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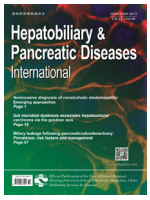

Meta-analysis

# Outcomes of adult patients adopting small-for-size grafts in living donor liver transplantation: A systematic review and meta-analysis

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ABSTRACT

*Background:* Small-for-size graft (SFSG) has emerged as one of the very contentions in adult-to-adult living donor liver transplantation (LDLT) as a certain graft size is related to recipients' prognosis. Graft-to-recipient weight ratio (GRWR) ≥0.8% was considered as a threshold to conduct LDLT. However, this also has been challenged over decades as a result of technique refinements. For a better understanding of SFSG in practice, we conducted this meta-analysis to compare the perioperative outcomes and long-term outcomes between patients adopting the grafts with a lower volume (GRWR < 0.8%, SFSG group) and sufficient volume (GRWR ≥ 0.8%, non-SFSG group) in adult-to-adult LDLT.

*Data sources:* The studies comparing recipients adopting graft with a GRWR < 0.8% and ≥ 0.8% were searched by three authors independently in PubMed, Web of Science, Embase, the Cochrane Library, MEDLINE and Google Scholar databases until September 2018 and data were analyzed by RevMan 5.3.5.

*Results:* Sixteen studies with a total of 3272 subjects were included in this meta-analysis. In terms of small-for-size syndrome (SFSS), no significant difference was found in subjects enrolled after year 2010 (before 2010, OR=3.00, 95% CI: 1.69–5.35, $P=0.0002$; after 2010, OR=1.23, 95% CI: 0.79–1.90, $P=0.36$; $P$ for interaction: 0.02). There was no significant difference in operative duration, blood loss, cold ischemia time, biliary complications, acute rejection, postoperative bleeding, hospitalization time, perioperative mortality, and 1-, 3- and 5-year overall survival rates between two groups.

*Conclusions:* This meta-analysis suggested that adopting SFSG in adult LDLT has comparable outcomes to those with non-SFSG counterparts since 2010.



## Introduction

Adult living donor liver transplantation (LDLT) has been considered one of the most effective treatments for end-stage liver disease since 1993 [1]. There are two paradoxical concerns of adult LDLT. One is the size of liver remnant for the donor, and another is minimum graft size for the recipient. In considering living donor safety and recipients' prognosis, most of transplantation centers adopt the following criteria in adult-to-adult LDLT: graft-to-recipient weight ratio (GRWR) ≥ 0.8%, or a graft volume (GV)/standard liver volume (SLV) ratio ≥ 40% [2]. The representative article published by Kiuchi et al. [3] reported grafts with a GRWR of less than 1% leads to lower graft survival and graft dysfunction, and presumed to be liver parenchymal injury caused by portal hyperperfusion. The impairment of graft metabolism and synthesis further leads to small-for-size syndrome (SFSS) [3,4]. However, to expand the pool of available grafts, adopting small-for-size graft (SFSG) is certainly an option. Some researchers demonstrated the feasibility of using SFSG in LDLT in recent years [5–9]. For a better understanding of SFSG in practice, we conducted meta-analysis to compare the perioperative outcomes and 1-, 3- and 5-year overall survival rates between patients adopting grafts with a GRWR < 0.8% and GRWR ≥ 0.8% in adult-to-adult LDLT.

## Methods

### *Literature search and study selection*

Clinical controlled studies comparing liver graft with the GRWR <0.8% and ≥0.8% in adult-to-adult LDLT were collected from PubMed, Web of Science, Embase, the Cochrane Library, MEDLINE and Google Scholar before September 2018. Three researchers (YY, ZDF and PJL) carried out the searching works independently with a combination of following terms: living donor liver transplantation, LDLT, graft-to-recipient weight ratio, GRWR, small-for-size graft, SFSG and liver transplantation. In accordance with the inclusion

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criteria and exclusion criteria, three researchers screened comprehensively for data extraction and manually retrieved current and past periodicals, posters, reviews, case reports and searching literature references.

*Inclusion and exclusion criteria*

The inclusion criteria were as follows: (1) published clinical cohort studies comparing recipients liver graft with a GRWR < 0.8% and ≥0.8% in adult LDLT; (2) randomized, semi-randomized and non-randomized controlled studies, including retrospective and prospective studies; (3) studies containing at least one outcome of interest mentioned before. The exclusion criteria were: (1) studies without a control group; (2) studies without available data of interest; (3) studies divided into groups according to different lobes or without the non-SFSG group; (4) the cut-off value of GRWR failing to meet requirements; (5) overlapped publication; (6) failing to get full-text; (7) the reviews, systematic analyses, editorials and case reports.

*Data extraction and outcomes*

The data extraction from included studies with standardized processes was also conducted by three researchers (YY, ZDF, PJL) independently. Extracted data include trials characteristics, such as first author, year of publication, country and center, number of subjects, recipient sex ratio (male/female), liver lobes, MELD score, etiologies, period of subject enrolled, portal inflow modulations and trial design. Nine perioperative outcomes (blood loss, operative duration, cold ischemia time, hospitalization time, acute rejection, biliary complications, postoperative bleeding, SFSS and perioperative mortality) and cumulative 1-, 3- and 5-year overall survival rates were main parameters extracted for assessing. Moreover, we adopted Newcastle-Ottawa Scale [10] to evaluate the quality of evidence in each trial and any discrepancies on data extraction or quality scoring were dispelled by discussion with specialists.

*Statistical analysis*

This meta-analysis was performed with RevMan 5.3.5 software according to the Cochrane handbook for systematic reviews of Interventions and PRISMA for systematic review protocols. *P* values <0.05 were considered statistically significant. Heterogeneity among studies was assessed with the Chi-square statistic and the $I^2$ statistic with $I^2 \geq 50\%$ as significant heterogeneity. If there was no significant statistical heterogeneity, a fixed-effect model was used. Otherwise, a random-effect model was adopted. Dichotomous variables were calculated by odds ratios (ORs) with 95% confidence interval (CI). Continuous variables were calculated by weighted mean difference (WMD) and 95% CI. If variables were reported in form of median and interquartile range (IQR), rather than mean and standard deviation (SD), we used the formulas recommended by Luo et al. and Wan et al. to estimate [11,12]. For some of the studies adopting median and range for parameters, estimated mean and SD were obtained with formulas proposed by Hozo et al. [13]. Moreover, the funnel plots were used to judge potential publication bias for included trials and we also planned to conduct sensitivity analysis and subgroup analysis to appraise the influence of certain factors on pooled estimate.

## Results

*Characteristics and quality of pooled studies*

A flowchart of literatures screening is shown in Fig. 1. A total of 824 relevant studies were retrieved initially by systematic searching according to the criteria described before. After removal of duplications and articles irrelevant to the topic, 40 articles were left for full review. Twenty-four articles were excluded owing to the following reasons: 4 articles were no controls, 8 lacked of available data of interest, 2 with ineligible grouping, 5 overlapping publications and 5 reviews, systematic analyses, editorials or case reports. For ethical restrictions, researchers cannot randomize patients in these trials. Finally, 16 qualified studies [6,8,14–27], 3272 subjects, with 3 prospective and 13 retrospective cohorts, were included into the meta-analysis. It is necessary to point out that the studies conducted by Moon et al. [14] and Lee et al. [15], or Lee et al. [16,17] are from the same center. The data of interest within these cohorts were extracted without overlap to avoid duplicate pooling. The characteristics of eligible studies are presented in Table 1. Studies quality assessment adopting a modified Newcastle-Ottawa Scale system is shown in Table 2, and all of the included studies got three or more stars.

*Perioperative outcomes*

A total of 9 perioperative outcomes (biliary complications, postoperative bleeding, SFSS, perioperative mortality, blood loss, operative duration, cold ischemia time, hospitalization time and acute rejection) were pooled into analysis. Interestingly, 12 of the 13 studies reported SFSG group was non-inferior to non-SFSG group. However, pooled results suggested that the incidence of SFSS was significantly higher in SFSG group than counterpart (OR=1.64, 95% CI: 1.16–2.33, $P=0.005$; Fig. 2). No significant heterogeneity was found in 13 studies ($P=0.49$, $I^2=0\%$), and a fixed-effect model was used to amalgamate the data. In addition to SFSS, three studies provided data for blood loss and hospitalization time; four studies reported postoperative bleeding; five studies presented the operative duration, cold ischemia time, acute rejection; eight studies demonstrated on biliary complications and eleven studies showed data for perioperative mortality. Each of parameters in pooled data showed no significant difference between two groups (Figs. 2 and 3). Moreover, there was no significant heterogeneity in parameters among the studies except operative duration ($P=0.07$, $I^2=53\%$); a random-effect model was adopted.

*Long-term outcomes*

The pooled analysis showed that the 1-year, 3-year overall survival rates were lower in the SFSG group compared with the non-SFSG group (OR=0.73, 95% CI: 0.54–0.97 and OR=0.76, 95% CI: 0.58–0.98, $P=0.03$ respectively; Fig. 4). The 5-year overall survival was not significantly different (OR=0.82, 95% CI: 0.57–1.16, $P=0.26$) (Fig. 4).

*Subgroup analysis*

The SFSS incidence in SFSG group was significantly higher in patients enrolled before 2010 (OR=3.00, 95% CI: 1.69–5.35, $P=0.0002$) (Table 3); there was no significant difference in patients enrolled after 2010 (OR=1.23, 95% CI: 0.79–1.90, $P=0.36$; *P* for interaction = 0.02). Although left lobe grafts were more frequently used in Japanese centers, the SFSS showed no significant differences between regions. Examination of portal inflow modulation was not feasible, because only part of patients has been conditionally conducted with modulation procedures, let alone the specific implementation used in each study. There were no significant differences in the trial design or definitions of SFSS.

*Publication bias and sensitivity analysis*

Funnel plots were used to evaluate potential publication bias in this meta-analysis. Large sample studies were more concentrated

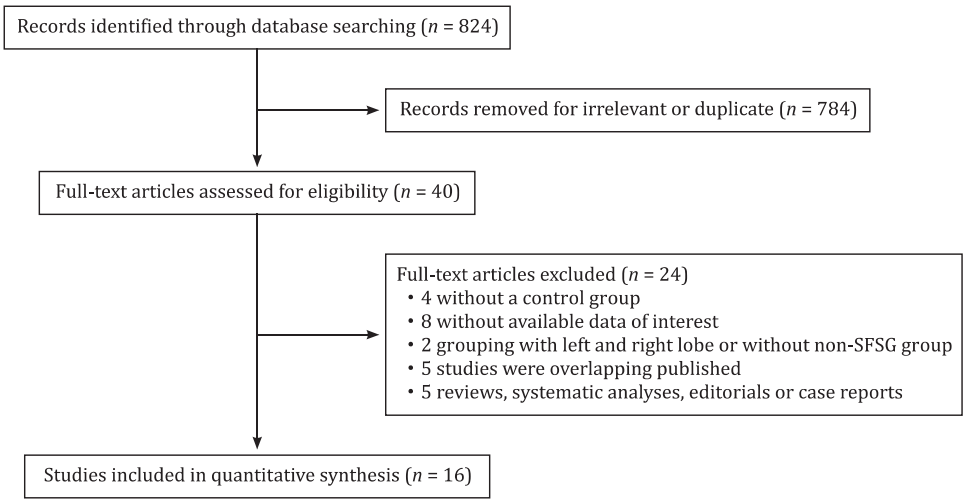


**Fig. 1.** Flow chart of literatures searched, included and excluded according to PRISMA.

**Table 1**
Characteristics of the included studies.

| Studies | Year | Country | Sample size (*n*) | | Sex (male/female) | | Liver lobe | MELD[a] | Etiology | Subjects enrolled | Trial design |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | SFSG | non-SFSG | SFSG | non-SFSG | | | | | |
| Klair et al. [6] | 2016 | United States | 41 | 95 | NA | NA | Mixed | 15.6 | Mixed | 2002.01-NA | Prospective cohort |
| Sethi et al. [8] | 2018 | India | 58 | 142 | 54/4 | 126/16 | Right | 23.9 | Mixed | 2014.01–2016.09 | Prospective cohort |
| Moon et al. [14] | 2010 | Korea | 35 | 392 | 35/0 | 304/88 | Right | 21.6 | Mixed | 1997.06–2008.04 | Retrospective cohort |
| Lee et al. [15] | 2004 | Korea | 11 | 68 | NA | NA | Mixed | NA | Mixed | 1997.06–2002.06 | Retrospective cohort |
| Lee et al. [16] | 2018 | Korea | 82 | 246 | 72/10 | 198/48 | Right | 12.1 | Mixed | 2005.01–2015.12 | Retrospective cohort |
| Lee et al. [17] | 2014 | Korea | 50 | 267 | 41/9 | 207/60 | Right | 16.3 | Mixed | 2005.01–2011.11 | Retrospective cohort |
| Kaido et al. [18] | 2011 | Japan | 52 | 146 | NA | NA | Left | NA | Mixed | 2006.04–2010.02 | Retrospective cohort |
| Selzner et al. [19] | 2009 | Canada | 22 | 249 | 13/9 | 157/92 | Right | 19.2 | Mixed | 2000.04–2008.09 | Prospective cohort |
| Chen et al. [20] | 2014 | China | 45 | 151 | 40/5 | 131/20 | Right | 16.4 | Mixed | 2001.11–2010.12 | Retrospective cohort |
| Hu et al. [21] | 2016 | China | 56 | 239 | 55/1 | 216/23 | Mixed | NA | HCC | 2007.01–2009.12 | Retrospective cohort |
| Vasavada et al. [22] | 2014 | India | 54 | 132 | 49/5 | 110/22 | Mixed | 13.5 | Mixed | 2010.01–2013.06 | Retrospective cohort |
| Matsuyama et al. [23] | 2017 | Japan | 23 | 59 | NA | NA | NA | NA | Mixed | 2003.08–2016.07 | Retrospective cohort |
| Gyoten et al. [24] | 2010 | Japan | 12 | 80 | NA | NA | NA | NA | Mixed | 2002.12–2009.08 | Retrospective cohort |
| Uemura et al. [25] | 2016 | Japan | 67 | 154 | 35/32 | 75/79 | Mixed | 18.0 | Mixed | 2008.03–2013.12 | Retrospective cohort |
| Lei et al. [26] | 2012 | China | 46 | 156 | 42/4 | 129/27 | Right | NA | Mixed | NA | Retrospective cohort |
| Ishizaki et al. [27] | 2012 | Japan | 17 | 25 | 6/11 | 9/16 | Left | NA | Mixed | 2003.09–2011.03 | Retrospective cohort |

[a] Mean MELD score in each trial. MELD: model for end-stage liver disease; HCC: hepatocellular carcinoma; NA: not available.

**Table 2**
Modified Newcastle-Ottawa Scale scoring for cohort studies.

| Studies | Selection | Comparability | Outcome assessment | Quality |
|---|---|---|---|---|
| Klair et al. [6] | 2 | 1 | 1 | 4 |
| Sethi et al. [8] | 2 | 2 | 2 | 6 |
| Moon et al. [14] | 2 | 1 | 2 | 5 |
| Lee et al. [15] | 2 | 0 | 1 | 3 |
| Lee et al. [16] | 2 | 2 | 2 | 6 |
| Lee et al. [17] | 2 | 1 | 2 | 5 |
| Kaido et al. [18] | 2 | 0 | 1 | 3 |
| Selzner et al. [19] | 2 | 2 | 2 | 6 |
| Chen et al. [20] | 2 | 2 | 2 | 6 |
| Hu et al. [21] | 1 | 2 | 2 | 5 |
| Vasavada et al. [22] | 2 | 2 | 2 | 6 |
| Matsuyama et al. [23] | 2 | 0 | 1 | 3 |
| Gyoten et al. [24] | 2 | 0 | 1 | 3 |
| Uemura et al. [25] | 2 | 1 | 2 | 5 |
| Lei et al. [26] | 2 | 1 | 2 | 5 |
| Ishizaki et al. [27] | 2 | 2 | 2 | 6 |

Selections: 1. subject definition described clearly (one star); 2. the subjects have obvious representativeness of the population (one star). Comparability: study shows no differences between SFSG group and non-SFSG group in adult LDLT with following main characteristics: recipient factors (age, MELD score, sex ratio, Child-Pugh score and etiology) and donor factors (mean age, sex ratio, graft type and BMI) (one star for partly reported or two stars). Outcome assessment: 1. studies clearly defined outcome of interest (one star); 2. adequate follow-up of cohorts, censoring less than 20%, was recorded (one star). MELD: model for end-stage liver disease; BMI: body mass index.

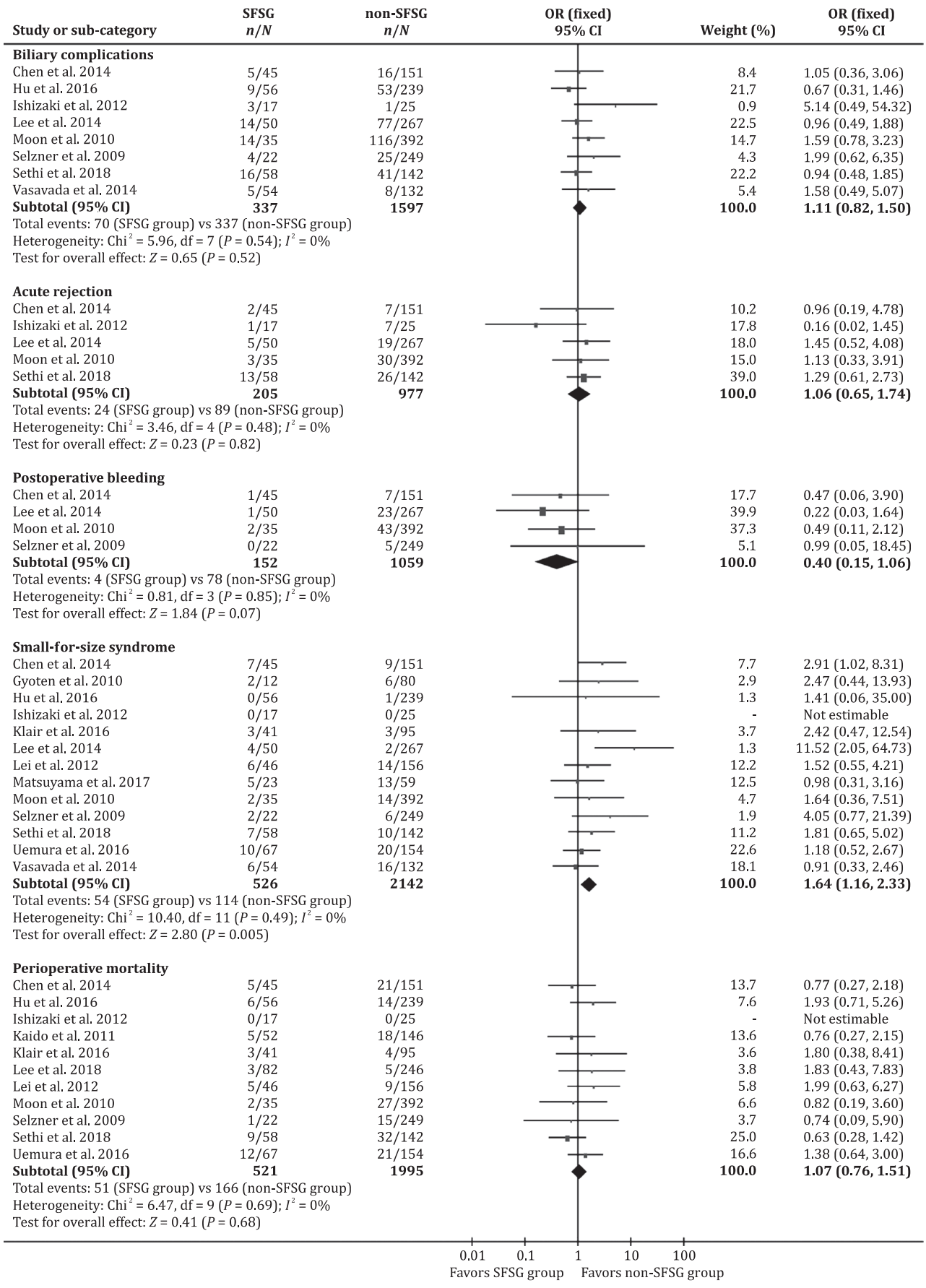


**Fig. 2.** Forest plot of included studies comparing SFSG group and non-SFSG group for the biliary complication, acute rejection, postoperative bleeding, SFSS and perioperative mortality based on a fixed-effect model. SFSG: small-for-size graft.

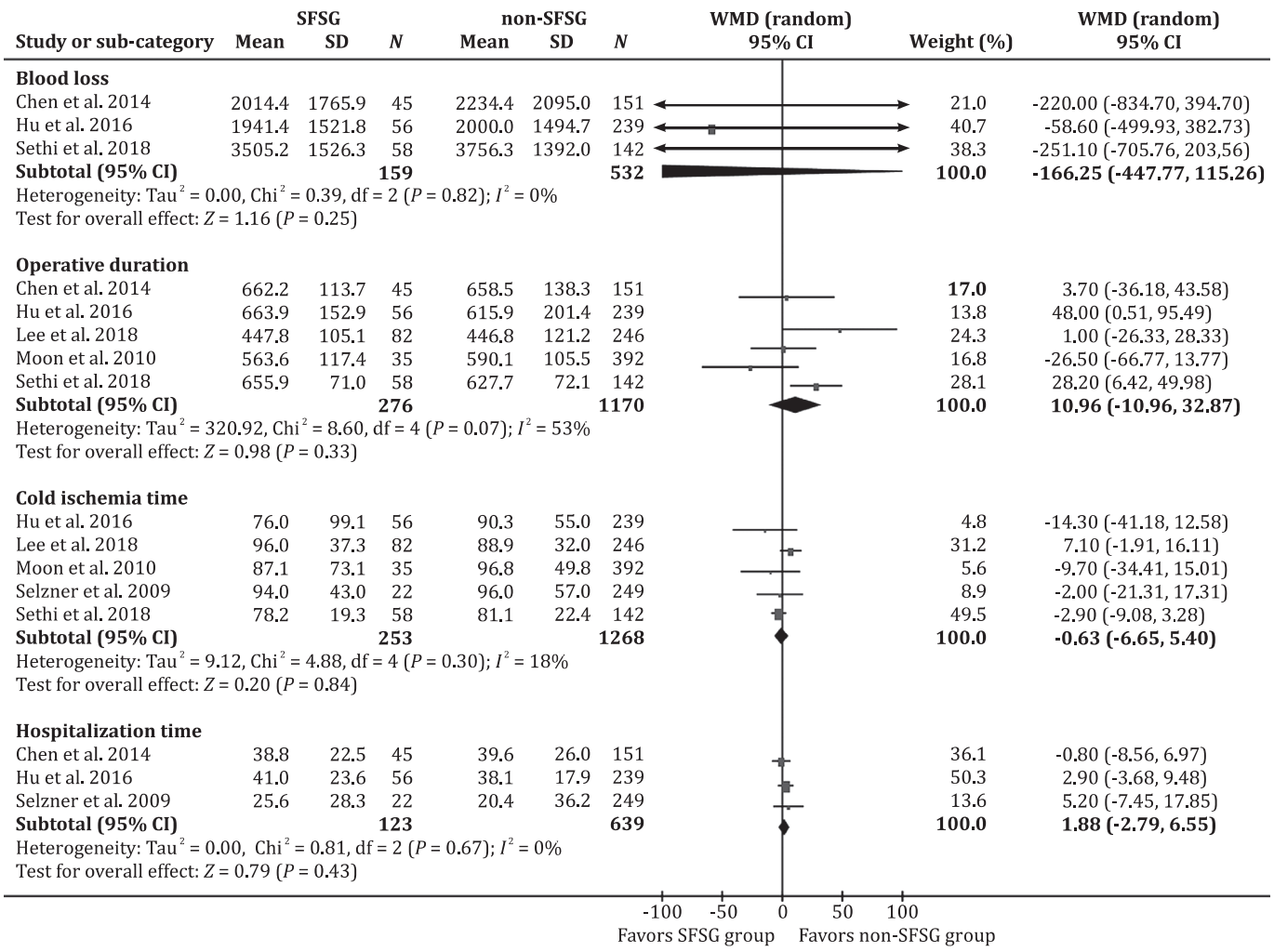


**Fig 3.** Forest plot of included studies comparing SFSG group and non-SFSG group for the blood loss, operative duration, cold ischemia time and hospitalization time based on a random-effect model. SFSG: small-for-size graft.

**Table 3**
Results of subgroup analysis for SFSS.

| Subgroups | Trials | Effect estimate | *P* value | Heterogeneity | *P*-interaction |
|---|---|---|---|---|---|
| Trial design | | | | | |
| Prospective | 3 | 2.20 (1.01–4.79) | 0.05 | $P=0.72$, $I^2=0\%$ | 0.41 |
| Retrospective | 10 | 1.53 (1.04–2.26) | **0.03** | $P=0.34$, $I^2=11\%$ | |
| Period of subjects enrollment | | | | | |
| Before 2010 | 8 | 3.00 (1.69–5.35) | **0.0002** | $P=0.76$, $I^2=0\%$ | **0.02** |
| After 2010 | 5 | 1.23 (0.79–1.90) | 0.36 | $P=0.87$, $I^2=0\%$ | |
| The regions | | | | | |
| Japanese | 4 | 1.21 (0.65–2.26) | 0.55 | $P=0.68$, $I^2=0\%$ | 0.36 |
| Western | 2 | 2.98 (0.90–9.90) | 0.07 | $P=0.66$, $I^2=0\%$ | |
| Others | 7 | 1.80 (1.15–2.82) | **0.01** | $P=0.30$, $I^2=17\%$ | |
| Definitions of SFSS[a] | | | | | |
| By Dahm | 5 | 1.74 (1.10–2.75) | **0.02** | $P=0.33$, $I^2=13\%$ | 0.73 |
| By Kyushu | 6 | 1.53 (0.89–2.63) | 0.13 | $P=0.32$, $I^2=14\%$ | |
| Total | 13 | 1.64 (1.16–2.33) | **0.005** | $P=0.49$, $I^2=0\%$ | |

[a] Only 11 studies contained the corresponding analyzing parameters.

in upper part of the plots, none of studies fell outside 95% CI limits and the shape was generally symmetrical as to blood loss, operative duration, cold ischemia time, hospitalization time, mortality and postoperative bleeding. However, the acute rejection and biliary complications may have the potential publication bias due to a small sample size study scattered at the bottom of the plots. Sensitivity analysis was conducted by omitting each single study and then recorded corresponding varies. There were no significant changes in comparing with primary overall findings except 1- and 3-year overall survival rates. We carefully scrutinized the studies, and found that the study conducted by Hu et al. [21] resulted in instability and involved all of the recipients undergoing LDLT for the cause of hepatocellular carcinoma (HCC). After excluding this article, there was no significant statistical difference in 1- and 3-year overall survival between the SFSG and non-SFSG groups (OR=0.80, 95% CI: 0.58–0.98, $P=0.16$ and OR=0.84, 95% CI: 0.63–1.11, $P=0.22$

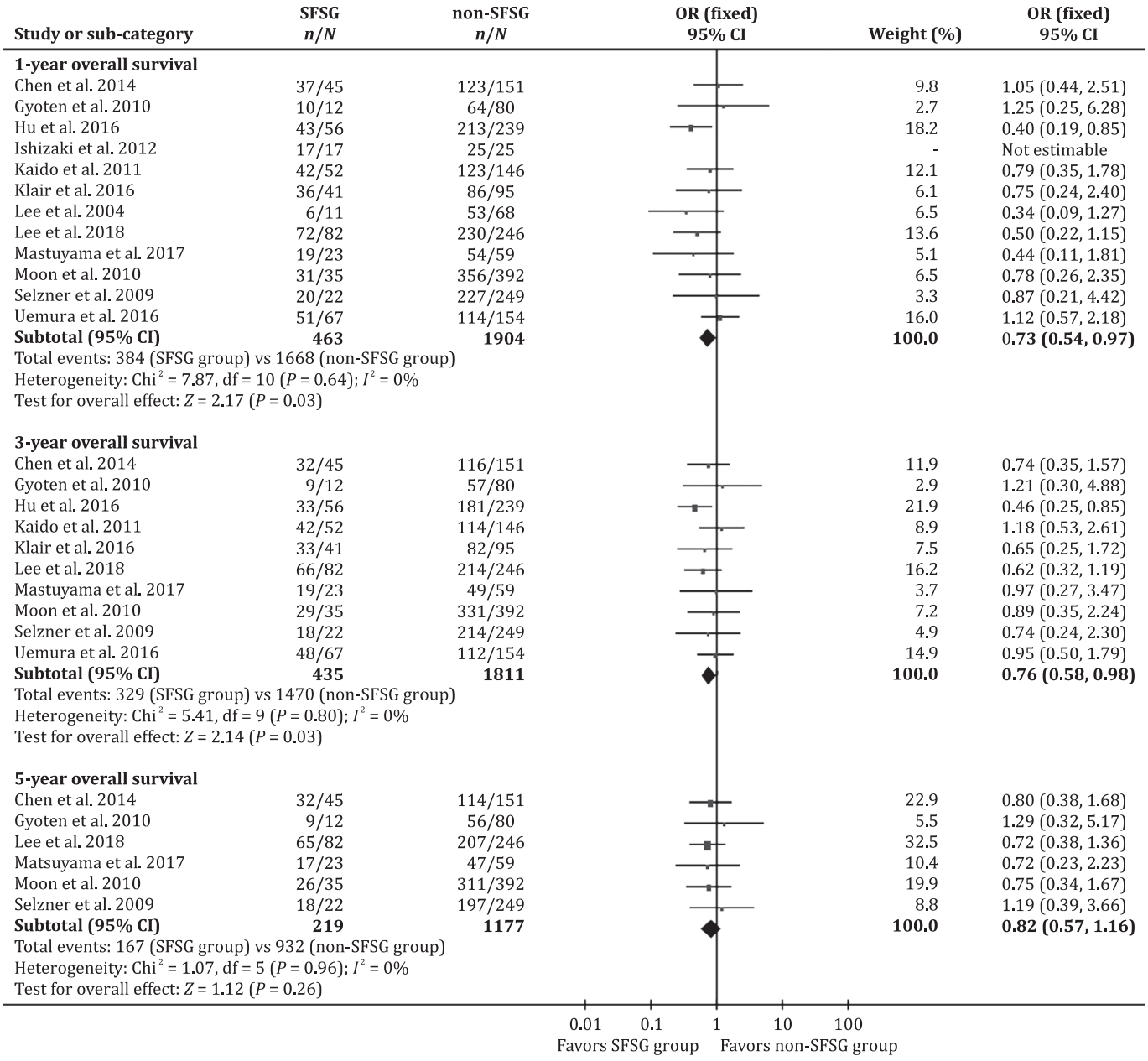


**Fig. 4.** Forest plot of included studies comparing SFSG group and non-SFSG group for the 1-, 3- and 5-year overall survival rates based on a fixed-effect. SFSG: small-for-size graft.

respectively) and no significant heterogeneity was found in pooling results ($P = 0.81$, $I^2 = 0\%$ and $P = 0.97$, $I^2 = 0\%$ respectively). Moreover, when every single study was excluded to investigate heterogeneity among them with regard to the operative duration ($P = 0.07$, $I^2 = 53\%$), the result was found to be robust and the heterogeneity did not shift obviously (31%–64%).

## Discussion

The present meta-analysis suggested that blood loss, cold ischemia time, operative duration, hospitalization time, biliary complications, postoperative bleeding, acute rejection, perioperative mortality and 1-, 3- and 5-year overall survival are similar in SFSG group compared to non-SFSG group. While SFSS occurs more frequently in SFSG group at preliminary pooling, nevertheless no significant difference has been found in subjects enrolled after period of 2010 by subgroup analysis.

The SFSS generally refers to a dysfunction or failure of the adopting grafts with a GRWR <0.8% and characterized by cholestasis, prolonged coagulopathy, ascites and encephalopathy. The possible mechanism of SFSS may include the size or function mismatch for recipients' need, vascular inflow hyperperfusion, obstruction of hepatic venous outflow, the portal vein systemic shunting and parenchyma cells dysfunction or other donor and recipient factors [3,28,29]. A study conducted by Cho et al. stated that the key factor in causing SFSS is the functional graft mass failing to meet the recipient needs [30]. Although a variety of causes could lead to a reduction in liver functional mass, portal hyperperfusion is the one that has been mentioned the most [28,29]. Attenuation of portal hyperperfusion is generally applied for treatment of SFSS because it has a significant damaging effect on SFSG. The portal stream directly flows through the neo-liver, and the SFSG turns to subject to hypertention, causing severe sinusoidal endothelial injury, hemorrhage,

edema as well as structural disruption, and the variations also could be observed early after grafts reperfusion [2,29,31,32]. The same morphological changes were also shown in the rats experiment, with sinusoidal lining endothelial gapping, mitochondrial swelling and vacuolar changes in hepatocytes. A further consequence is the ischemia-reperfusion injury, cholestasis, ischemic cholangitis, spatial collapse of Dissé and disruption of sinusoidal lining endothelial cells [33]. Moreover, hepatic artery flow even could be reduced to aggravate ischemic injury, cholestasis and ischemic cholangitis. It has been previously reported that low hepatic arterial blood flow was associated with the diversion through the effect known as "artery steal syndrome", but it is now thought to be a homeostatic mechanism named hepatic artery buffer response [34]. Compared with the hepatic artery, the autoregulation mechanism of portal vein fails to be functional robustly. Fluctuations in venous inflow induce interactions with arterial flow through a hepatic artery buffer response. This effect could exist even after LDLT and is prone to compensate for deleterious effects of reduced portal venous inflow. Dahm et al. stated that a beneficial effect of portal inflow reduction could attribute to the increase in arterial flow of the liver grafts [28].

Although SFSS should be multifactorial, the SFSG is the main reason for unsuitability to recipients in many centers. The issue of sufficient graft volume is still a matter of debate. Our findings in comparing SFSS incidence rate between SFSG group and non-SFSG group were inconsistent with those of a previous meta-analysis [35] whichdemonstrated that SFSS rate was more frequent in patients with GRWR $<$ 0.8% grafts. Patients adopting SFSG are not as well as their counterparts. However, the conclusion is based on limited studies with relative small size of subjects. The present analysis involved 3272 subjects in sixteen eligible cohorts. Our analysis showed that SFSG is not a deteriorate factor of patient survival in liver recipients after year 2010. This result was consistent with those of most other neoteric studies [9,19,27]. Possible reasons might be the improvement of surgeons' skills, comprehensive preoperative assessment, donor selection and efficacious inflow and outflow modulation. The portal inflow modulation strategies include portocaval shunts, splenectomy and splenic artery modulation, such as ligation or embolization [29,31,36]. In this analysis, 11 of the 16 articles reported the portal modulation, 7 of them adopted modulations for patients conditionally and 4 of them stated without modulations. Kaido et al. [18] or Uemura et al. [25] used splenectomy to decrease portal pressure below 15 mmHg. To alleviate graft congestion, Selzner et al. [19] did splenectomy for 2 of the 22 LDLT recipients with a GRWR $<$ 0.8% vs. 6 of 249 cases with a GBWR $\geq$ 0.8%, the Chen et al. [20] reported 3 in GRWR $<$ 0.8% group and 8 in GBWR $\geq$ 0.8% group who underwent concurrent splenectomy, and the splenectomy was base upon severity of hypersplenism rather than portal pressure. Vasavada et al. [22] modulated portal inflow via splenic artery ligation or splenectomy when the portal inflow was greater than 250 mL/min/100 g and hepatic arterial flow less than 100 mL/min. Gyoten et al. [24] used splenectomy and/or portacaval shunt to regulate portal inflow when portal pressure was above 20 mmHg after reperfusion. Ishizaki et al. [27] did splenic artery ligation in 2 cases in GRWR $<$ 0.8% group and 4 in $\geq$ 0.8% group. Although portal inflow $>$ 250 mL/min/100 g or portal pressure $>$ 20 mmHg are the indication of portal vein regulation, Ishizaki et al. reported that in 19 patients who had portal pressure greater than 20 mmHg, and in 21 patients who had portal flow greater than 250 mL/min/100 g, none of them had SFSS [27]. Portal pressure of less than 15–20 mm Hg and inflow rate below 250–260 mL/min/100 g have been recommended as the safe lines of SFSS for LDLT [4,29,36]. Clearly, there are still no consensuses methods and specific criteria to do portal inflow modulation and the pathogenesis of SFSS is still not clear. Many centers prefer to conduct more procedures to deal with graft hyperperfusion and congestion for the patients who use SFSG. Perioperative outcomes would be affected after modulation procedures performed. However, we could not find any difference in operative blood loss, cold ischemia time, hospitalization time, operative duration, biliary complication, acute rejection, perioperative mortality or postoperative bleeding between the two groups. There are two potential explanations. Firstly, inflow modulation techniques were at forefront aim to prevent SFSS. However, SFSS occurred not only in SFSG recipients but also in those transplanted with normal volume graft. As mentioned before, if the functional liver mass failed to meet the recipients' actual needs or portal hypertension had already established, the inflow modulation procedures still needed to be done. Secondly, we have not imposed strict restrictions on the etiologies of recipients or graft lobes; in most articles, the etiologies of recipients were mixed and more right lobes were adopted. Heterogeneity such as complex etiologies and various techniques might assimilate the final statistical results and could lead to a certain bias. Furthermore, for 1- and 3-year overall survival rates, although preliminary analysis suggested decreased survival in SFSG group, after excluding one study in which all recipients were diagnosed as HCC, the 1- and 3-year overall survival rates were comparable respectively. Mixed etiologies among studies might increase the heterogeneity and the overall survivals may be mainly affected by the primary diseases. We presumed that if one study only focused on HCC patients, the long-term outcomes would have been definitely different from those of others as to early recurrence and death.

Our meta-analysis has some limitations. The majority of the included studies were retrospective cohorts, there is no randomized controlled trial due to the ethics issue. The second limitation is that the manifestations of SFSS are neither specific nor inevitable and the pathogenesis is not clear. Diagnostic criteria were still not completely unified. The third limitation is the heterogeneity of transplantation techniques/skills and liver lobe.

In conclusion, we found no evidence of inferior outcomes with SFSG group vs. non-SFSG group, especially in recent practice. SFSG is still an option in liver transplantation. Further researches are still needed to clarify the factors affecting the function of SFSG and thereby define the optimal low limit of graft volume for LDLT.

## Contributors

YY and WZJ proposed the study and wrote the first draft. YY, ZDF and PJL searched the literatures, collected and analyzed the data. All authors contributed to the design and interpretation of the study and to further drafts. WZJ is the guarantor.

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## Ethical approval

Not needed.

## Competing interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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