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Review Article

Anterior approach with or without liver hanging maneuver versus conventional approach in major liver resections. A systematic review and meta-analysis of randomized controlled trials

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ABSTRACT

Introduction: The anterior approach (AA), whether or not associated with the liver hanging maneuver (LHM), has been advocated to improve survival and postoperative outcomes in HCC patients undergoing major liver resection. This systematic review and meta-analysis of randomized controlled trials aims to explore intra/peri-operative and long-term survival outcomes of AA ± LHM compared to CA regardless of tumor histology.

Methods: The study was conducted according to the Cochrane recommendations searching the PubMed, Scopus, and EMBASE databases until January 27, 2024 (PROSPERO ID: CRD42024507060). Only English-language RCTs were included. The primary outcome, expressed as hazard ratio (HR) and 95 % confidence intervals (CI), was the overall and disease-free survival. Random effects models were developed to assess heterogeneity. The risk of bias in included studies was assessed with the RoB 2 tool. The certainty of evidence was assessed following GRADE recommendations.

Results: Six RCTs, for a total of 736 patients were included. A significant survival benefit was highlighted for patients undergoing AA ± LHM in terms of overall (HR: 0.65; 95 % CI: 0.62–0.68; $p < 0.0001$) and disease-free survival (HR: 0.65; 95 % CI: 0.63–0.68; $p < 0.0001$). AA ± LHM was associated with a longer duration of surgery (WMD: 29.5 min; 95 % CI: 17.72–41.27; $p = 0.004$), and a lower intraoperative blood loss (WMD: 24.3; 95 % CI: 31.1 to −17.5; $p = 0.0014$). No difference was detected for other postoperative outcomes. The risk of bias was low.

Conclusion: AA ± LHM provides better survival outcomes compared to CA. Furthermore, AA ± LHM is related to a modest reduction in intraoperative blood loss, at the price of a slightly longer duration of hepatectomy. Regarding other postoperative outcomes, the two techniques appear comparable.

1. Introduction

The conventional approach (CA) to major liver resections encompasses full mobilization of the liver by dissecting the falciform ligament up to the hepato-caval confluence, detaching the coronary ligaments, controlling the vascular inflow and outflow, and transecting liver parenchyma. However, especially in the presence of large tumors invading surrounding extrahepatic organs and the retrohepatic region, this

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approach may be extremely challenging and somewhat hazardous. An alternative method is represented by the anterior approach (AA), encompassing inflow vascular control, parenchymal transection, and venous outflow control before liver mobilization, along with the liver hanging maneuver (LHM). This latter technique consists of passing a tape or tube through the retrohepatic avascular plane between the anterior surface of the inferior vena cava (IVC) and the posterior surface of the liver. The traction exerted on the liver parenchyma is advocated to allow better control of the bleeding from the transection surface even for right-sided liver tumors exceeding 5 cm or retrohepatic neoplasms [1,2]. Nevertheless, LHM is burdened by non-negligible drawbacks, mainly vascular injuries to the IVC or its tributaries leading to potentially fatal bleeding, and tumor breach, especially in case of large paracaval/retrohepatic neoplasms [3].

Previously published meta-analyses on this topic mainly focused on right hepatectomies for large hepatocellular carcinoma (HCC). This systematic review and meta-analysis of randomized controlled trials aims to explore intra/perioperative and long-term survival outcomes of AA ± LHM compared to CA regardless of tumor histology.

2. Methods

A systematic review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses “PRISMA” and the Assessing the methodological quality of systematic reviews “AMSTAR” Guidelines [4,5]. The protocol of the present systematic review was registered on PROSPERO (ID: CRD42024507060).

The PubMed, Scopus, EMBASE, and Cochrane Library databases were screened without time restrictions up to January 27, 2024. The research also included all the MeSH Terms. The full search queries are available in the supplementary materials.

Articles without free full text available were searched through the University of Milan digital library and direct contact with authors. A hand-search of references of included studies and previous reviews on the topic was also performed to include additional relevant studies according to our selection criteria. Two investigators (SG, BT) carried out the literature search independently.

2.1. Inclusion criteria

A specific population “P”, intervention “I”, comparator “C”, outcome “O”, and study design “S” “PICOS” framework was specified to define study eligibility, as recommended. In particular, the following criteria were outlined.

- Population (P): patients undergoing right- or left-sided major liver resection for primary or secondary liver tumors;
- Intervention (I): AA ± LHM;
- Comparison (C): CA without LHM;
- Outcomes (O): intraoperative, postoperative, and oncologic outcomes (see *2.6 Primary* and secondary outcomes);
- Study design (S): Randomized Controlled Trials (RCT).

Studies with insufficient reporting of the PICOS criteria were excluded.

Major hepatectomy was defined according to the definition provided by Reddy et al. [6].

2.2. Exclusion criteria

The studies with the following criteria were deemed non-eligible.

a) Studies including also patients undergoing minor liver resections without separate outcome data;
b) Studies reporting overlapping series;
c) All study designs other than RCTs;
d) Case reports, editorials, abstracts, unpublished studies, book chapters, and commentaries;
e) Non-English language papers;
f) Previously published reviews.

2.3. Systematic review process and data extraction

Rayyan web application was used to identify and remove duplicates among identified records [7]. Overall, 3729 articles were preliminarily identified by the literature search. After the exclusion of duplicates, two independent reviewers (SG, BT) screened titles and abstracts of 2222 records. An a priori-developed screening form was created to guide study selection. Investigators were blinded to each other’s decisions. A third party (EG), who supervised the systematic review process, solved the disagreement. 2214 records were excluded: 1663 failed to meet the PICOS criteria, 68 were written in a language other than English, 394 were case reports, and 89 were previously published systematic reviews/meta-analyses.

Eight articles were assessed for eligibility. Two RCTs did not match the intervention and comparator criteria of the PICOS framework and thus were excluded. Finally, 6 studies fulfilling all inclusion criteria were selected for qualitative and quantitative analysis. The flowchart depicting the overall review process according to PRISMA is reported in Fig. 1.

Data were extracted independently by two authors (SG, BT). Information about participant demographics and baseline characteristics, operative characteristics, pathological and postoperative outcomes were gathered in a computerized spreadsheet (Microsoft Excel 2016; Microsoft Corporation, Redmond; WA).

In case of disagreement, two further investigators (AG, EG) helped resolve it through discussion.

2.4. Assessment of the methodological quality (risk of bias) and certainty of evidence

The risk of bias was assessed for individual studies according to the RoB 2 tools provided by the Cochrane Collaboration [8,9] by one investigator (SF).

Data were collected according to the methodology proposed by Higgins [8] in a computerized spreadsheet. Bar and traffic light plots were created to display the results of the risk of bias assessment graphically.

One investigator (SG) assessed the certainty of the evidence (CoE) according to the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach, using the GRADEpro Guideline Development Tool (GDT) [10]. As recommended, the overall CoE was determined by using the lowest grade for any of the outcomes deemed critical (sensitivity and specificity). A “Summary of findings” table was produced to condense the certainty of evidence assessment.

GRADE recommendations were applied as follows.

- Risk of bias was assessed using the RoB 2 tool.
- Indirectness: RoB 2 “Bias arising from the randomization process”, “Bias due to deviations from intended interventions”, and “Bias in measurement of the outcome” domains were used to assess applicability and surrogate outcomes concerns.
- Inconsistency was evaluated based on the similarity of the point estimates, the extent of overlap among CIs, and heterogeneity. Sensitivity analysis was conducted to detect potential sources of heterogeneity.
- Imprecision assessment was mainly based on both the width of the CI and the number of participants in the studies.
- Publication bias was assessed using funnel plot and regression test.

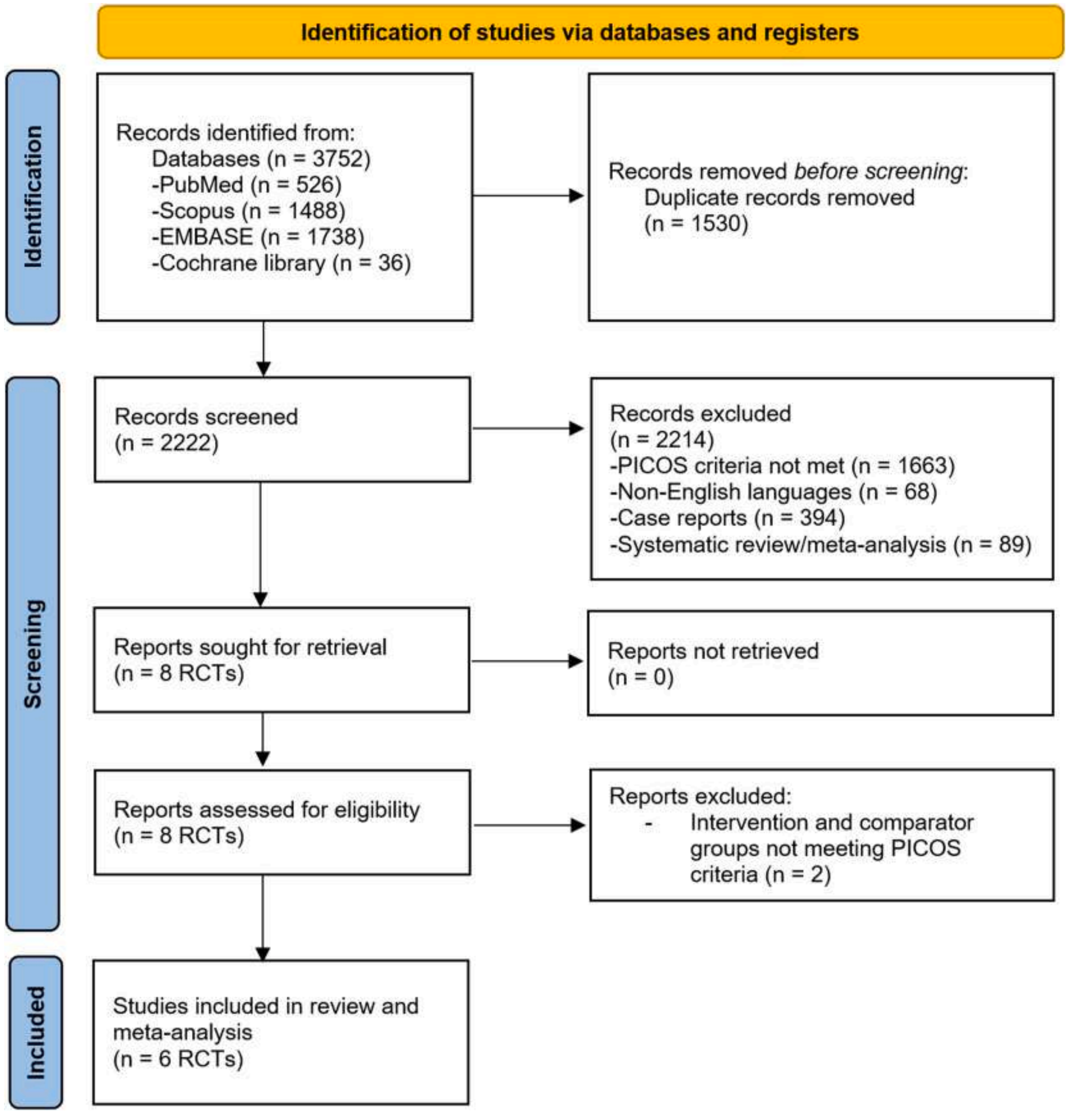

Fig. 1. PRISMA flow diagram.

2.5. *Primary and secondary outcomes*

The primary outcomes were overall survival (OS) and disease-free survival (DFS). The secondary outcomes were operative time, blood loss during surgery, blood transfusion requirement, length of hospital stay, in-hospital morbidity, and mortality.

2.6. *Statistical analysis*

The primary outcome measure was expressed Hazard Ratio (HR) and 95 % Confidence Intervals (95%CI). HRs were retrieved from each manuscript, and their standard errors (S.E.) were computed from the reported 95 % confidence intervals (95 % CI). If not overtly reported, they were estimated using the method proposed by Liu et al. [11] whenever possible. HR and S.E. logarithmic transformation were derived to estimate treatment effects.

Secondary outcome measures were reported as MD or Risk Ratio (RR) with 95 % CI as appropriate. Means were retrieved from each manuscript. Whenever not overtly reported, they were computed from medians, ranges, interquartile ranges (IQR), and sample sizes according to Wan's method [12]. Meta-analyses of means and binary outcomes were developed.

Random effects models based on the inverse variance method and DerSimonian-Laird estimator for τ^2 were built to assess the impact of heterogeneity on results. Between-studies heterogeneity was quantified by I^2 statistic and Cochran's Q test; cut-off values of 25 %, 50 %, and 75 % were considered low, moderate, and high, respectively [13]. Ninety-five percent prediction intervals (PI) were provided as well. Sensitivity analysis was conducted to explore the presence of outliers; influential cases were detected through the leave-one-out method and graphical display of study heterogeneity (GOSH) analysis. Forest plots were developed to display the results graphically.

Funnel plots were developed to explore publication bias, and Egger's test of the intercept was used to quantify funnel plots' asymmetry. Duval & Tweedie's trim-and-fill method was adopted to estimate and adjust the number and outcomes of missing studies each time Egger's test demonstrated significant asymmetry.

Statistical analysis was conducted with R statistical software (The Comprehensive R Archive Network – CRAN, ver. 4.0.0 x64) [14], using "meta", "metafor", "robvis" and "dmetar" packages [15–18].

3. Results

3.1. *Descriptive noncomparative analysis of included studies*

After the literature search, 6 RCTs were included in the qualitative and quantitative analysis [3,19–23]. The study by Hao et al. published in 2016 was not excluded because the overlap of data with the study published by the same group in 2017 was less than 50 %.

In total, 736 patients were included in the meta-analysis; of these 361 underwent hepatectomy with AA ± LHM, and 375 with CA. Four studies were conducted in China, and two in Europe. In four studies the indication for surgery was HCC, in one, was colorectal liver metastases, and in one was a mixed sample of HCC, liver metastases, gallbladder carcinoma, and intrahepatic cholangiocarcinoma. In the studies by Wen et al., Capussotti et al., and Rahbari et al. all but 3 patients undergoing AA had LHM performed. In the studies by Liu et al., and Hao et al. the proportion of patients undergoing LHM along with AA was not specified. The maneuver was performed if necessary. Further details are reported in Table 1.

3.2. Primary outcome

3.2.1. Overall survival

Four studies reported data regarding OS [19,21–23]. AA ± LHM was associated with a significant survival benefit compared to CA (HR: 0.65; 95 % CI: 0.62–0.68; $p < 0.0001$). No heterogeneity was detected ($I^2 = 0$ %; 95 % CI: 0%–84.7 %; p = 0.565). No sensitivity analysis was conducted.

3.2.2. Disease free survival

Four studies reported data regarding DFS [19,21–23]. AA ± LHM was associated with a significantly improved DFS compared to CA (HR: 0.66; 95 % CI: 0.63–0.68; $p < 0.0001$). Heterogeneity was moderate ($I^2 = 40.3$ %; 95 % CI: 0%–79.8 %; p = 0.17). The study by Liu et al. was identified as overtly contributing to heterogeneity through the leave-one-out method. After removing it, the effect size was confirmed (HR: 0.65; 95 % CI: 0.63–0.68; $p < 0.0001$), and the heterogeneity dropped to zero ($I^2 = 0$ %; 95 % CI: 0%–89.6 %; p = 0.452). Forest plots of the primary outcomes are reported in Fig. 2.

3.3. Secondary outcomes

3.3.1. Operative time

All studies reported data regarding operative time. AA ± LHM was associated with a significantly longer length of surgery compared to CA (WMD: 25 min; 95 % CI: 6.45–43.48; p = 0.018). Heterogeneity was moderate ($I^2 = 56.8$ %; 95 % CI: 0%–82.6 %; p = 0.04). After sensitivity analysis (removing the studies by Capussotti et al. and Wen et al.), the effect size was confirmed (WMD: 29.5 min; 95 % CI: 17.72–41.27; p = 0.004). Heterogeneity dropped to low ($I^2 = 17.8$ %; 95 % CI: 0%–87.4 %; p = 0.3).

3.3.2. Intraoperative blood loss

All studies reported data regarding intraoperative bleeding. AA ± LHM was associated with a non-significantly lower blood loss compared to CA (WMD: 46.9 ml; 95 % CI: 154.6 – 60.9; p = 0.31). Heterogeneity was moderate ($I^2 = 60.5$ %; 95 % CI: 3.1%–83.9 %; p = 0.03). After removing the studies by Wen et al., and Rahbari et al., AA ± LHM turned out to be associated with a significantly lower intraoperative blood loss (WMD: 24.3 ml; 95 % CI: 31.1 to −17.5; p = 0.0014); heterogeneity dropped to zero ($I^2 = 0$ %; 95 % CI: 0%–84.7 %; p = 0.99).

3.3.3. Blood transfusion requirements

All studies reported data regarding the proportion of patients requiring blood transfusion. AA + LHM was associated with a non-significant reduction in blood transfusion requirement (RR: 0.76; 95 % CI: 0.58–1.01; p = 0.056). Heterogeneity was moderate ($I^2 = 37.1$ %; 95 % CI: 0%–75 %; p = 0.16). After excluding the study by Liu et al., the effect size was confirmed (RR: 0.84; 95 % CI: 0.63–1.11; p = 0.22), and the heterogeneity dropped to zero ($I^2 = 0$ %; 95 % CI: 0%–79.2 %; p = 0.64).

3.3.4. Length of hospital stay

Four studies reported data regarding the length of hospitalization [3,19,20,23]. AA ± LHM was associated with a non-significant reduction in the length of hospital stay (WMD: 0.39 days; 95 % CI: 2.71-1.94; p = 0.63). Heterogeneity was moderate ($I^2 = 27.6$ %; 95 % CI: 0%–73 %; p = 0.25). After excluding the study by Rahbari et al., the effect size was confirmed (WMD: 0.96 days; 95 % CI: 3.29-1.38; p = 0.22), and heterogeneity dropped to zero ($I^2 = 0$ %; 95 % CI: 0%–89.6 %; p = 0.54).

3.3.5. Postoperative morbidity

All studies reported data regarding postoperative morbidity. AA ± LHM was associated with a lower, although non-significant, risk of postoperative complications (RR: 0.83; 95 % CI: 0.68–1.03; p = 0.098). Heterogeneity was null ($I^2 = 0$ %; 95 % CI: 0%–74.6 %; p = 0.78).

3.3.6. In-hospital mortality

Five studies reported data regarding in-hospital mortality [3,19,21–23]. AA ± LHM was associated with a non-significant reduction in the risk of postoperative mortality (RR: 0.91; 95 % CI: 0.34–2.45; p = 0.86). Heterogeneity was moderate ($I^2 = 27.8$ %; 95 % CI: 0%–71.7 %; p = 0.24). After sensitivity analysis (excluding the study by Liu et al.), AA ± LHM turned out to be related to a non-significant higher risk of postoperative death compared to CA (RR: 1.3; 95 % CI: 0.51–3.3; p = 0.58); heterogeneity dropped to zero ($I^2 = 0$ %; 95 % CI: 0%–84.7 %; p = 0.49).

The forest plots of secondary outcomes before sensitivity analysis are displayed in Fig. 3. The forest plots of secondary outcomes after sensitivity analysis are reported in supplementary materials.

3.4. Risk of bias

None of the studies was burdened by a serious risk of bias. A graphical representation of the risk of bias assessment is reported through the barplot in Fig. 4. A more detailed representation through traffic light plot is reported in supplementary materials.

Table 1
Characteristics of included studies. HCC: Hepatocellular Carcinoma; LM: Liver Metastases; CC: Cholangiocarcinoma; GBC: Gallbladder Cancer; LHM: Liver Hanging Maneuver; NR: not reported.

Study	Years of enrollment	Country	Study design	Indication for surgery	Mean Age AA (SD)	Mean Age CA (SD)	Male pts	Female pts	AA (LHM)	CA
Liu - 2006	1999–2004	China	RCT	100 % HCC	52 ± 10,6	53,3 ± 12,1	103	17	60 (NR)	60
Wen - 2009	2007	China	RCT	100 % HCC	45,7 ± 12,6	41,9 ± 13,4	38	16	24 (24)	30
Capussotti - 2012	2005–2009	Italy	RCT	67.7 % LM, 20 % HCC, 10.8 % CC, 1.5 % GBC	54 ± 41,1	56,5 ± 41,9	36	39	33 (30)	32
Hao - 2016	2010–2013	China	RCT	100 % HCC	50,6 ± 8,2	51,3 ± 8,5	164	54	107 (NR)	111
Hao - 2017	2012–2014	China	RCT	100 % HCC	50,8 ± 8	51,5 ± 7,5	154	45	98 (NR)	101
Rahbari - 2021	2003–2012	Germany	RCT	100 % LM	63 ± 10	60 ± 11	48	32	39 (39)	41

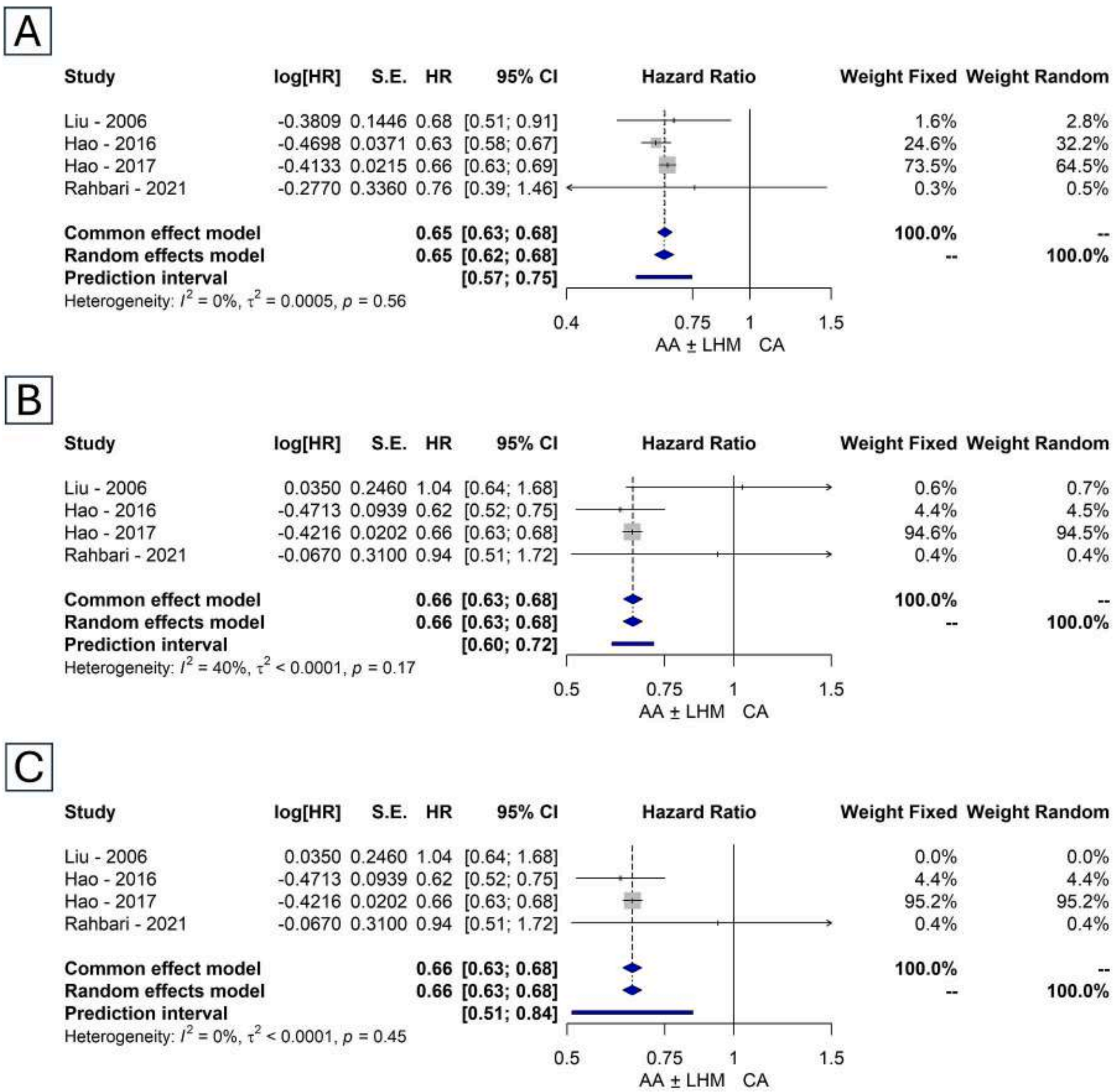

Fig. 2. Forest plots - OS (A), DFS before (B), and after (C) sensitivity analysis.

3.5. Publication bias

No publication bias was detected for the primary and secondary endpoints (Egger's test for OS $p = 0.897$; DFS $p = 0.31$, operative time $p = 0.41$, intraoperative blood loss $p = 0.67$, blood transfusion requirements $p = 0.68$, length of hospital stay $p = 0.69$, postoperative morbidity $p = 0.85$, In-hospital mortality $p = 0.92$). Contour-enhanced funnel plots for the primary endpoint are reported in Fig. 5.

3.6. Grade

Table 2 summarizes the certainty of evidence according to GRADE recommendations

4. Discussion

Liver resection remains the cornerstone of treatment of a wide variety of primary and secondary hepatic neoplasms. The CA represents the standard approach for major liver resections, mainly right hepatectomy [24]. However, especially in the presence of large tumors, it could result in uncontrollable hemorrhage with hemodynamic instability, tumor rupture, tumor cell spread, and liver ischemia due to the prolonged rotation of the liver [25]. The AA was first proposed by Ozawa et al., in 1990 [26] as an alternative to the CA. Nevertheless, AA still brings the potential risk of major, life-threatening bleeding, especially when reaching the deeper plane of the parenchymal transection, due to the lack of proper outflow control and no protection of the IVC. In an attempt to overcome these issues, the AA was implemented by Belghiti et al., in 2001 [27] who ameliorated the technique by introducing the LHM.

Our study pooled the data from 736 patients from 6 RCTs. The meta-analysis pointed out a significant survival benefit for patients undergoing AA ± LHM in terms of both overall (HR: 0.65; 95 % CI: 0.62–0.68; $p < 0.0001$) and disease-free survival (HR: 0.65; 95 % CI: 0.63–0.68; $p < 0.0001$). This finding is consistent with other evidence available in the literature and might be the result of a more reduced manipulation of the liver and squeezing of the tumor during surgery [28,29]. In the study by Liu et al. cell-free plasma albumin-mRNA was assayed for evidence of circulation of liver cells during liver mobilization and surgery. This mRNA was chosen as a surrogate because previous assays for circulating cancer cell markers were not reliable. Circulating albumin-mRNA levels were significantly lower in the AA group compared with the CA, both before parenchymal transection and at the end of the surgical procedure. Similarly, in the study by Hao et al. [22], a significantly lower amount of

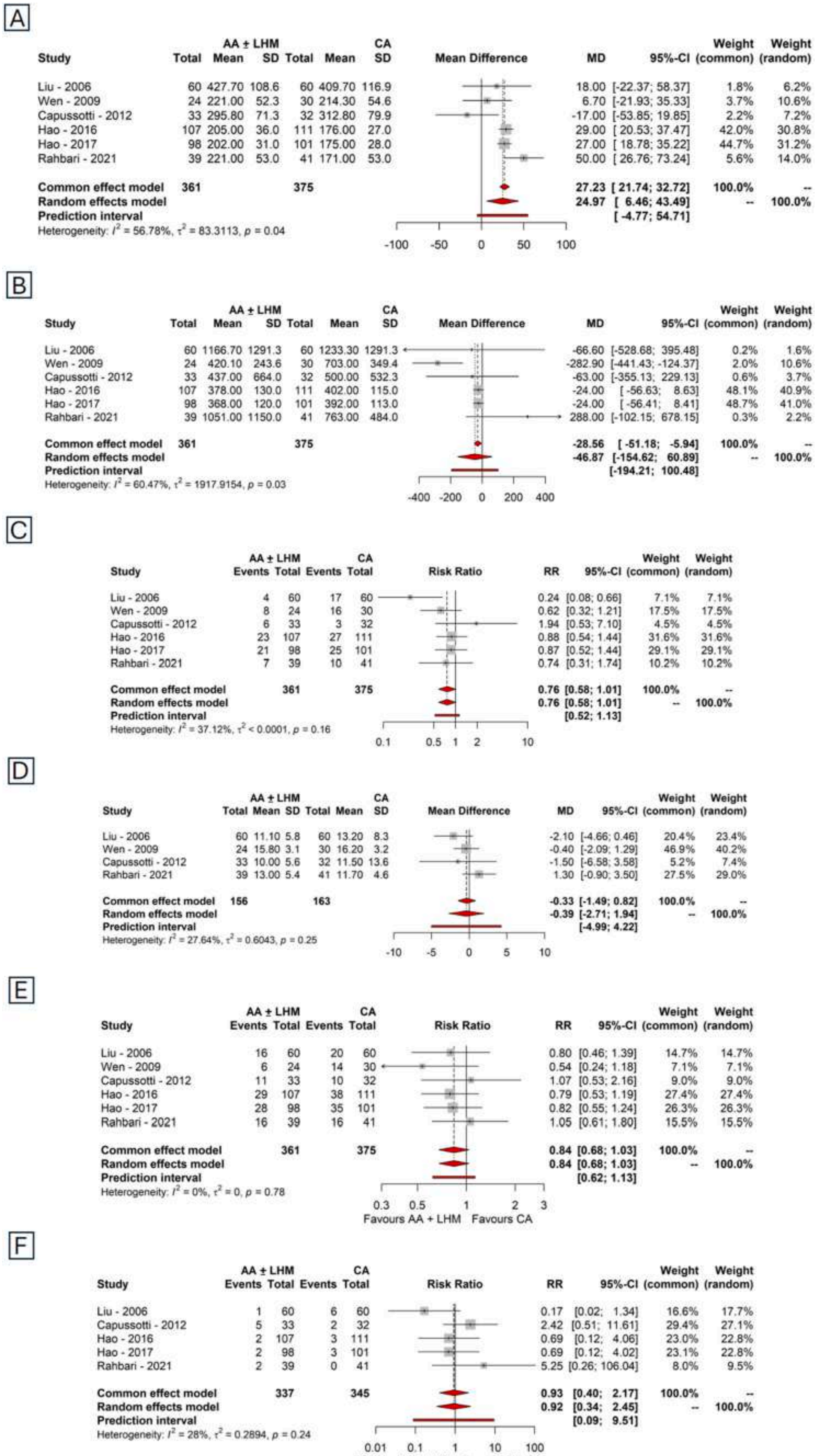

Fig. 3. Forest plots of secondary outcomes before sensitivity analysis - operative time (A), intraoperative blood loss (B), blood transfusion requirements (C), length of hospitalization (D), postoperative morbidity (E), and in-hospital mortality (F).

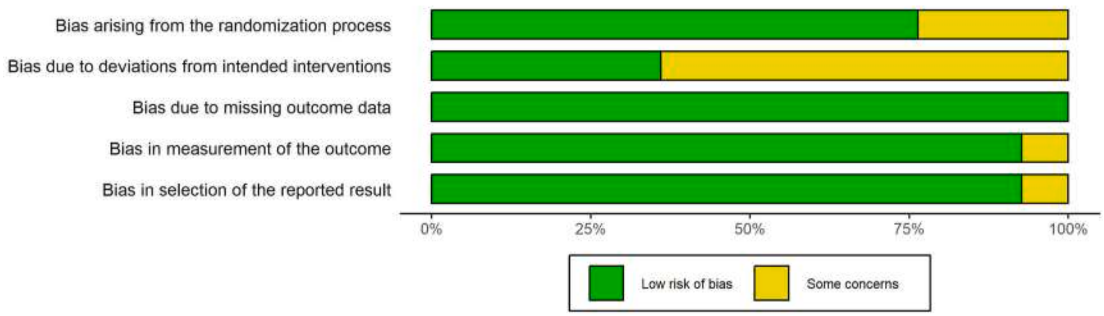

Fig. 4. Risk of bias assessment through barplot.

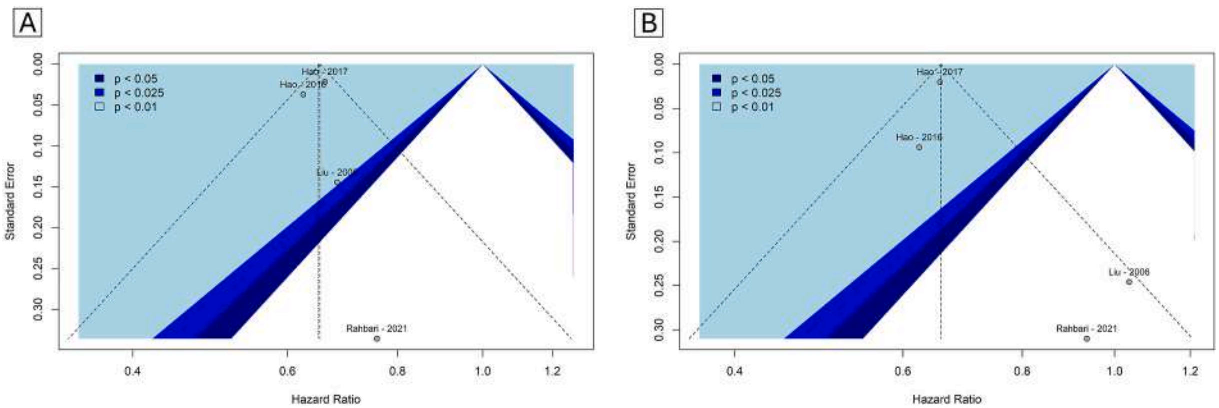

Fig. 5. Funnel plots for the primary endpoint. A) OS, B) DFS.

circulating tumor cells was detected in patients undergoing major hepatectomy through AA compared to CA. Interestingly, in the study by Rahbari et al. [23], no difference between the two techniques was found regarding intraoperative tumor cell detection. These findings may suggest that AA ± LHM may prove useful in lowering the amount of circulating tumor cells only in HCC patients; thus, the "no touch technique" might not be helpful in improving survival outcomes in patients suffering from CRLM. In this regard, it is worth noting that 3 out of 4 studies included in the primary outcome analysis enrolled exclusively HCC patients.

Although associated with a longer duration of surgery (WMD: 29.5 min; 95 % CI: 17.72–41.27; $p = 0.004$), after sensitivity analysis AA ± LHM was found to be related to a lower intraoperative hemorrhage (WMD: 24.3; 95 % CI: 31.1 to −17.5; $p = 0.0014$). Conversely, no difference between AA ± LHM and CA was found regarding blood transfusion requirements, length of hospital stay, postoperative morbidity, and in-hospital mortality. Nevertheless, it should be kept in mind the difference between statistical and clinical significance: a 30-min longer surgery, as well as 24 mL less intraoperative blood loss, might not substantially impact the postoperative course.

The present meta-analysis is not the first to compare AA with CA, but, to the best of our knowledge, it is the first encompassing randomized trials only. The meta-analyses by Tang et al. [30], and Ishii et al. [31] focused on the comparison between these two approaches in the case of right hepatectomy performed for HCC. These studies highlighted that AA is associated with more favorable survival outcomes and improved perioperative outcomes (including a lower transfusion rate, transection time, estimated blood loss, length of hospital stay, and complication rate), compared to CA. However, both reviews included also non-randomized studies resulting in moderate to high heterogeneity of the results for both primary and secondary outcomes. In the study by Tang et al., even after removing the studies scoring less than 6 points in the Newcastle-Ottawa scale in subgroup analysis, more than half of the results were burdened by moderate or high heterogeneity. On the other hand, the results published by Ishii et al. were more homogeneous, and consistent after sensitivity analysis.

Another recent study published in 2018 by Li et al. [32] focused on the impact of the LHM on perioperative and long-term outcomes compared to conventional hepatectomy in patients suffering from primary and secondary liver tumors, as well as benign disease. The pooled outcomes underscored that LHM was associated with lower blood loss, intraoperative transfusion rate, complication rate, shorter transection time length of hospital stay, and longer overall survival. These findings were consistent with the aforementioned meta-analysis and similarly included randomized and non-randomized studies.

4.1. Limitations

Although based on RCTs only, the present study is burdened by non-negligible limitations. Only six studies were deemed eligible after the selection process; of these, just four reported data regarding long-term survival outcomes. Furthermore, only 93 out of 361 patients (25.8 %) in the AA group received also LHM. This hindered the possibility of conducting subgroup analysis to investigate the role of the LHM when added to AA.

Finally, most of the studies focused on HCC, whereas only the study by Rahbari et al. enrolled exclusively patients suffering from CRLM, and in the study by Capussotti et al. two-thirds of the sample was represented by metastatic patients. The scarcity of studies enrolling non-HCC patients precluded the possibility of assessing the consistency of our findings among different liver tumor etiologies.

5. Conclusion

The AA, whether or not associated with the LHM, provides better survival outcomes compared to the CA, mainly in HCC patients.

Table 2
GRADE summary of recommendations.

Certainty assessment							№ of patients		Effect		Certainty
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	AA ± LHM	CA	Relative (95 % CI)	Absolute (95 % CI)	
Overall Survival (assessed with: HR)											
4	randomized trials	not serious	not serious	not serious	not serious	none	304 participants	313 participants	**HR 0.65** (0.62–0.68) [mortality]	**– per 1.000** (from – to –)	⨁⨁⨁⨁ High
							–	0.0 %		**– per 1.000** (from – to –)	
Disease-free Survival (assessed with: HR)											
4	randomized trials	not serious	not serious	not serious	serious[a]	none	304 participants	313 participants	**HR 0.66** (0.63–0.68) [mortality]	**– per 1.000** (from – to –)	⨁⨁⨁◯ Moderate
							–	0.0 %		**– per 1.000** (from – to –)	
Intraoperative blood loss (assessed with: WMD)											
6	randomized trials	not serious	serious[b]	not serious	serious[c]	none	361	375	–	MD **24.97 ml higher** (6.46 higher to 43.49 higher)	⨁⨁◯◯ Low
Operative time (assessed with: WMD)											
6	randomized trials	not serious	serious[b]	not serious	serious[c]	none	361	375	–	MD **46.87 min lower** (154.62 lower to 60.89 higher)	⨁⨁◯◯ Low
Blood transfusion requirements (assessed with: RR)											
6	randomized trials	not serious	not serious	not serious	not serious	none	69/361 (19.1 %)	98/375 (26.1 %)	**RR 0.76** (0.58–1.01)	**63 fewer per 1.000** (from 110 fewer to 3 more)	⨁⨁⨁⨁ High
Length of hospitalization (assessed with: WMD)											
4	randomized trials	not serious	not serious	not serious	serious[c]	none	156	163	–	MD **0.39 days lower** (2.71 lower to 1.94 higher)	⨁⨁⨁◯ Moderate
Postoperative morbidity (assessed with: RR)											
6	randomized trials	not serious	not serious	not serious	serious[c]	none	106/361 (29.4 %)	133/375 (35.5 %)	**RR 0.84** (0.68–1.03)	**57 fewer per 1.000** (from 113 fewer to 11 more)	⨁⨁⨁◯ Moderate
Postoperative mortality (assessed with: RR)											
5	randomized trials	not serious	not serious	not serious	serious[c]	none	12/337 (3.6 %)	14/345 (4.1 %)	**RR 0.92** (0.34–2.45)	**3 fewer per 1.000** (from 27 fewer to 59 more)	⨁⨁⨁◯ Moderate

CI: confidence interval; **HR:** hazard ratio; **MD:** mean difference; **RR:** risk ratio.
[a] 2 out of 4 studies had wide confidence intervals.
[b] Heterogeneity of the pooled estimate >50 %.
[c] Wide CI for point and pooled estimates.

Furthermore, AA ± LHM is related to a modest reduction in intraoperative blood loss, at the price of a slightly longer duration of hepatectomy. Regarding other postoperative outcomes, the two techniques appear comparable.

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CRediT authorship contribution statement

Stefano Granieri: Conceptualization, Data curation, Methodology, Formal analysis, Software, Writing – original draft, Project administration. **Simone Frassini:** Investigation, Data curation. **Beatrice Torre:** Investigation. **Alessandro Bonomi:** Writing – original draft, Visualization. **Dr Sissi Paleino:** Visualization. **Federica Bruno:** Visualization. **Andrea Chierici:** Methodology, Validation. **Elson Gjoni:** Visualization, Validation. **Alessandro Germini:** Visualization, Validation. **Fabrizio Romano:** Visualization. **Mattia Garancini:** Visualization. **Mauro Alessandro Scotti:** Visualization. **Christian Cotsoglou:** Visualization, Validation.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejso.2024.108535.

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