3 months postoperative change percentage of eGFR of the affected kidney. Heterogeneity showed that there

was severe heterogeneity among the studies ($I^2=87.7\%$, $P=0.003$). Therefore, a random-effect model was used. The result showed SAC group had a less change than MAC group in 3 months postoperative change percentage of eGFR of the affected kidney between SAC group and MAC group [SMD:-0.662, 95%CI (-0.840, -0.484), $P=0.000$]. See Figure 13.

6 months postoperative change percentage of eGFR of the total kidney: Total 4 articles [19, 29, 31, 35] were included. Heterogeneity showed that there was severe heterogeneity among the studies ($I^2=84.0\%$, $P=0.000$). Therefore, a random-effect model was used. The result showed that there was no significant difference in 6 months postoperative change percentage of eGFR between SAC group and MAC group [SMD:0.081, 95% CI (-0.398, 0.560), $P=0.741$]. See Figure 14.

Discussion

In the current study, we systemically evaluated the impact of SAC and MAC on OT, EBL, WIT, LOS, postoperative complication rate, postoperative percentage decrease in eGFR. During the reports, the doctors conducted a case-control study by dividing the patients into two groups including SAC and MAC. However, some patients included into SAC had to be subjected to main arterial clamping when excessive bleeding from the defect and no enough time for modulating the clamped branches or no satisfactory ischemic area obtained by clamping multiple branches. That is that the two operation ways can be transferred when it is necessary. Shao et al. first reported the nephrectomy technique of selectively blocking renal artery, and learned that SAC not only retains the affected nephrons, but also reduces the disadvantages of renal ischemic injury[13]. RPN with segmental SRA clamping with the guidance of double source computerized tomography(DSCT), and skilled robotic experience, can be feasible and maximize renal function preservation [46]. However, Large-scale multicenter clinical studies are still needed to further prove these results.

Our result showed that OT in LPN with SAC is a little longer in SAC group than that in LPN with MAC group, which wasn't observed in the RPN group. Compared with traditional PN with MAC, PN with SAC requires the separation of renal artery, anterior and posterior branches and segmental renal arteries. When necessary, the kidney should be slightly cut open to separate the 3rd and 4th grade renal artery branches, which requires more steps of vessel separation. The above mentioned procedures can result in prolonged surgery. The length of time it takes to separate blood vessels during surgery is related to the doctor's skill and familiarity with the anatomical location of blood vessels. In addition to the duration of surgery, WIT's length was emphasized because WIT is a key factor affecting renal function.

About Ischemia reperfusion injury(IRI), it is a major cause of acute ischemic renal injury. In PN, in order to control intra-operative hemorrhage and maintain clear vision, it is often necessary to temporarily block renal pedicle vessels, which can cause renal ischemia and reperfusion injury[47]. LPN is widely used in the surgical treatment of renal tumors because of its safe and effective minimally invasive features: LPN with MAC has a good operative field, but the heat ischemia for a long time will cause damage to renal function [48, 49]. Benway showed that branch occlusion significantly reduced the thermal ischemia reperfusion injury using pig kidney model[50]. In recent years, selective renal artery branch blocking technology is gradually used in PN, the technology only block renal artery branch of supply of the tumor blood supply, can effectively avoid or reduce the normal renal unit thermal ischemia injury. It was reported the WIT over 30 min will produce irreversible damage to kidney function, some position is deeper, especially those with intra-operative need to suture the

drainage system, warm ischemia time difficult to control. This Meta analysis showed that OT is longer in SAC group than in MAC group in LPN, but there was no significant difference in OT between SAC and MAC in RPN Group. Meanwhile, it was proved that no significant difference in WIT was observed between SAC and MAC group. The length of hospital stay is mainly related to the patient's condition. Our study showed no obvious difference between PN with SAC and PN with MAC which indicating that the PN with SAC did not affect the length of hospital stay.

About EBL the result showed that EBL is more in SAC group than in MAC group ($P=0.000$). However, our result also showed no significant difference was observed in blood transfusion rate between SAC and MAC group. Although the combined effect indicator showed that there was difference between the two groups, however 17 articles of 30 articles showed that no difference was observed between the two groups. The number of articles in which no difference existed between the two groups is more than the number of the articles in which difference was observed between the two groups. Therefore, the conclusion that EBL in SAC group was more than MAC group cannot be drawn. The amount of bleeding may have a lot to do with a doctor's experience and skill. Which kind of operation should be adopted depends on the ability of the doctor and the patient's condition.

About PSM%, 17 articles of 23 articles showed that none of the patients had positive surgery margin. 6 articles of the left 6 articles showed that no difference in PSM % between SAC and MAC group. And the combined effect indicator also proved that no difference was observed between SAC and MAC groups ($P=0.8$). The result showed there was no significant difference in post-operative complications (hemorrhage, hematuria, urine leak) and Clavien \geq 3 between SAC group and MAC group. Heterogeneity analysis showed that there was no heterogeneity among the studies.

Eight articles related to 1 week postoperative change percentage of eGFR were eligible for this Meta-analysis, which indicated SAC group had a less change than MAC group in LPN group and RPN group. Total 6 articles related to postoperative 1 month-percentage change of eGFR were included, which indicated that SAC group had a less change than MAC group. Total 6 articles related to 3 months postoperative change percentage of eGFR of the total kidney were included, which indicated that no significant difference in 3 months postoperative change percentage of eGFR between SAC group and MAC group. Total 3 articles with severe heterogeneity related to postoperative 3 months change percentage of eGFR of the affected kidney were included, which indicated that SAC group had a less change than MAC group in 3 months postoperative change percentage of eGFR of the affected kidney between SAC group and MAC group. Total 4 articles with severe heterogeneity related to 6 months postoperative change percentage of eGFR of the total kidney were included, which indicated that no significant difference in 6 months postoperative change percentage of eGFR between the two groups was observed.

The number of articles investigating eGFR change was 3 to 10. Our study showed that SAC reduces the percentage change of eGFR within 3 months but had no obvious effect on eGFR in 6 months. The analysis on 6 months and above eGFR change wasn't carried out because of lacking in relative literatures. No kidney loss by 18 months' median followup was observed in T Taweemonkongsap's study. This study suggests SAC has certain advantage in the short term recovery of renal function, which also needs more random clinical experimental to further demonstrate the results. Our study results provide a basis for surgeons to actively screen and adapt patients to perform branch occlusion.

Deficiencies

Although a large number of literatures have been searched according to inclusion and exclusion criteria of the literatures, however, most of the studies included in this paper are not randomized controlled studies, and many of the data are expressed in different ways, some of which are calculated by transforming the median and quartile into the mean and standard deviation. In terms of kidney function, different article expression index is different like some with eGFR and some blood creatinine. So it is difficult to merge data. Moreover, the research results show that there is publication bias in three indicators. So the present study has preliminary conclusion. To get more reliable conclusions, large scale-randomized controlled trials are needed to carry out to confirm the effect of SAC to more objectively evaluate its' application value.

Abbreviations

CI: Confidence interval, SMD: Standard mean deviation, SAC:Segmental artery clamping

MAC: Main artery clamping, PN: Partial nephrectomy, PSM: Positive surgery margin

eGFR: estimated Glomerular Filtration Rate, OT: Operation time, WIT: Warm ischemia time

LOS: length of hospital stay.

Declarations

Ethics approval and consent to participate

This article does not contain any studies with animals performed by any of the authors.

Consent for publication

The manuscript is approved by all authors for publication

Availability of data and material

We declared that data and material described in the manuscript will be freely available to any scientist without commercial purposes, without breaching participant confidentiality.

Competing interests

The authors have declared that no conflict of interest exists.

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Authors' contributions

JHX, YGX, HS and SXX conceived and designed the study. And they participated in the literature research, data extraction, data disposal and manuscript drafting. QQ and FS reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1 Basic information and remarks of the included papers

Study	Year	Language	Tsample	Csample	Operation methods	Observed indicators	Length of follow up	NOS marks
Daniele Mattevi	2018	English	42	15	RPN	□□□□□□	1Mos	8
Tawatchai Taweemonkongsap	2018	English	38	27	RPN	□□□□□□□	18.2Mos	8
Gang Xu	2018	Chinese	25	31	LPN	□□□□	3Mos	8
Pengtao Wei	2018	Chinese	29	36	LPN	□□□□□	3Mos	7
Yongjian Zhang	2018	Chinese	28	22	LPN	□□□	3days	7
DeZhu Qi	2017	Chinese	31	32	LPN	□□□□□	12Mos	8
Qian Cai	2017	Chinese	15	19	LPN	□□□	6Mos	8
Paulucci	2016	English	66	132	RPN	□□□□□□	24Mos	7
Pu Li	2016	English	314	152	LPN	□□□	70Mos	8
Furukawa	2016	English	19	20	RPN	□□□□□	1Mo	7
Komninos	2015	English	25	114	RPN	□□□□□	47Mos	8
Shin	2015	English	20	97	RPN	□□□□	3Mos	7
Akca	2015	English	111	468	RPN	□□□□□□	6Mos	7
Wu Wei	2015	Chinese	39	43	LPN	□□□□□	42Mos	6
JianZhou Liu	2015	Chinese	29	27	LPN	□□□□	36Mos	6
Peng Li	2015	Chinese	10	13	LPN	□□□□	3Mos	8
Yuan Ruan	2016	Chinese	45	45	LPN	□□□	22.5Mos	7
(To be continued)								
Hao Yang	2015	Chinese	35	45	LPN	□	24Mos	6
JianFeng Zhao	2015	Chinese	21	21	LPN	□□□□□□□	Not mentioned	6
LiYong Xing	2014	Chinese	27	28	LPN	□□□	Not mentioned	6
Harke	2014	English	15	15	RPN	□□□□	8days	7
McClintock	2014	English	42	42	RPN	□□□□	3Mos	8
Yue Gao	2014	Chinese	21	38	LPN	□□□□□	12Mos	6
SiMei Zhu	2014	Chinese	13	44	LPN	□□□□□□	6Mos	7
Desai	2014	English	58	63	RPN	□□□□□□	6Mos	7
Sheng Li	2014	Chinese	18	38	LPN	□□□□□	24Mos	6
Borofsky	2013	English	27	27	RPN	□□□□□□	1Mos	8
Martin	2012	English	13	32	RPN	□□□□	3Mos	7
JianGang Gao	2012	Chinese	42	37	LPN	□□□□□□□□	48Mos	6
Ng	2012	English	22	22	RPN	□□□□□□□□	2Mos	8
Pengfei Shao	2011	English	31	37	LPN	□□□□	33Mos	8
Nohara	2008	English	18	27	Not mentioned	□□□	8Mos	6

Note:□OT □WIT □PSM □ Blood transfusion rate □EBL □Postoperative complications (Hemorrhage,

Hematuria, Urine leak) LOS Clavien classification ≥ 3

Table 2. Meta analysis of geographics of the patients of the included studies.

Indicators	Number of studies	Number of SAC	Number of MAC	Heterogeneity analysis					
				χ^2	df	I^2	<i>P</i> value	OR/ <i>SMD</i> (95%CI)	<i>P</i> value
Male	22	1072	1541	157.90	21	86.70	0.31	-0.41(-0.39,0.118)	0.27
BMI (kg/m ²)	21	979	1441	122.30	20	83.60	0.00	-0.71(-0.41,0.07)	0.16
RENAL scores	16	841	1268	80.40	15	81.30	0.00	0.15(-0.09,0.40)	0.21
Tumor size(cm)	22	1000	1504	157.98	21	86.70	0.00	-0.14(-0.40,0.40)	0.29
Preoperative eGFR(mL/min/1.73 m ²)	21	694	1364	0.00	20	0.00	1.00	0.0(-0.105,0.105)	1.00

Table 3 The pooled effect of outcome indicators by different models

Outcome indicators (continuous variables)	Fixed model of consolidation effect		Random model of consolidation effect	
	SMD/OR(95% CI)		SMD/OR(95% CI)	
Operation time				
	LPN	0.707(0.190, 0.355)	1.167(0.754, 1.579)	
	RPN	-0.104(-0.201, 0.008)	0.001(-0.380, 0.381)	
	Overall	0.272(0.190, 0.355)	0.562(0.252, 0.871)	
Warm ischemia time				
	LPN	0.073(-0.065, 0.210)	0.12(-0.25, 0.49)	
	RPN	0.149(0.041, 0.258)	-0.07(-0.42, 0.28)	
	Overall	0.120(0.035, 0.205)	0.04(-0.21, 0.28)	
Estimated blood loss				
	LPN	0.471(0.363, 0.579)	0.653(0.355, 0.952)	
	RPN	0.271(0.156, 0.385)	0.413(0.113, 0.713)	
	Overall	0.377(0.299, 0.456)	0.545(0.336, 0.755)	
Length of hospital stay				
	LPN	-0.112(-0.295, 0.071)	-0.131(-0.355, 0.092)	
	RPN	0.174(0.028, 0.321)	0.152(-0.019, 0.322)	
	Overall	0.063(-0.052, 0.177)	-0.006(-0.166, 0.154)	
	1 week postoperative change percentage of eGFR	-0.78(-0.97,-0.60)	-0.97[-1.41,-0.53]	
	1 month postoperative change percentage of eGFR	-0.40(-0.61,-0.184)	-0.41[-0.77,-0.05]	
	3 months postoperative change percentage of eGFR	-0.15(-0.32,0.02)	-0.26[-0.59,0.07]	
	6 months postoperative change percentage of eGFR	-0.06(-0.10,0.22)	-0.08[-0.40,0.56]	
	Positive surgical margin	1.173(0.547, 2.517)	1.173(0.547, 2.517)	
	Blood transfusion rate	1.065(0.610, 1.860)	1.065(0.610, 1.860)	
	Clavien classification ≥ 3	0.890(0.507, 1.564)	0.890(0.507, 1.564)	
	Postoperative complications (Hemorrhage, Hematuria, Urine leak)	0.816(0.601, 1.107)	0.816(0.601, 1.107)	

Table 4 Egger linear regression results of outcome indicators

Outcome indicators	<i>P</i> value of Egger test
Operation time	0.027
Warm ischaemia time	0.287
Estimated blood loss	0.012
Length of hospital stay	0.008
1 week postoperative change percentage of eGFR	0.457
1 month postoperative change percentage of eGFR	0.744
3 months postoperative change percentage of eGFR	0.126
6 months postoperative change percentage of eGFR	0.898
Positive surgical margin	0.827
Blood transfusion rate	0.953
Clavien classification ≥ 3	0.176
Postoperative complications (Hemorrhage, Hematuria, Urine leak)	0.314

Figures

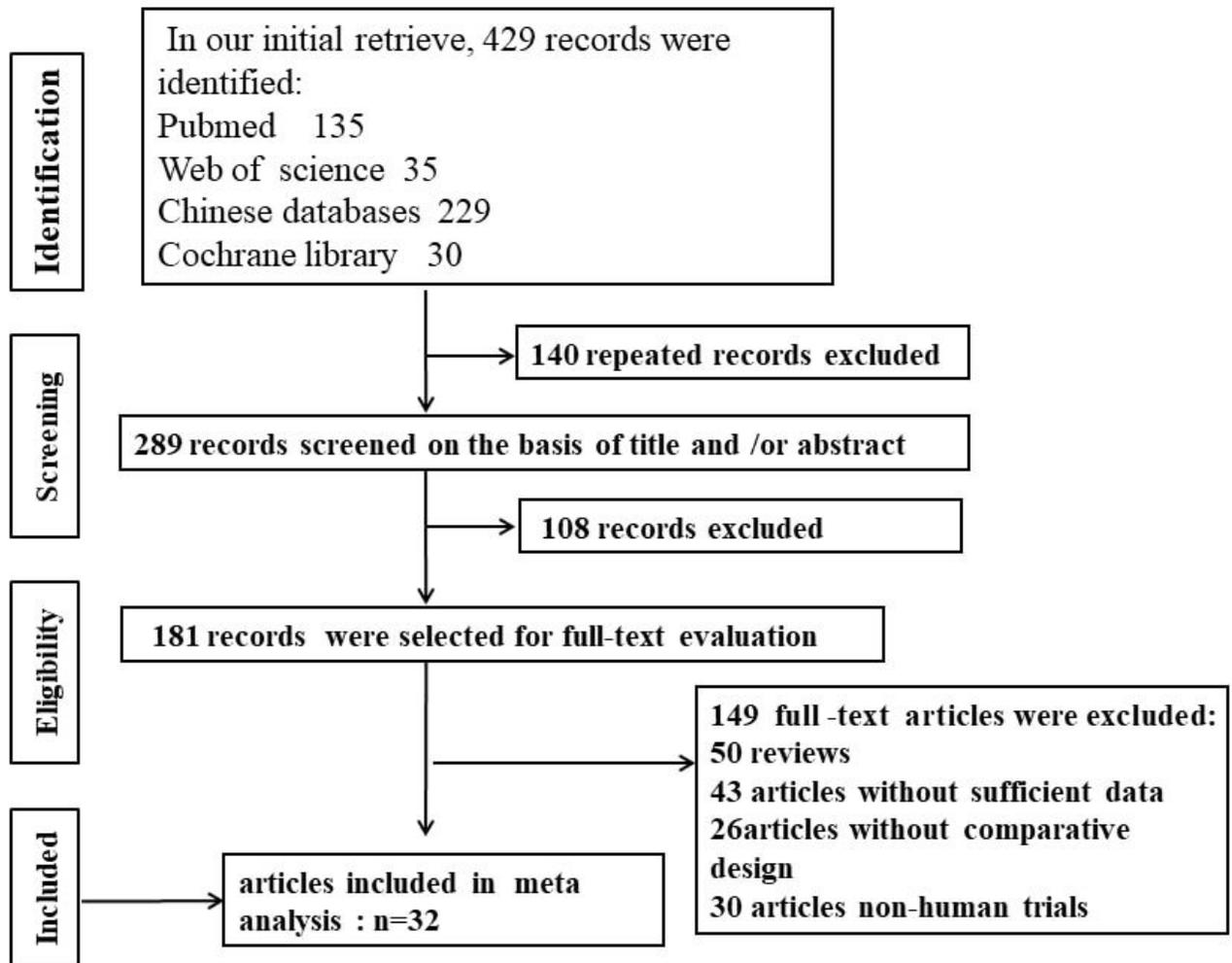


Figure 1

Flow chart of the included literature.

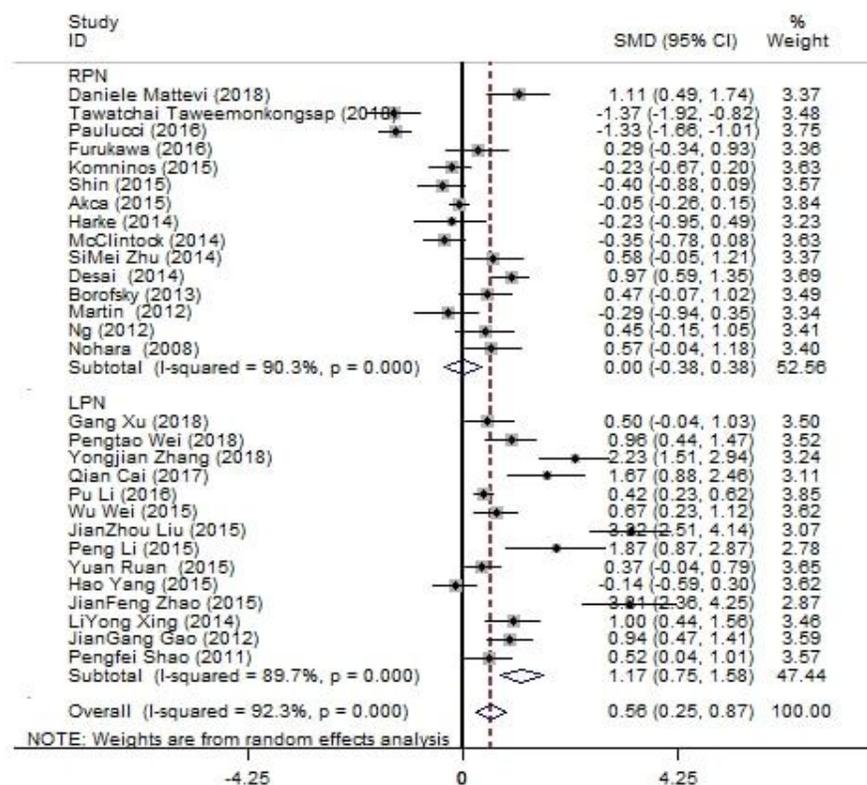


Figure 2

Forest plot and meta-analysis of operation time (OT) between SAC and MAC group.

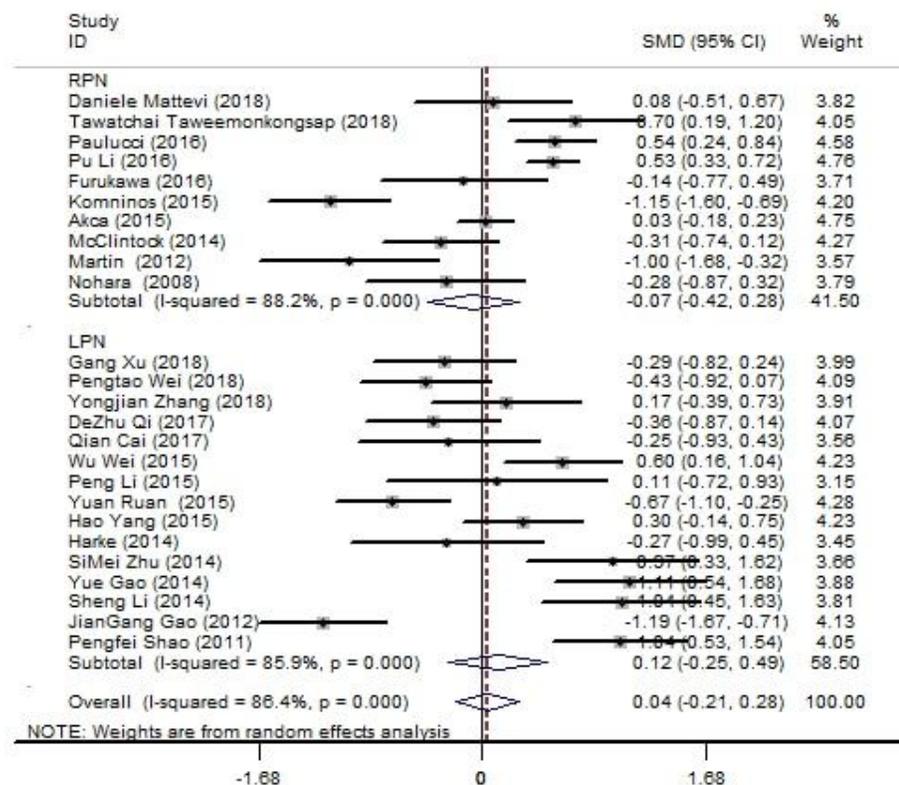


Figure 3

Forest plot and meta-analysis of warm ischemia time (WIT) between SAC and MAC group.

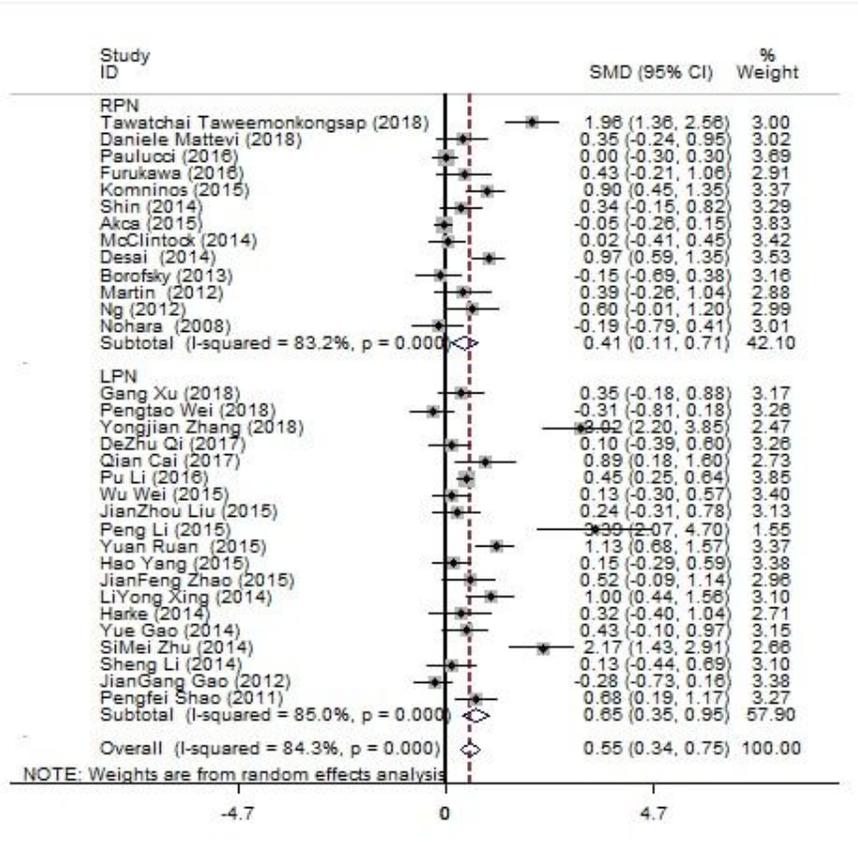


Figure 4

Forest plot and meta-analysis of estimated blood loss (EBL) between SAC and MAC group.

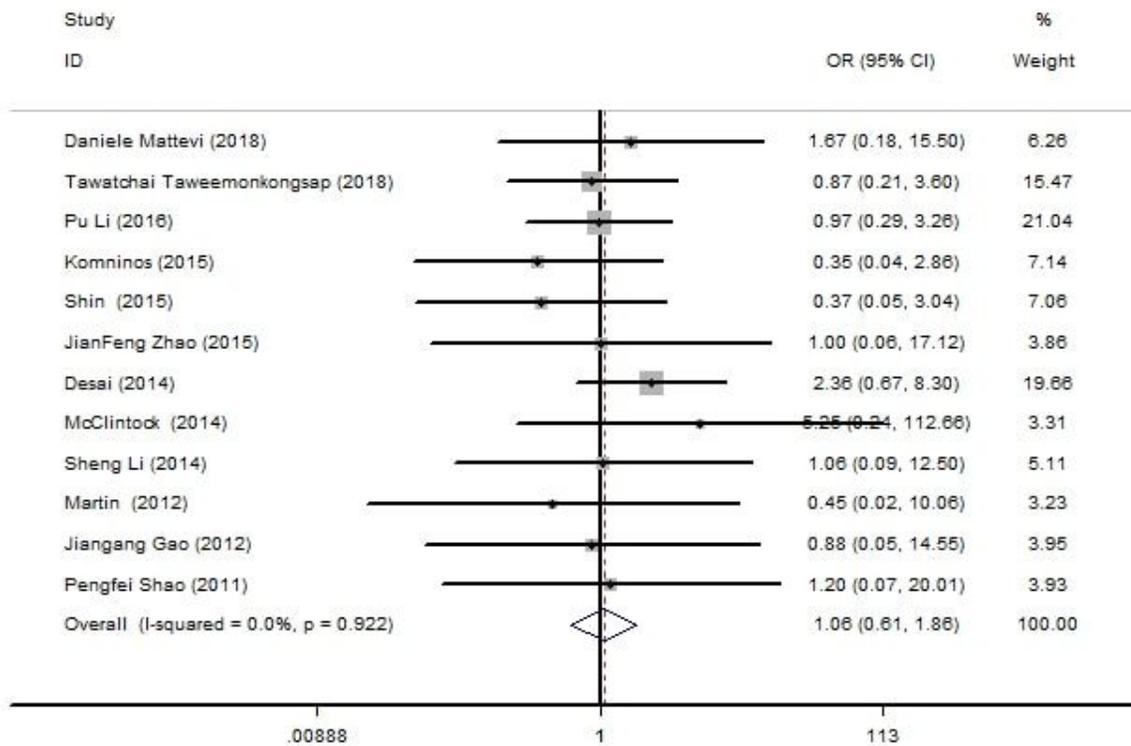


Figure 5

Forest plot and meta-analysis of blood transfusion rate in SAC and MAC group.

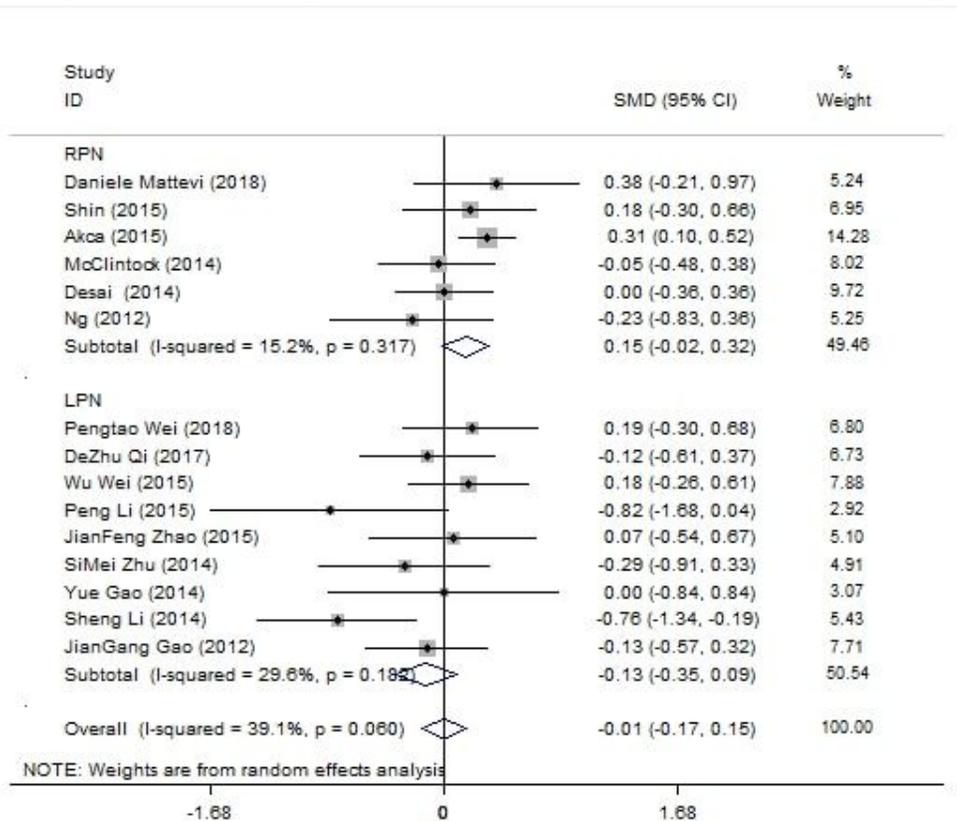


Figure 6

Forest plot and meta-analysis of LOS between SAC and MAC group.

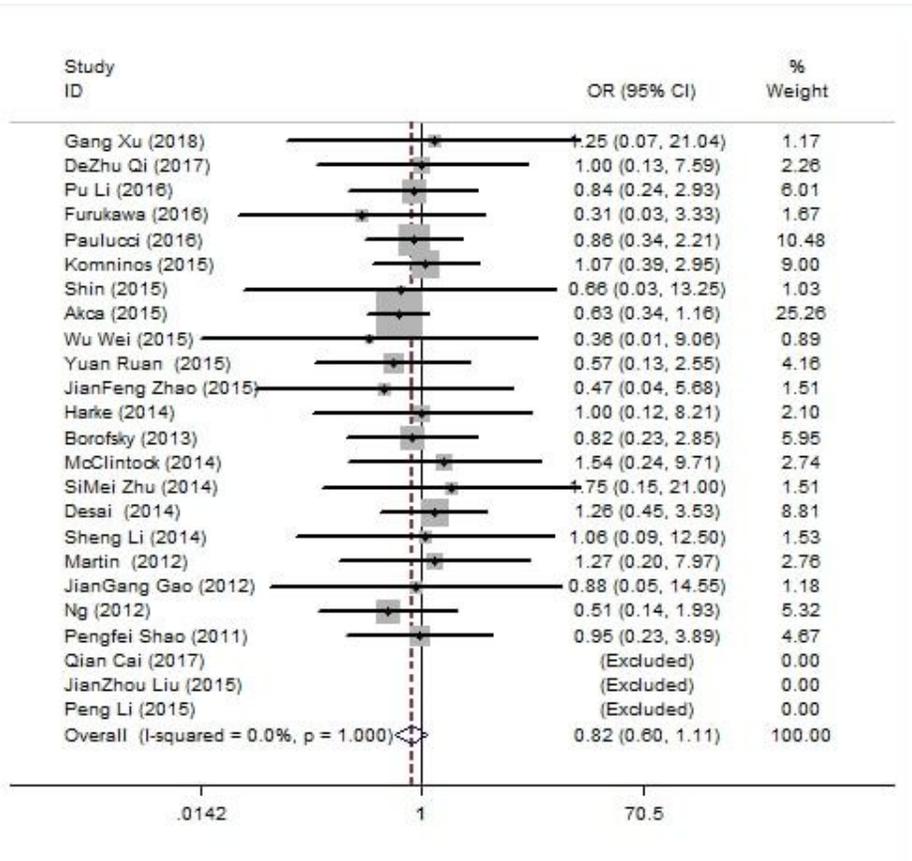


Figure 7

Forest plot and meta-analysis of postoperative complication rate between SAC and MAC group.

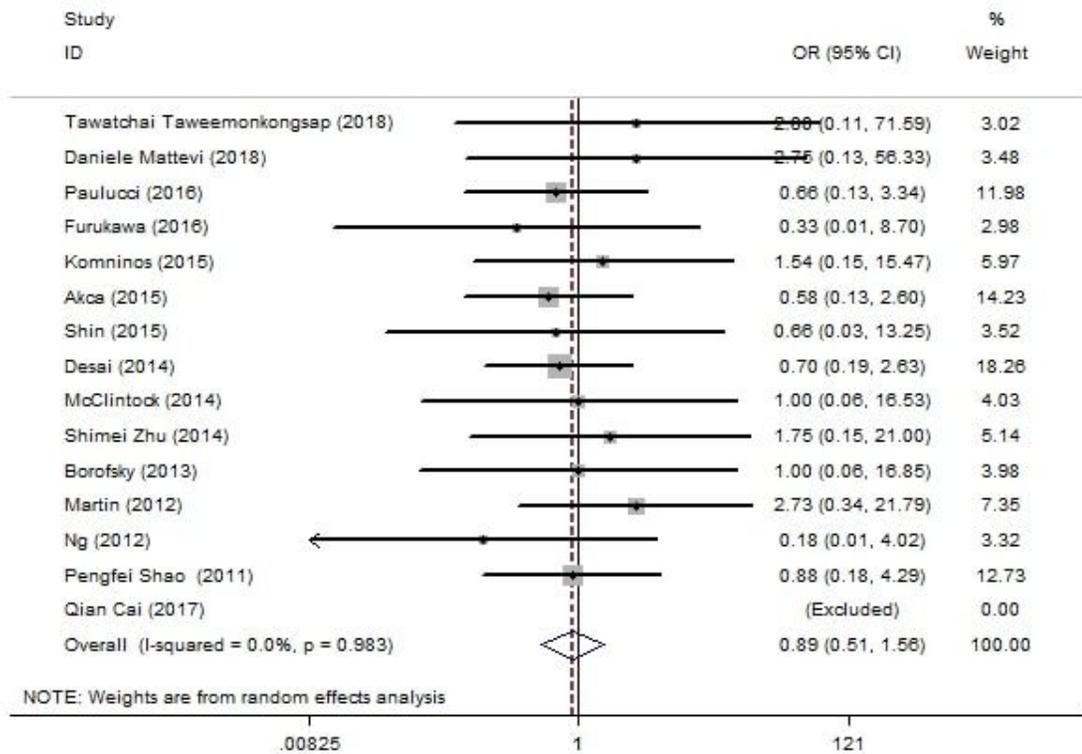


Figure 8

Forest plot and meta-analysis of Clavien classification ≥ 3 between SAC and MAC group.

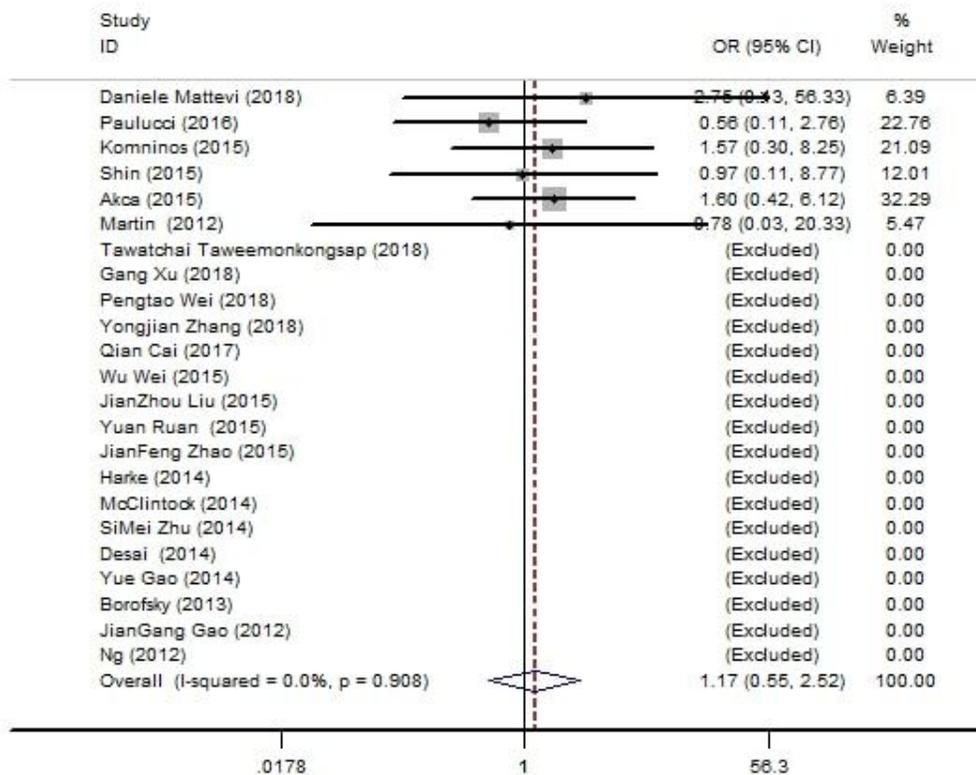


Figure 9

Forest plot and meta-analysis of PSM between SAC and MAC group.

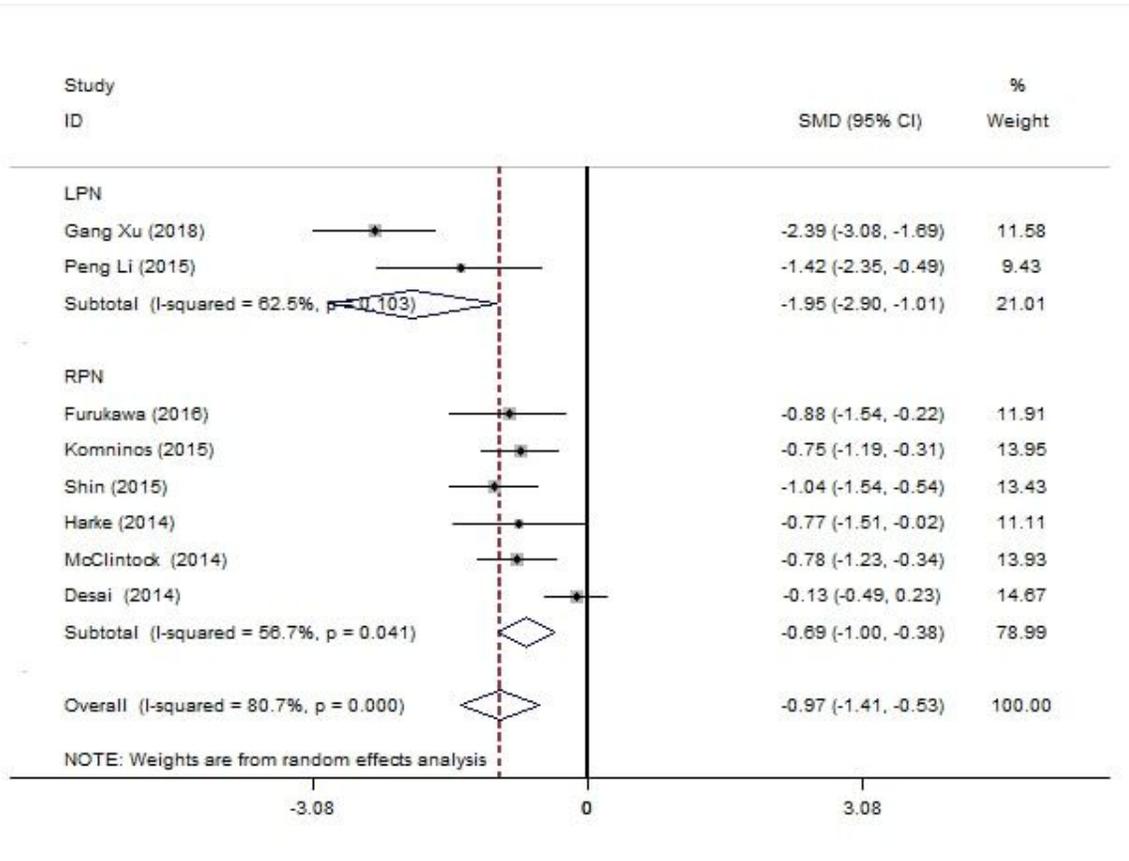


Figure 10

Forest plot and meta-analysis of 1 week postoperative change percentage between SAC and MAC group.

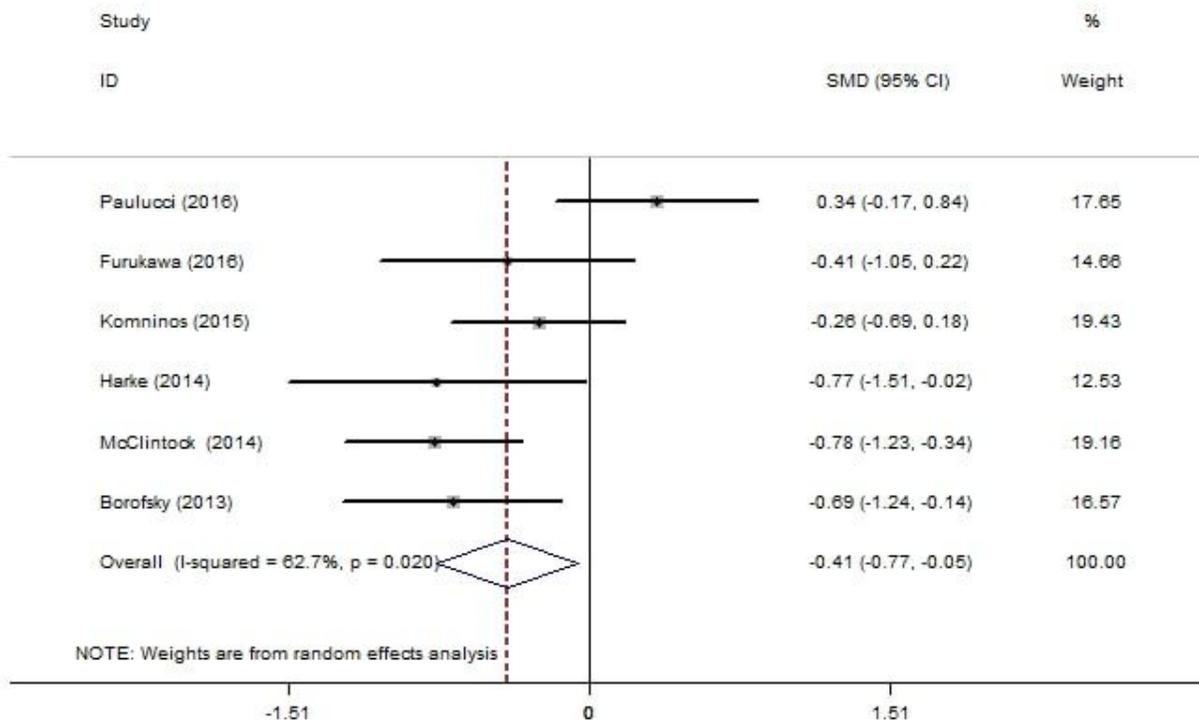


Figure 11

Forest plot and meta-analysis of 1 month postoperative change percentage of eGFR in SAC and MAC group.

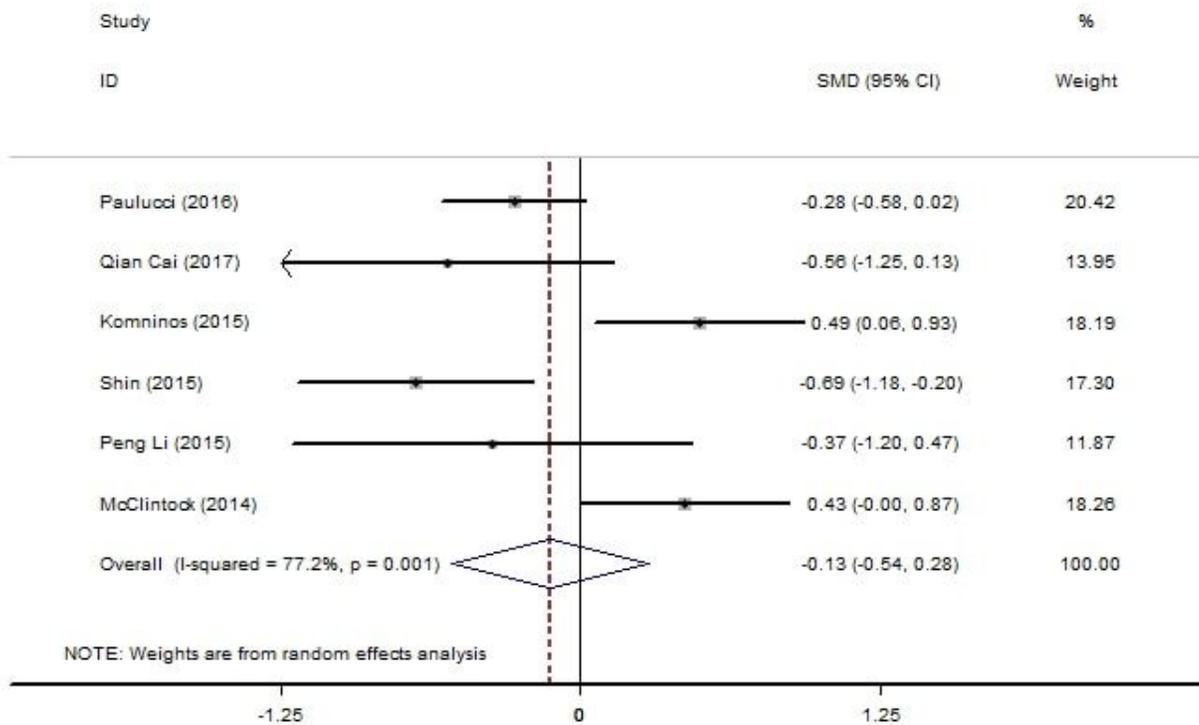


Figure 12

Forest plot and meta-analysis of 3 months postoperative change percentage of eGFR of the total renal between SAC and MAC group.

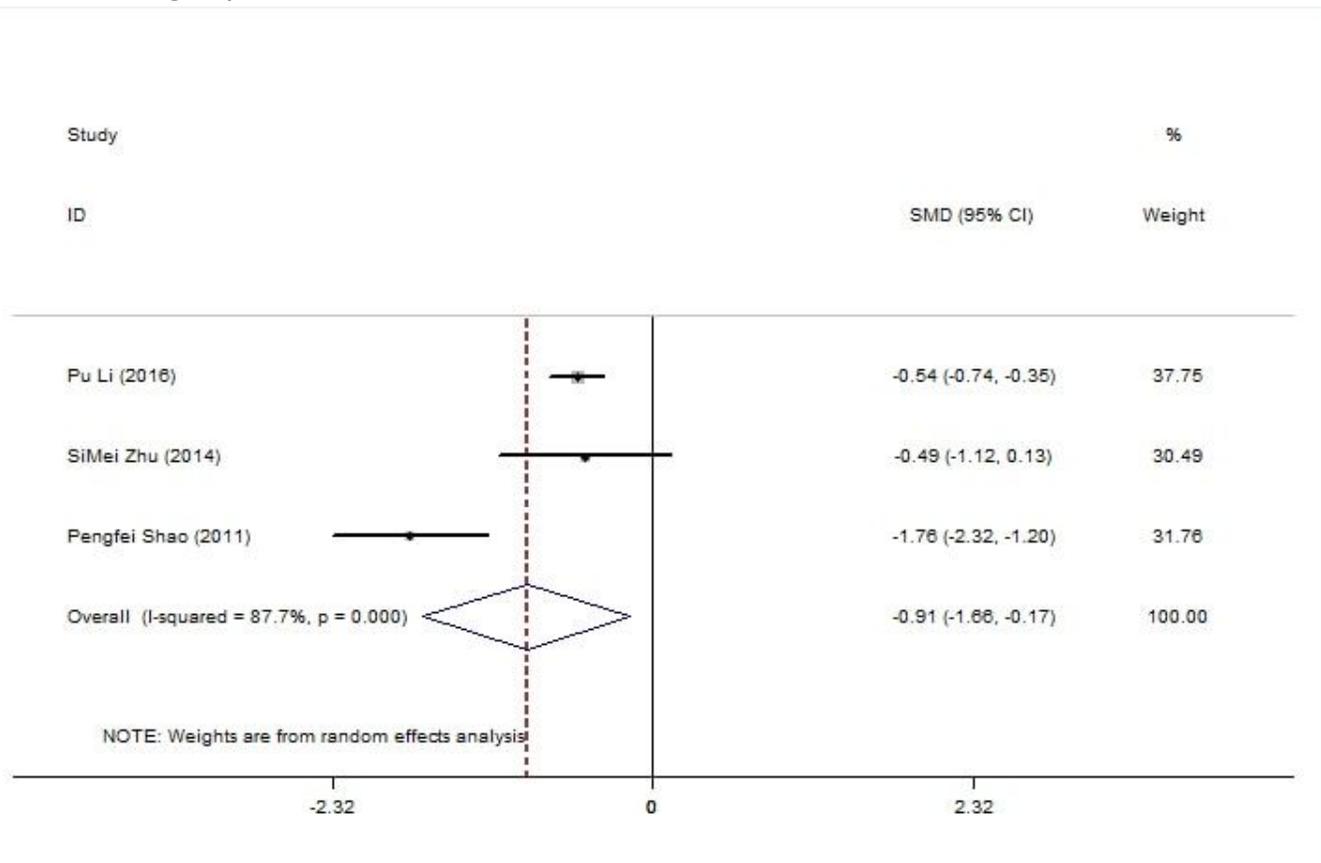


Figure 13

Forest plot and meta-analysis of 3 months postoperative change percentage of eGFR of the affected renal between SAC and MAC group.

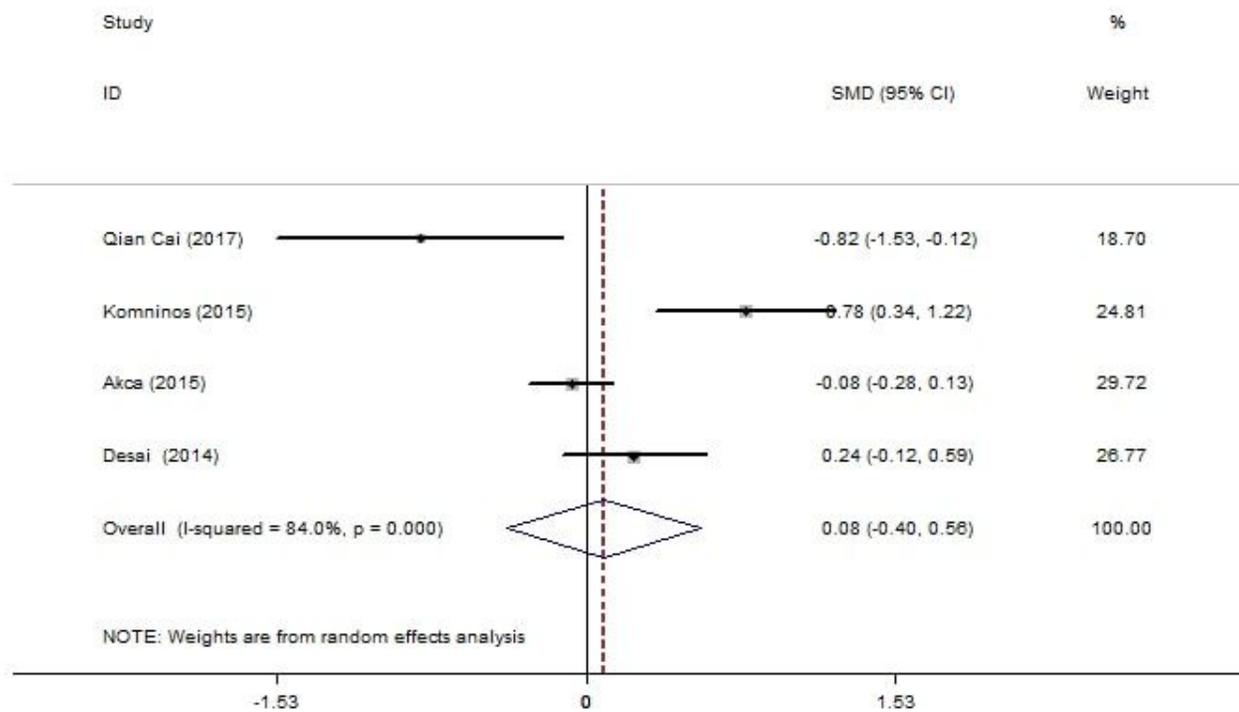


Figure 14

Forest plot and meta-analysis of 6 months postoperative change percentage of eGFR between SAC and MAC group.