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Review Article

Procedural outcomes of laparoscopic caudate lobe resection: A systematic review and meta-analysis

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A systematic review was conducted in compliance with PRISMA statement standards to identify all studies reporting outcomes of laparoscopic resection of benign or malignant lesions located in caudate lobe of liver. Pooled outcome data were calculated using random-effects models. A total of 196 patients from 12 studies were included. Mean operative time, volume of intraoperative blood loss, and length of hospital stay were 225 minutes (95% confidence interval [CI], 181–269 minutes), 134 mL (95% CI, 85–184 mL), and 7 days (95% CI, 5–9 days), respectively. The pooled risk of need for intraoperative transfusion was 2% (95% CI, 0%–5%). It was 3% (95% CI, 1%–6%) for conversion to open surgery, 6% (95% CI, 0%–19%) for need for intra-abdominal drain, 1% (95% CI, 0%–3%) for postoperative mortality, 2% (95% CI, 0%–4%) for biliary leakage, 2% (95% CI, 0%–4%) for intra-abdominal abscess, 1% (95% CI, 0%–4%) for biliary stenosis, 1% (95% CI, 0%–3%) for postoperative bleeding, 1% (95% CI, 0%–4%) for pancreatic fistula, 2% (95% CI, 1%–5%) for pulmonary complications, 1% (95% CI, 0%–4%) for paralytic ileus, and 1% (95% CI, 0%–4%) for need for reoperation. Although the available evidence is limited, the findings of the current study might be utilized for hypothesis synthesis in future studies. They can be used to inform surgeons and patients about estimated risks of perioperative complications until a higher level of evidence is available.

Key Words: Laparoscopy; Caudate lobe; Liver resection; Hepatectomy

INTRODUCTION

Despite a steep learning curve and technical challenges, laparoscopy for liver resections has been an alternative surgical approach for liver tumors in recent years. Studies have shown advantages of laparoscopic liver resections over the traditional open approach, including reduced postoperative morbidity, less blood loss, less need for blood transfusion, and shorter length of hospital stay [1,2]. This has been the case even for tumors in posterosuperior segments [3]. Nevertheless, its steep learning curve has frequently been seen as the hindrance to the widespread adoption of laparoscopic liver resection, with posterior segment resections being very technically challenging and requiring high level technical skills [4].

Laparoscopic resection of caudate lobe of liver is particularly difficult for several reasons. The caudate lobe, which consists of Spiegel's lobe, the paracaval portion, and the caudate process, is located in the posterior part of the liver in front of inferior vena cava and behind hepatic vessels and portal vein [5]. Moreover, multiple short hepatic veins with varying numbers and sizes drain the caudate lobe directly into the inferior vena cava [6]. All of these could make dissection challenging and potentially hazardous with respect to bleeding. Nevertheless, safety and feasibility of laparoscopic resection of caudate lobe have been reported by several individual studies, providing a

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basis for performing a systematic review. Therefore, the aim of this study was to evaluate procedural outcomes of laparoscopic caudate lobe resection by conducting a systematic review.

MATERIALS AND METHODS

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement standards were followed to prepare the study protocol, conduct the study and report a systematic review [7].

Eligibility criteria

All randomized controlled trials, cohort studies, case-control studies, and case series evaluating outcomes of laparoscopic resection of caudate lobe of liver were considered eligible. Adult patients who had malignant or benign lesions in the caudate lobe of liver were defined as population of interest. The intervention of interest included laparoscopic resection of caudate lobe of liver.

Types of outcome measures

Outcomes included need for intraoperative transfusion, conversion to open surgery, need for intra-abdominal drain, postoperative mortality, biliary leakage, intra-abdominal abscess, biliary stenosis, postoperative bleeding, pancreatic fistula, pulmonary complications, paralytic ileus, and need for reoperation.

Search methods

The search strategy provided in Appendix 1 was used by two independent authors to search Scopus, CENTRAL, EMBASE, CINAHL, and MEDLINE without applying any language limitations. Moreover, we screened references cited in relevant papers for more eligible studies. The last date for the search was September 1, 2021.

Study selection and data extraction

Two independent authors screened the title and abstract of each article obtained. We obtained full-texts of potentially eligible articles and included studies that met the eligibility criteria. A data extraction sheet was then created using a pilot-testing technique. We extracted information on bibliographic data, design of each study, sample size of each study, included population description, tumor size, intraoperative blood loss, length of hospital stay, operative time, need for intraoperative transfusion, need for intra-abdominal, conversion to open surgery, drain, biliary leakage, intra-abdominal abscess, biliary stenosis, postoperative bleeding, pancreatic fistula, pulmonary complications, paralytic ileus, postoperative mortality, and need for reoperation. A third independent author was consulted when there was a disagreement between the first two authors.

Risk of bias assessment

We used the JBI (Joanna Briggs Institute) Critical Appraisal tool for case-series for assessing the risk of bias [8]. The JBI tool

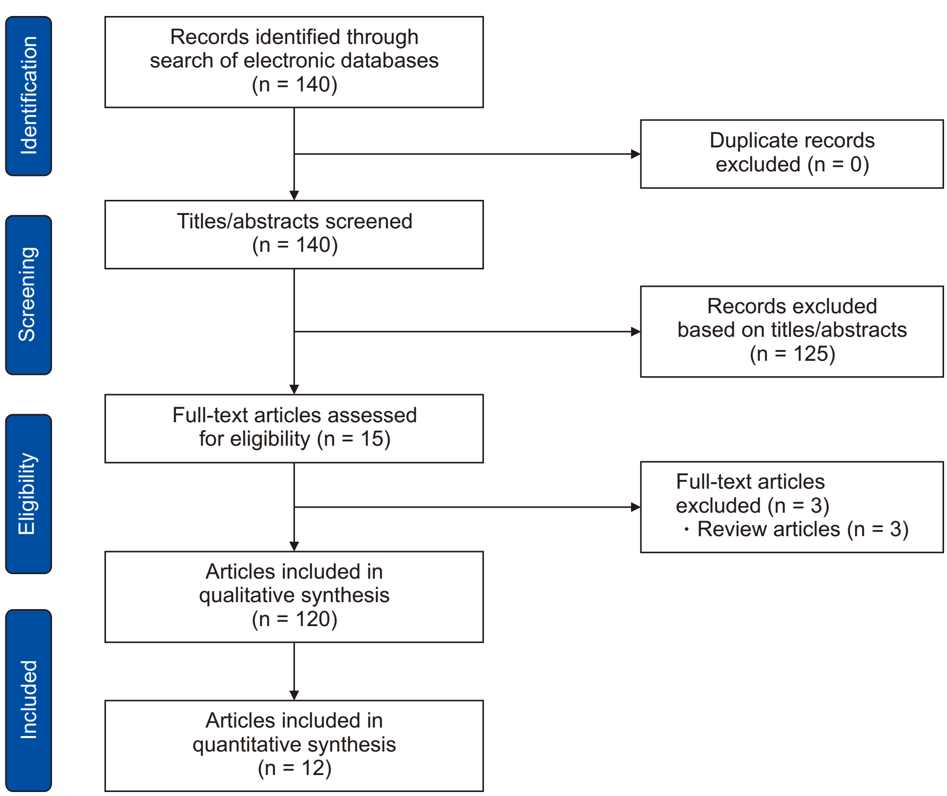

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart.

takes into account eligibility criteria used in each study, methods used for measurement of condition of interest, detail of recruitment process, baseline characteristics, outcome measures, and statistical models used in each study. Risk of bias assessment was conducted by two independent reviewers. An independent author was consulted in case of any disagreements.

Data analysis

To construct a proportion meta-analysis model, we integrated quantitative risks of need for intraoperative transfusion, conversion to open surgery, need for intra-abdominal drain, postoperative mortality, biliary leakage, intra-abdominal abscess, biliary stenosis, postoperative bleeding, pancreatic fistula, pulmonary complications, paralytic ileus, and need for reoperation from individual studies. MetaXL plug-in for Microsoft Excel was used to calculate overall effect according to methods suggested by Petrie et al. [9] Weighted summary proportions were calculated using the Freeman-Tukey double arcsine transformation. Random effects modelling was applied for analyses. We evaluated statistical heterogeneity by calculating I^2 using Cochran Q test (χ^2) (low heterogeneity = I^2 0%–25%; moderate heterogeneity = I^2 25%–75%; high heterogeneity = I^2 75%–100%). Symmetry of Doi plot and LFK index were used to assess publication bias.

Additional analyses

Sensitivity analyses were conducted to evaluate the robustness of primary analyses. Influence of fixed and random effects modelling on pooled risk of each outcome was assessed. Moreover, the influence of each study on pooled risk of each outcome was evaluated by repeating analyses after eliminating one study at a time.

RESULTS

Search results

Using the search strategy described above, 140 articles were identified. We excluded 125 articles directly because they did not match the subject of this review. Full texts of the remaining 15 articles were evaluated, which resulted in exclusion of another three articles which were review articles. Consequently, 12 articles [6,10-20] consisting of four retrospective cohort studies [17-20] and eight case-series [6,10-16] including 196 patients were considered eligible for inclusion. The study flow chart is shown in Fig. 1. Three studies [6,10,11,15] included only patients with malignant liver lesions and nine studies [11-14,16-20] included patients with malignant or benign lesions. The mean tumor size was 3.8 cm (95% confidence interval [CI]: 2.9–4.8 cm). Mean operative time, volume of intraoperative blood loss, and length of hospital stay were 225 minutes (95%

Table 1. Baseline characteristics of included studies

Study	Country	Journal	Design	Included patient	Sample size
Chen et al. 2013 [10]	Taiwan	J Gastrointest Surg	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant caudate lobe tumor	8
Oh et al. 2016 [6]	Korea	J Laparoendosc Adv Surg Tech A	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant caudate lobe tumor	6
Salloum et al. 2016 [11]	France	J Am Coll Surg	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	5
Araki et al. 2016 [12]	France	Surg Endosc	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	15
Chai et al. 2018 [13]	China	J Laparoendosc Adv Surg Tech A	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	6
Jin et al. 2018 [14]	China	Biomed Res Int	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	12
Hayami et al. 2019 [15]	Japan	Asian J Endosc Surg	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant caudate lobe tumor	6
Cappelle et al. 2020 [16]	Belgium	Langenbecks Arch Surg	Case series	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	32
Ding et al. 2020 [17]	China	Langenbecks Arch Surg	Retrospective cohort	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	10
Xu et al. 2021 [18]	China	Surg Endosc	Retrospective cohort	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	18
Peng et al. 2021 [19]	China	ANZ J Surg	Retrospective cohort	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	31
Ruzzenente et al. 2022 [20]	Italy	Surg Endosc	Retrospective cohort	Patients undergoing laparoscopic caudate lobe resection for malignant or benign caudate lobe tumor	47

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CI: 181–269 minutes), 134 mL (95% CI: 85–184 mL), and 7 days (95% CI: 5–9 days). The baseline characteristics of the included studies and included population are provided in Table 1 and Table 2, respectively.

Risk of bias in included studies

Results of risk of bias assessment using the JBI assessment tool are presented in Fig. 2.

Outcome synthesis

Need for intraoperative transfusion: Evaluation of 196 patients from 12 studies showed a pooled intraoperative blood transfusion rate of 2% (95% CI: 0%–5%) with a low statistical heterogeneity ($I^2 = 0\%$, $p = 0.85$). The probability of publication bias was deemed to be low (LFK index: 1.81; minor asymmetry) (Fig. 3A).

Conversion to open surgery: Evaluation of 196 patients from 12 studies showed a pooled conversion to open surgery rate of 3% (95% CI: 1%–6%) with a low statistical heterogeneity ($I^2 = 0\%$, $p = 0.98$). The probability of publication bias was deemed to be low (LFK index: –1.00; minor asymmetry) (Fig. 3B).

Need for intra-abdominal drain: Evaluation of 196 patients from 12 studies showed a pooled intra-abdominal drain use rate of 6% (95% CI: 0%–19%) with a high statistical heterogeneity ($I^2 = 90\%$, $p < 0.001$). The probability of publication bias was deemed to be low (LFK index: 0.00; no asymmetry) (Fig. 3C).

Postoperative mortality: Evaluation of 196 patients from 12 studies showed a pooled postoperative mortality rate of 1% (95% CI: 0%–3%) with a low statistical heterogeneity ($I^2 = 0\%$, $p > 0.99$). The probability of publication bias was deemed to be high (LFK index: 5.19; major asymmetry) (Fig. 3D).

Biliary leakage: Evaluation of 196 patients from 12 studies showed a pooled biliary leakage rate of 2% (95% CI: 0%–4%) with a low statistical heterogeneity ($I^2 = 0\%$, $p = 0.98$). The probability of publication bias was deemed to be low (LFK index: 1.66; minor asymmetry) (Fig. 3E).

Intra-abdominal abscess: Evaluation of 196 patients from 12 studies showed a pooled intra-abdominal abscess rate of 2% (95% CI: 0%–4%) with a low statistical heterogeneity ($I^2 = 0\%$, $p > 0.99$). The probability of publication bias was deemed to be high (LFK index: 2.08; major asymmetry) (Fig. 3F).

Biliary stenosis: Evaluation of 196 patients from 12 studies showed a pooled biliary stenosis rate of 1% (95% CI: 0%–4%) with a low statistical heterogeneity ($I^2 = 0\%$, $p = 0.98$). The probability of publication bias was deemed to be high (LFK index: 3.63; major asymmetry) (Fig. 3G).

Postoperative bleeding: Evaluation of 196 patients from 12 studies showed a pooled postoperative bleeding rate of 1% (95% CI: 0%–3%) with a low statistical heterogeneity ($I^2 = 0\%$, $p > 0.99$). The risk of publication bias was high (LFK index: 5.19; major asymmetry) (Fig. 3H).

Pancreatic fistula: Evaluation of 196 patients from 12 studies showed a pooled pancreatic fistula rate of 1% (95% CI: 0%–4%)

Table 2. Baseline characteristics of included population

Study	Age (yr)*	Male sex	Tumour origin				Part of caudate lobe resected			Operative time (min)*	Blood loss (mL)*	Length of stay (day)*
			Hepatocellular carcinoma	Cholangiocarcinoma	Metastasis	Benign	Caudate process	Paracaval portion	Spiegel lobe			
Chen et al. 2013 [10]	55	6 out of 8	4 out of 8	0 out of 8	4 out of 8	0 out of 8	6 out of 8	7 out of 8	6 out of 8	254	202	7
Oh et al. 2016 [6]	58	4 out of 6	4 out of 6	1 out of 6	1 out of 6	0 out of 6	5 out of 6	6 out of 6	6 out of 6	382	243	8
Salloum et al. 2016 [11]	66	3 out of 5	4 out of 5	0 out of 5	0 out of 5	1 out of 5	2 out of 5	1 out of 5	3 out of 5	249	280	6
Araki et al. 2016 [12]	64	7 out of 15	1 out of 15	0 out of 15	12 out of 15	2 out of 15	15 out of 15	15 out of 15	15 out of 15	150	75	8
Chai et al. 2018 [13]	50	4 out of 6	4 out of 6	0 out of 6	0 out of 6	2 out of 6	0 out of 6	3 out of 6	6 out of 6	249	260	7
Jin et al. 2018 [14]	48	5 out of 12	7 out of 12	0 out of 12	0 out of 12	5 out of 12	12 out of 12	12 out of 12	12 out of 12	141	98	9
Hayami et al. 2019 [15]	67	6 out of 6	5 out of 6	0 out of 6	1 out of 6	0 out of 6	0 out of 6	0 out of 6	6 out of 6	207	35	8
Cappelle et al. 2020 [16]	61	20 out of 32	0 out of 32	1 out of 32	26 out of 32	5 out of 32	9 out of 32	15 out of 32	20 out of 32	155	100	3
Ding et al. 2020 [17]	48	5 out of 10	5 out of 10	0 out of 10	0 out of 10	5 out of 10	10 out of 10	10 out of 10	10 out of 10	217	50	15
Xu et al. 2021 [18]	47	8 out of 19	7 out of 19	0 out of 19	1 out of 19	11 out of 19	5 out of 19	5 out of 19	16 out of 19	187	75	6
Peng et al. 2021 [19]	50	16 out of 31	10 out of 31	0 out of 31	4 out of 31	17 out of 31	5 out of 31	6 out of 31	7 out of 31	210	100	5
Ruzzenente et al. 2022 [20]	61	24 out of 47	17 out of 47	0 out of 47	16 out of 47	13 out of 47	0 out of 47	15 out of 47	45 out of 47	309	175	5

*Average value (mean or median).

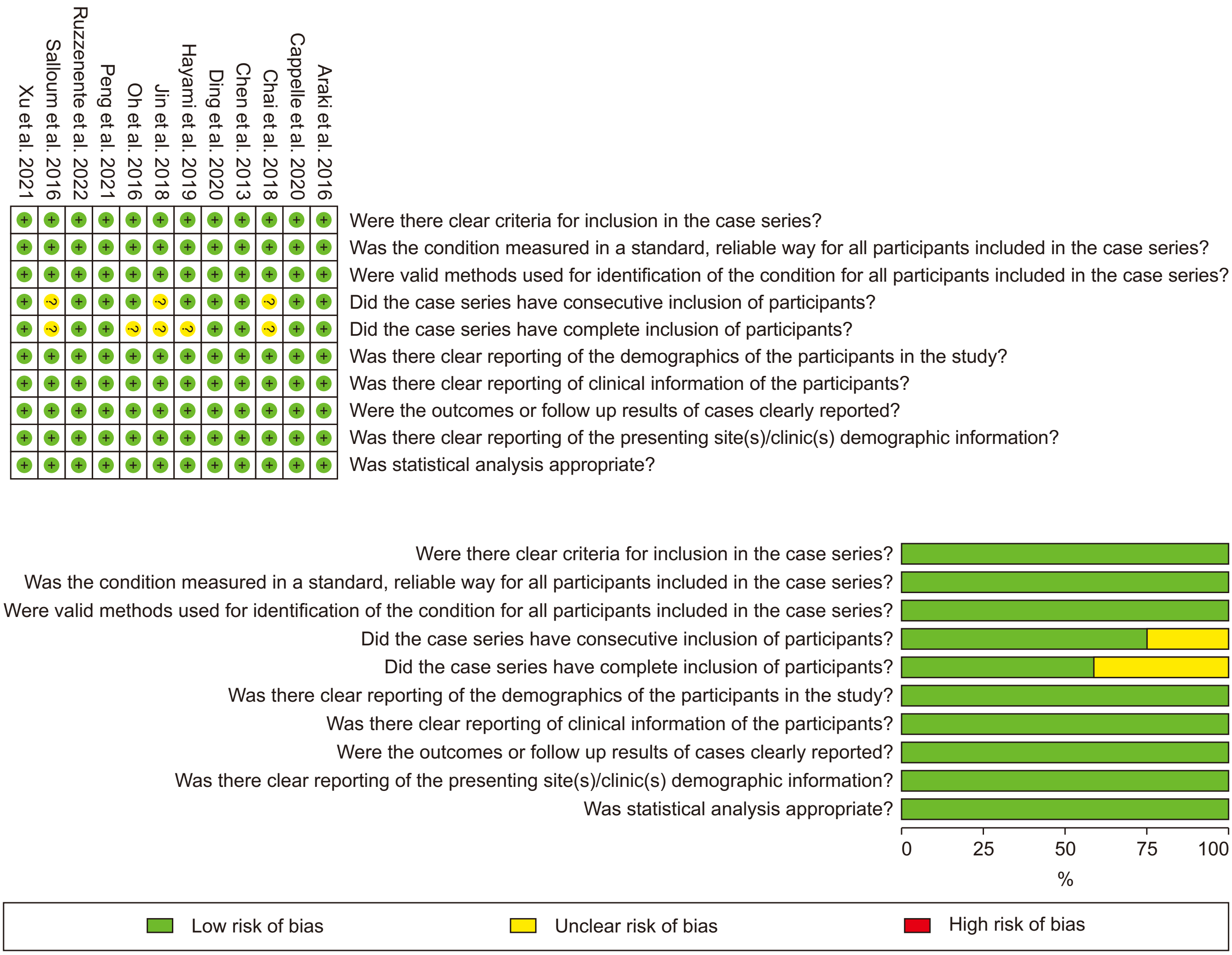

Fig. 2. Outcomes of methodological quality assessment of included studies using the Joanna Briggs Institute (JBI) Critical Appraisal tool for case-series.

with a low statistical heterogeneity (I^2 = 0%, p = 0.98). The risk of publication bias was high (LFK index: 3.63; major asymmetry) (Fig. 3I).

Pulmonary complications: Evaluation of 196 patients from 12 studies showed a pooled pulmonary complications rate of 2% (95% CI: 1%–5%) with a low statistical heterogeneity (I^2 = 0%, p = 0.92). The probability of publication bias was deemed to be low (LFK index: 1.48; minor asymmetry) (Fig. 3J).

Paralytic ileus: Evaluation of 196 patients from 12 studies showed a pooled paralytic ileus rate of 1% (95% CI: 0%–4%) with a low statistical heterogeneity (I^2 = 0%, p = 0.98). The probability of publication bias was deemed to be high (LFK index: 3.63; major asymmetry) (Fig. 3K).

Need for reoperation: Evaluation of 196 patients from 12 studies showed a pooled need for reoperation rate of 1% (95% CI: 0%–4%) with a low statistical heterogeneity (I^2 = 0%, p = 0.98). The probability of publication bias was deemed to be high (LFK index: 3.63; major asymmetry) (Fig. 3L).

Sensitivity analyses

Application of fixed effect and random effects modelling did not affect overall results. Moreover, eliminating one study at a time did not affect overall results for any outcomes except for the need for intra-abdominal drain where removal of Ruzzenente et al. [20] 2022 significantly reduced the heterogeneity.

DISCUSSION

We conducted a systematic review to provide evidence for procedural outcomes of laparoscopic caudate lobe resection. Evaluation of 196 patients from 12 case series showed that laparoscopic approach was safe, feasible, and promising for resecting lesions located in the caudate lobe of liver as indicated by a low rate of perioperative complications and a short length

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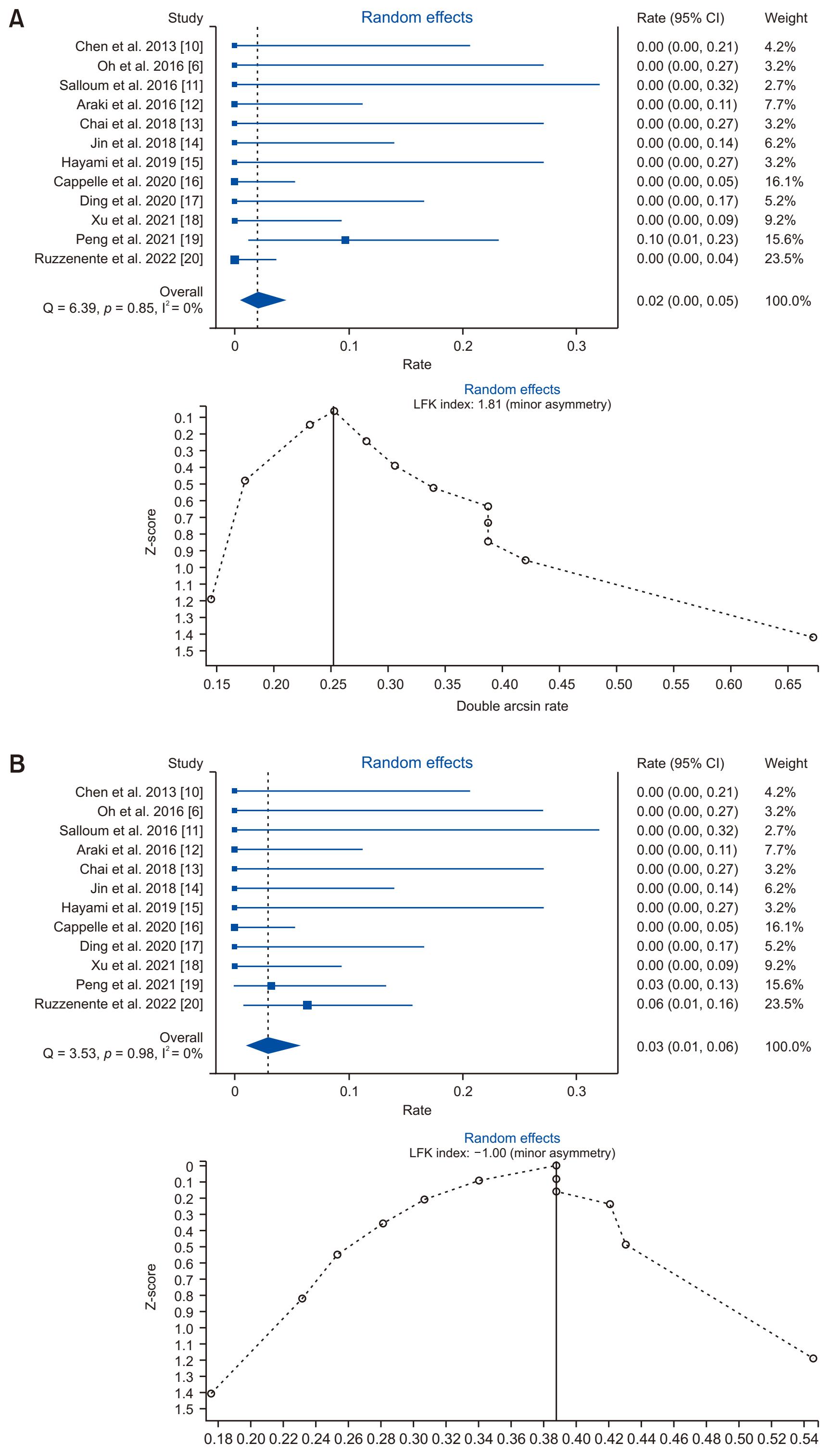

Fig. 3. Forest plots and Doi plots for: (A) need for intraoperative transfusion; (B) conversion to open surgery; (C) need for intra-abdominal drain; (D) postoperative mortality; (E) biliary leakage; (F) intra-abdominal abscess; (G) biliary stenosis; (H) postoperative bleeding; (I) pancreatic fistula; (J) pulmonary complications; (K) paralytic ileus; and (L) need for reoperation.

of hospital stay. The statistical heterogeneity was deemed to be low for most outcomes. Sensitivity analyses supported consistency of findings.

The current study provides the best available and the most recent evidence on outcomes of laparoscopic resection of caudate lobe. It quantifies risks of postoperative complications. Although four of the included studies compared laparoscopic approach with the open approach, we decided against syn-

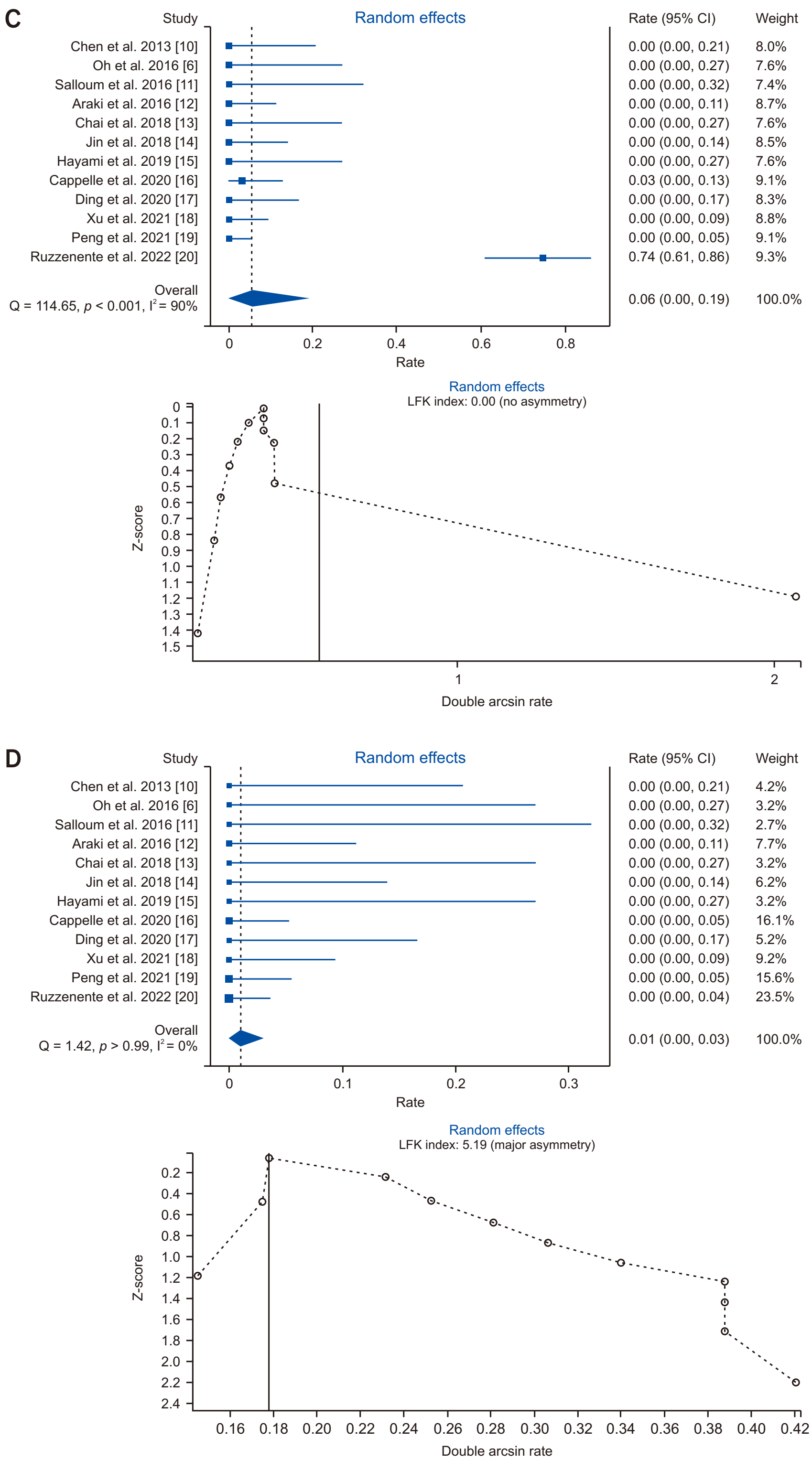

Fig. 3. Continued 1.

thesising comparative evidence due to a significant risk of selection bias, confounding by indication and the small sample size of included studies. Nevertheless, Ding et al. [21] have compared safety and feasibility of laparoscopic versus open caudate lobe resection in a meta-analysis of seven comparative studies and concluded that laparoscopic approach is associated with less intraoperative blood loss and shorter length of hospital stay. Most data in the study by Ding et al. [21] were from

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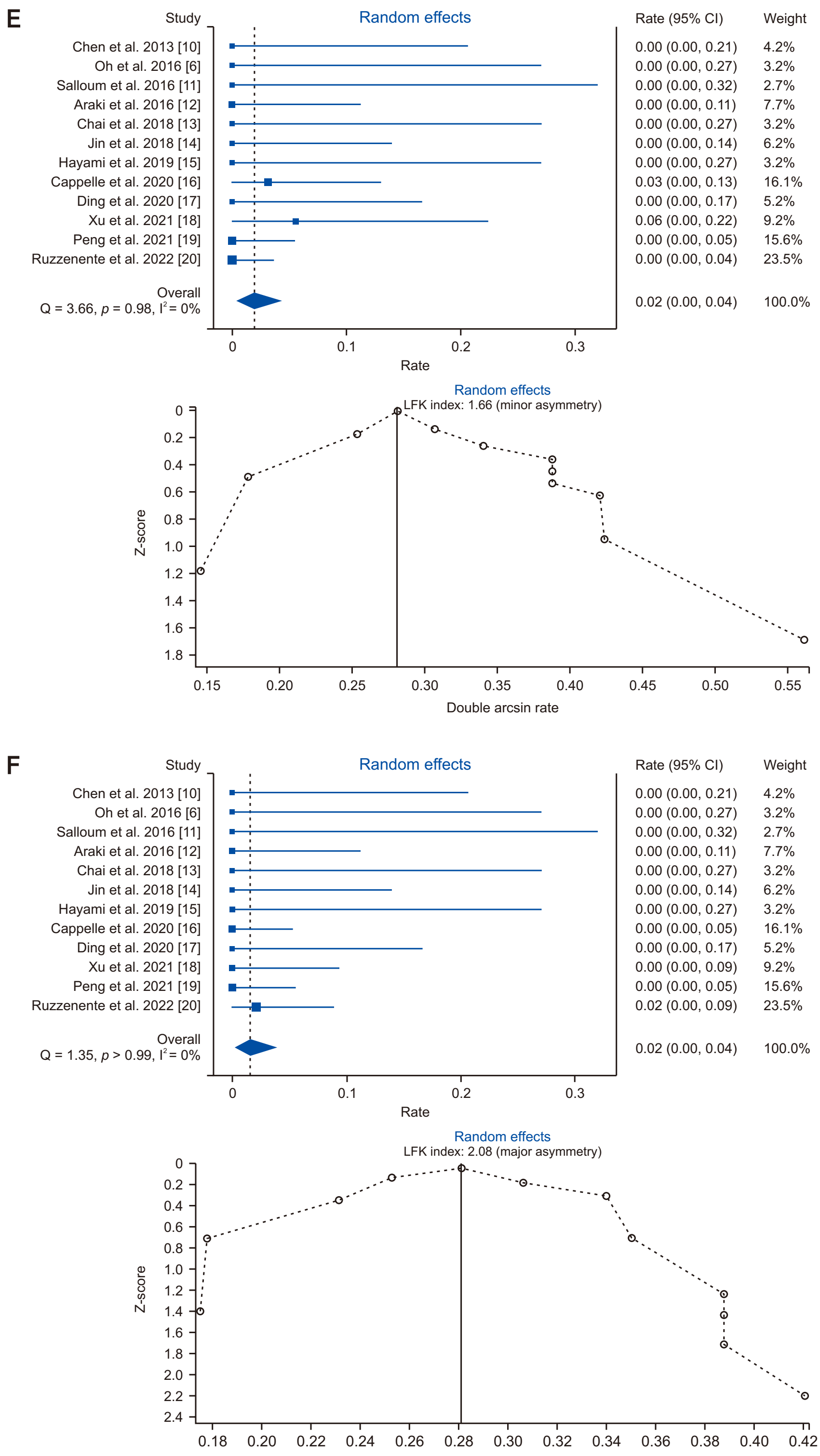

Fig. 3. Continued 2.

unpublished dissertations. Their results were subjected to several limitations as acknowledged by the authors. Taking these evident limitations into account, results of current study are consistent with findings of the study by Ding et al. [21].

We have previously demonstrated that laparoscopic resection of posterosuperior liver segments is associated with a lower risk of postoperative morbidity, less intraoperative blood loss, and shorter length of hospital stay than open approach [3].

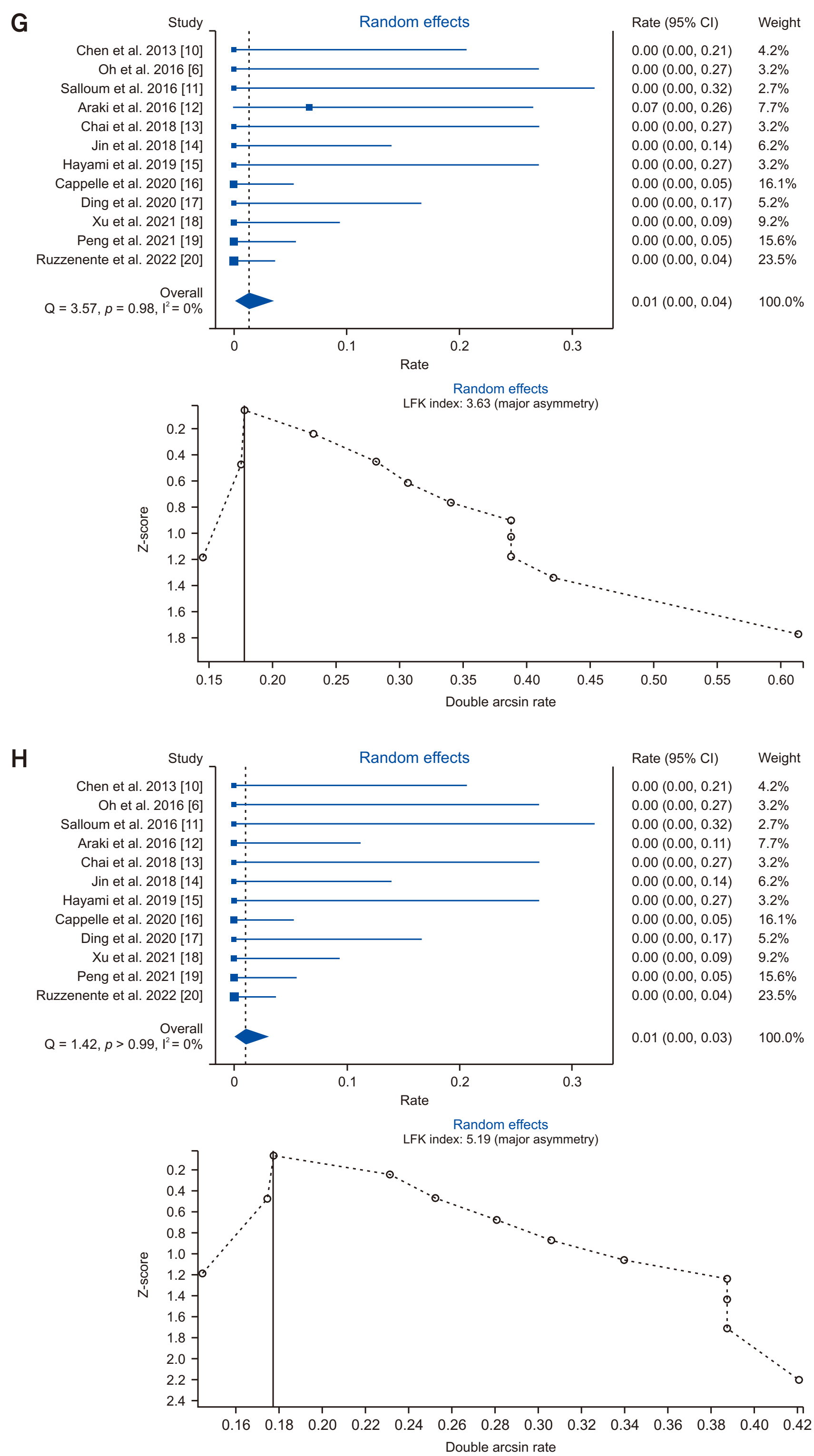

Fig. 3. Continued 3.

Reported outcomes of the laparoscopic arm in our previous meta-analysis were consistent with results of current study in terms of operative time, intraoperative blood loss, length of hospital stay, need for intraoperative transfusion, postoperative mortality, biliary leakage, intra-abdominal abscess, and pulmonary complications [3]. All of these results suggest that laparoscopic resection of caudate lobe might be safe and feasible.

As mentioned earlier, laparoscopic resection of caudate lobe

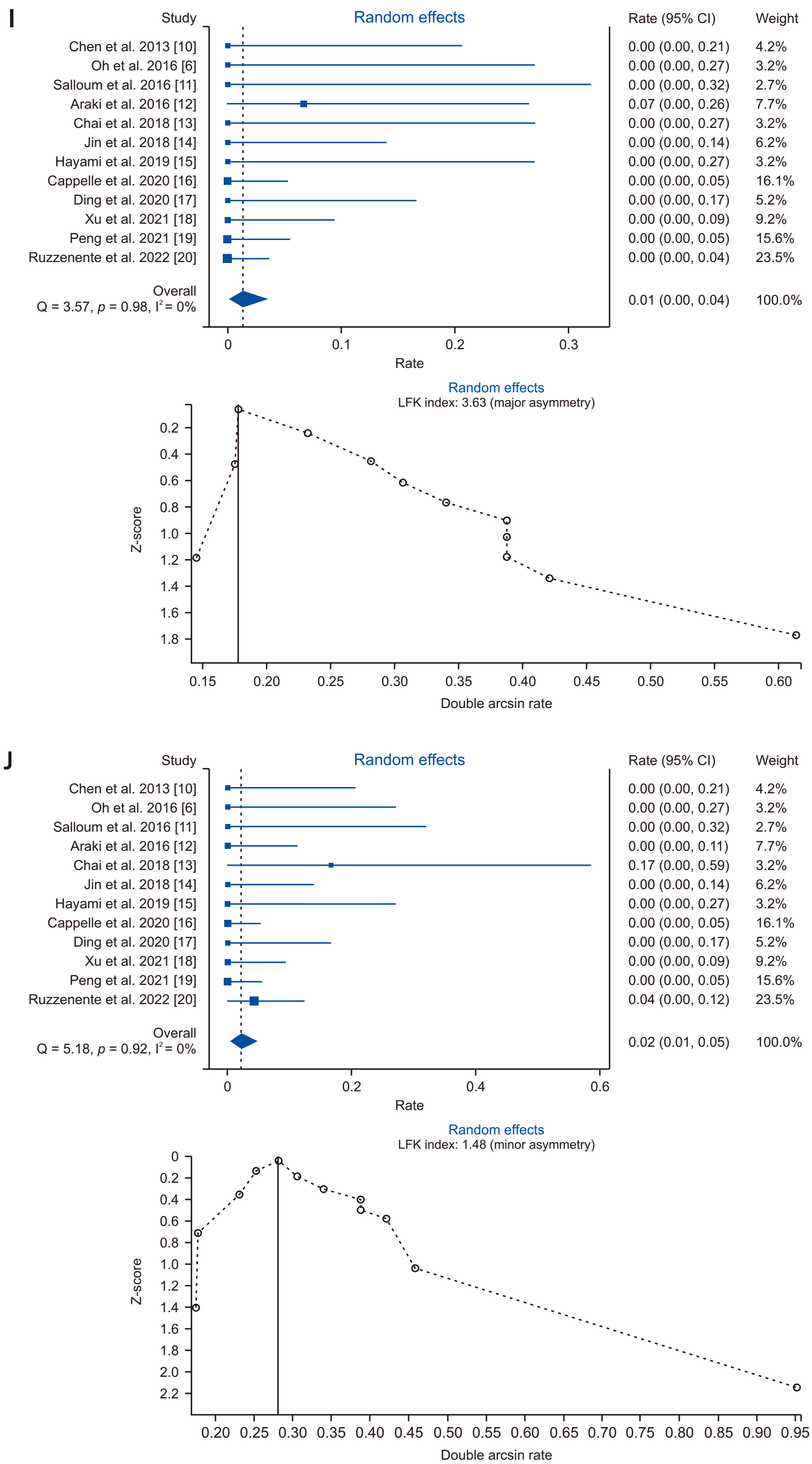

Fig. 3. Continued 4.

of liver is particularly challenging and potentially hazardous with respect to bleeding due to its close relation with inferior vena cava, hepatic vessels, portal vein, and multiple short hepatic veins draining the caudate lobe directly into the inferior vena cava [5,6]. Nevertheless, findings of current study suggest that laparoscopic resection of caudate lobe is associated with a very low risk of blood loss and intraoperative blood transfusion requirement.

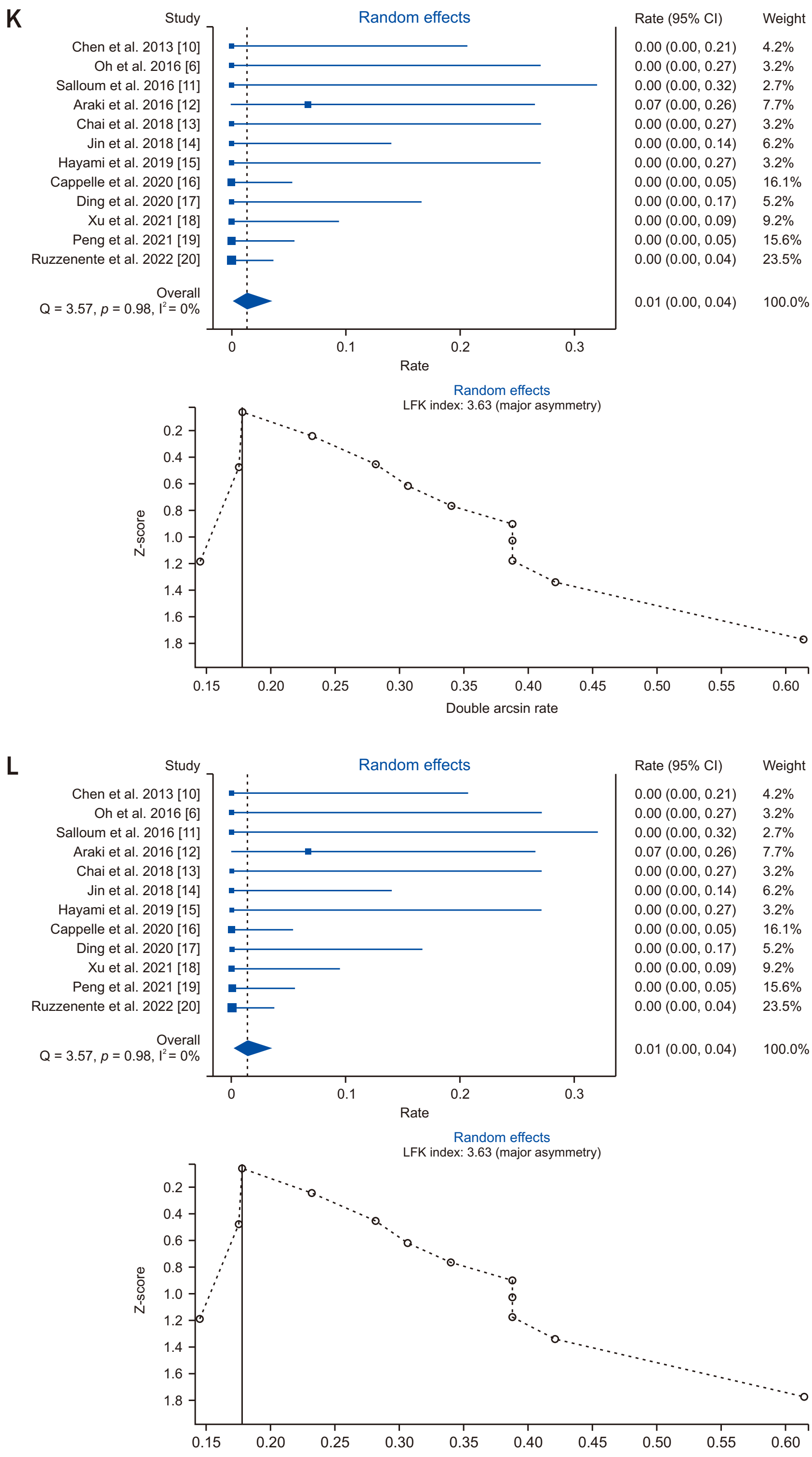

Fig. 3. Continued 5.

The low risk of bleeding associated with laparoscopic resection of caudate lobe found in the current study might be justified by several explanations. The caudal view achieved during laparoscopic approach might have facilitated precise dissection of the liver parenchyma along the inferior vena cava [18]. In fact, laparoscopic approach provides an excellent view and access to veins of caudate lobe originating from portal vein or inferior vena cava behind the liver which is normally difficult to achieve during an open approach [18]. Moreover, the balance between the central venous pressure and carbon dioxide pneumoperitoneum might help reduce venous bleeding [18]. We know from available evidence that large tumors can increase the risk of bleeding during laparoscopic liver resection [18]. The average tumor size in this study was 3.8 cm, which might have contributed to low risk of intraoperative bleeding in this study.

We are indeed mindful about the level of evidence which is currently available regarding outcomes of laparoscopic resection of caudate lobe. The current evidence, which is mainly derived from a limited number of case-series with small sample sizes, does not provide a robust basis for definite conclusions. However, findings of the current study might be utilized for hypothesis synthesis in future studies. They can be used to inform surgeons and patients about estimated risks of perioperative complications associated with laparoscopic resection of caudate lobe until a higher level of evidence is available.

This study has several limitations. As mentioned above, all included studies had a retrospective design with small sample sizes, subjecting our results to selection bias, confounding by indication, and possible type 2 error. Although the level of statistical heterogeneity was low, the level of clinical heterogeneity was significant among included studies. There was heterogeneity in terms of origin of tumor among included studies. In some studies, metastatic lesions were more common. However, in other studies, primary liver tumors were more common pathology. On the other hand, the part of caudate lobe resected was not homogeneous among studies, ranging from total caudate lobe resection to resection of Spiegel's lobe only. The clinical heterogeneity seen in above variables, together with variability in terms of surgical techniques used, would subject available evidence to potential risk of bias and low certainty. Future prospective studies with adequate statistical power and randomized control trials are needed to address aforementioned limitations.

CONCLUSIONS

Laparoscopic approach might be feasible, safe, and promising for resecting lesions in caudate lobe of liver. The available evidence is limited to data from case series with conspicuous clinical heterogeneity in terms of included population and operative techniques used. Findings of the current study might be utilized for hypothesis synthesis in future studies. They can also be used to inform surgeons and patients about estimated risks of perioperative complications until a higher level of evidence is available.

FUNDING

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Conceptualization: Shahab H, TS. Data curation: AK, LE, AN, Shahin H. Methodology: Shahab H, Shahin H. Visualization: Shahab H, Shahin H, TS. Writing - original draft: AK, LE, Shahin H. Writing - review & editing: All authors.

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Appendix 1. Search strategy[a)]

#1	laparoscopic: TI,AB,KW
#2	MeSH descriptor: [laparoscopic surgery] explode all trees
#3	#1 OR #2
#4	caudate near 2 lobe: TI,AB,KW
#5	caudate: TI,AB,KW
#6	#4 OR #5
#7	#3 AND #6

[a)]This search strategy was adopted for following databases: CINAHL, EMBASE, MEDLINE, CENTRAL, and Scopus.