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Impact of portal vein embolisation uses in colorectal liver metastases: evidence from a rapid review

Mohammed Moinuddin ,[1] Phuong Uyen Tran,[1] Mohamed Bekheit[2,3]

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[1]School of Medicine and Dentistry, University of Lancashire, Preston, UK
[2]Institute of Medical Sciences, University of Aberdeen, Aberdeen, UK
[3]Department of Surgery, NHS Grampian, Foresterhill Campus, Aberdeen, Scotland

Correspondence to
Dr Mohammed Moinuddin; moinuddin.bahezi@gmail.com

ABSTRACT

Objectives To compare the short- and long-term outcomes of patients with colorectal liver metastases (CRLM) who underwent portal vein embolisation followed by liver resection (PVEfLR) with those who underwent other treatment strategies.

Design Rapid review of the literature retrieved through a systematic search.

Data sources Electronic databases PubMed, Embase and Ovid MEDLINE were searched from 1 April 2014 to 31 December 2025.

Eligibility criteria Studies were included if they involved only patients with CRLM, applied PVEfLR and reported comparative outcomes against other interventions (eg, associating liver partition and portal vein ligation for staged hepatectomy (ALPPS), liver transplantation and portal vein ligation). Only randomised controlled trials, cohort and case–control studies published in English were included. Studies that included patients other than those with CRLM were excluded.

Data extraction and synthesis Two authors independently screened records, extracted data and assessed quality using the Newcastle-Ottawa Scale. Data were narratively synthesised and presented in summary tables.

Results 14 studies (n=2,022 patients) were included. The overall median survival time for the PVEfLR group was similar to that of the ALPPS group but significantly lower than that of the liver transplantation group (19 vs 41 months, p=0.007). Postoperative complications were significantly lower for PVEfLR than for ALPPS (27% vs 65%, p<0.05) but higher than for liver resection without portal vein embolisation (51% vs 36%, p<0.001). The future liver remnant growth and completion rates for PVEfLR were variable compared with those of other techniques.

Conclusions PVEfLR is an effective strategy for converting selected patients with initially unresectable CRLM to resectable status, achieving long-term survival comparable to other complex techniques such as ALPPS, although with a different perioperative risk profile. The choice of technique should be individualised based on the patient's anatomy, disease burden and institutional expertise.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This rapid review provides a contemporary synthesis of evidence extracted from major databases using a predefined population, exposure, comparator and outcome (PECO) framework from the last decade.
⇒ The inclusion of a wide range of comparative interventions and outcomes provides a broad clinical overview; however, some techniques, such as hepatic vein embolisation and liver venous deprivation, were excluded because of strict inclusion criteria.
⇒ The narrative synthesis of data (limited by the predominance of small sample sizes) and the inability to perform a meta-analysis limit the quantitative strength of these findings.
⇒ The inclusion of conference abstracts may have introduced bias due to the lack of peer-reviewed methodological details.
⇒ The lack of a minimum follow-up period in the inclusion criteria may affect the robustness of the conclusions regarding long-term survival.

INTRODUCTION

Liver metastasis occurs in more than half of patients with colorectal cancer and is also the leading cause of death from the disease.[1] The current guidelines for managing colorectal liver metastases (CRLM) include surgical and non-surgical approaches such as chemotherapy, local ablative treatments and liver transplantation.[2] Liver resection (LR) remains the only curative treatment for colorectal cancer and its benefits are evident.[3] However, due to factors including insufficient future liver remnant (FLR), bilobar disease or proximity to vital structures, less than 25% of patients with CRLM are considered resectable at diagnosis.[4] Systemic conventional and immunotherapies are the options for unresectable CRLM.[5] Patients with unresectable CRLM had a poor outcome, with a 5-year overall survival (OS) rate of only 12% compared with 41% in surgically treated patients.[6] Therefore, complex interventions provide a potential option for this patient cohort, which is immensely important to increase healthy liver volume and make more patients eligible for surgery.

Portal vein embolisation (PVE) is a minimally invasive procedure that was

developed to increase the residual liver volume for patients with unresectable liver tumours at diagnosis due to insufficient FLR.[7] This procedure blocks blood flow to the tumour—containing part of the liver by injecting embolic materials (gel foam, ethanol or polyvinyl-alcohol particles) into the portal vein branches that supply blood to that area.[8] This blockage diverts blood flow to the remaining healthy part of the liver, stimulating compensatory liver hypertrophy and thereby increasing the likelihood of liver tumour resection. 3–7 weeks after the procedure, the LR will be performed depending on FLR volume.[9] Among patients selected for PVE, approximately 80% subsequently undergo LR with a complication rate of less than 10% and a rate of achieving sufficient liver enlargement of 96.1%.[10 11] Therefore, PVE plays an important role in expanding the patient population eligible for curative LR, with potential benefits in terms of resectability and long-term survival outcomes.

In addition to PVE followed by LR (PVEfLR), other treatments have been developed to increase healthy liver volume. Associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) is a recently developed technique to rapidly induce liver hypertrophy with FLR volume reaching 74% within 9 days.[12] ALPPS had a high resection rate of 92% and is also used in some cases when the PVE approach fails.[13] Another technique developed based on the characteristics of liver hypertrophy, portal vein ligation (PVL), has the same purpose of blocking blood flow into the portal vein and promoting liver regeneration. This technique can be performed using an open or laparoscopic approach.[14] Another minimally invasive procedure, radiofrequency ablation (RFA), treats small, unresectable CRLM. As the name suggests, this method uses radiofrequency waves to remove liver tumours through targeted heat application, yielding results different from ablation or other hypertrophic techniques.[15] Another approach, two-stage liver transplantation (LT), once an abandoned technique due to poor results, has recently become an increasingly used procedure.[16] Although its effectiveness depends on donor availability, it remains a promising approach for patients with unresectable CRLM.

Although patients have a better chance of treating CRLM with these surgical and interventional treatments, there is varying evidence comparing the efficacy of PVEfLR (either one-stage or two-stage hepatectomy) with these treatments for short- and long-term outcomes. While they focus on the same aims to prolong patient survival, differences in outcomes such as survival rate, complication profiles, FLR growth and other outcomes have been a matter of debate. This rapid review provides a contemporary, head-to-head comparison of the short and long-term patient benefits of PVEfLR against other liver-directed strategies (ALPPS, LT, PVL followed by LR (PVLfLR), RFA, LVD and hepatectomy without PVE) for CRLM, synthesising the evidence from the past decade to inform current clinical decision-making.

METHODOLOGY

Design

To answer the research question, we conducted a rapid review. Rapid review methods are similar to systematic reviews but within a shorter time frame. It synthesises studies in a summary and timely manner within a limited scope (eg, search terms and inclusion criteria).[17]

The research question was based on the population (patients with CRLM), exposure (using PVE followed by LR/PVEfLR), comparator (using any methods of surgical or interventional procedure other than PVEfLR) and outcomes (short- and long-term patient outcomes) framework.[18]

Search strategy

We searched the electronic databases PubMed and OVID (accessing two resources: Embase and Ovid MEDLINE) using our predefined search strategy. The search utilised the Booleans and truncations using a combination of keywords and search terms “colorectal liver metastas*”, “CRLM”, “CLM”, “portal vein embolisation”, “portal vein embolization” and “PVE”. Details of the search strategy and number of articles detected are presented as an online supplemental appendix 1. Articles published in English only within the last 10 years (from 1 April 2014 to 31 December 2025) were included to ensure relevance and currency of the data.

The search is limited to including only randomised controlled trials (RCTs), cohort studies and case–control studies.

Review criteria

In this review, we included the articles based on the following inclusion criteria—(1) patients with CRLM were the participants, (2) applied PVEfLR, (3) reported outcomes related to the impact of PVEfLR, including but not limited to resectability, liver hypertrophy, postoperative complications, OS and disease-free survival (DFS) rates and recurrence rate.

Studies that—(1) did not report outcomes related to human participants, (2) studied diseases other than CRLM, (3) did not specifically address PVEfLR in patients with CRLM were excluded. A level of evidence of four or five is also an exclusion factor.[19]

Two authors screened the title and abstract independently, assessed the eligibility of inclusion against the inclusion and exclusion criteria and selected the studies for full review. Any disagreement was resolved by discussion with a third author. The selected studies were reviewed in full and relevant data were extracted.

This full process from study identification to inclusion is outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart.

Quality assessment

The quality of the included studies was evaluated using the Newcastle-Ottawa Scale, focusing on three key domains: selection of study populations, comparability

of study groups and ascertainment of outcomes.[20] The study design, population characteristics and intervention/exposure assignment of each study have been carefully considered to ensure that the PVEfLR is comparable to other liver-directed treatments in CRLM. The main criteria include clear definitions of outcomes, appropriate tracking time and sufficient detailed information about surgical techniques and complications. Studies have been selected to ensure consistency in reported metrics, such as the FLR volume, resection rates and survival outcomes. Online supplemental material 1 includes a detailed table summarising the key characteristics of the studies included and their alignment with the study objectives, ensuring transparency and replicability of the review process.

Data extraction and synthesis

A data extraction form was developed in an Excel spreadsheet and used to collect relevant data from the selected studies. The following data were extracted: title, author and year published, country, study design, sample size, patient age and sex, details of any interventions implemented or exposures, the approaches compared and the outcomes (OS, DFS, completion rate, mortality, morbidity rate, FLR growth, complications and hospital stays).

Data extraction was completed by one author and reviewed by the other. The extracted data were synthesised narratively, and the results were summarised in tables and text.

RESULTS

Literature search

A literature search of three databases yielded 575 results, of which 160 results were duplicates. After reviewing the titles and abstracts, 384 (373 unique records) articles were excluded because they did not satisfy the inclusion criteria, leaving 42 for full-text assessment. The PRISMA flow diagram with numbers (figure 1) presents the reasons for excluding the studies. Fourteen studies were included in the final analysis, and data were extracted from these 14 studies for narrative synthesis (see figure 1). Of the studies reviewed, four were available only as conference abstracts.[21–24] However, they were included because they provided sufficient information about the desired outcome. These selected studies presented results from the data for 2,022 patients with CRLM from eight countries.[21–32]

Characteristics of included studies

These 14 studies were conducted in eight countries—Sweden, Denmark,[33] USA,[33 34] Germany (5),[22 30–33] Canada (3),[23 27 28] France (2),[21 26] Norway (2)[25 33] and the Netherlands (1)[29] (table 1). The most common study design was retrospective cohort studies with 10 articles,[21 22 25 26 28 29 31–34] and 3 were prospective cohort studies.[23 27 30] Of the total 2,022 patients from the 14 studies, the number of patients undergoing different surgical procedures was as follows: PVEfLR (n=806, 39.9%), ALPPS (n=189, 9.3%), LT (n=59, 2.9%), PVLfLR (n=18, 0.9%), LR without PVE (n=902, 44.6%), LVD (n=22, 1.1%) and RFA (n=26, 1.3%) (figure 2). Among them, 18 patients underwent PVL in two articles written by the same group of authors, which examined different aspects of the same cohort.[21 26]

Short- and long-term outcomes

Outcome

Studies have compared short- and long-term outcomes to assess the efficacy and safety of different treatment strategies (or therapeutics) for CRLM. Short-term outcomes included FLR growth, complication rates, length of hospital stay, completion rate and time to liver regeneration. The comparative findings are presented in table 2. These measures highlight the immediate impact of each

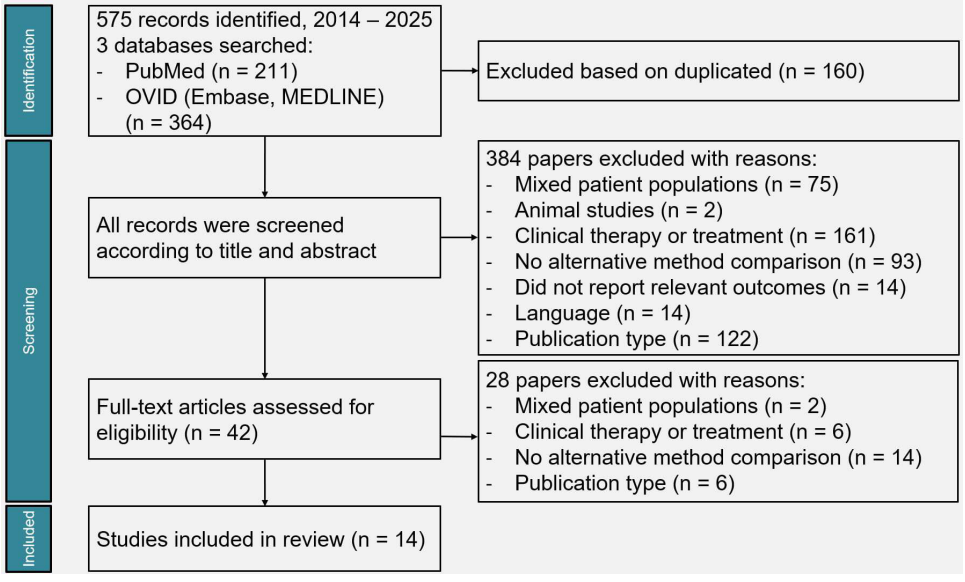

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 flow diagram of included studies. Some articles may fall into more than one category.

Table 1 Summary of included studies

Citation	Publication year	Country	Study design	Sample size	Type of treatment	Median age (years)	Female (%)
Dueland *et al*[25]	2021	Norway	Retrospective cohort study	103	LT, PVEfLR	61.8	32.0
Werey *et al*[26]	2023	France	Retrospective comparative study	54	RPVLfLR, RPVEfLR	NR	53.7
Collin *et al*[27]	2019	Canada	Prospective cohort study	128	PVEfLR, no-PVE	NR	35.2
Simoneau *et al*[28]	2016	Canada	Retrospective study	226	PVEfLR, no-PVE	NR	38.9
Huiskens *et al*	2017	Netherlands	Retrospective cohort study	745	PVEfLR, no-PVE	64.0	38.0
Ali Deeb *et al*[30]	2023	Germany	Prospective cohort study	43	ALPPS, PVEfLR, LT	NR	NR
Bednarsch *et al*[31]	2020	Germany	Retrospective cohort study	58	ALPPS, PVEfLR	60.0	43.1
Reissfelder *et al*[32]	2014	Germany	Retrospective study	356	PVEfLR, no-PVE, RFA	57.0	28.8
Werey *et al*[26]	2023	France	Retrospective comparative study	54	RPVLfLR, RPVEfLR	NR	NR
Bednarsch *et al*[22]	2018	Germany, Netherlands	Retrospective comparative study	73	PVEfLR, ALPPS	NR	NR
Collin *et al*[23]	2015	Canada	Prospective study	128	PVEfLR, no-PVE	63.0 (M)	NR
H-Alejandro *et al*	2014	Canada, USA	Retrospective cohort study	25	ALPPS, PVEfLR	NR	NR
Reese *et al*[33]	2025	Sweden, Denmark, Norway, Germany	Retrospective cohort study	302	PVEfLR, TSH-PVE, ALPPS	NR	33.1
Haddad *et al*	2024	USA	Retrospective cohort study	78	LVD, PVEfLR	54.0	41.0

ALPPS, associating liver partition and portal vein ligation for staged hepatectomy; LT, two-stage liver transplantation; LVD, liver venous deprivation ; M, mean age; NR, not reported; PVE, portal vein embolisation; PVEfLR, portal vein embolisation followed by liver resection; RFA, radiofrequency ablation; RPVEfLR, right portal vein embolisation followed by liver resection; RPVLfLR, right portal vein ligation followed by liver resection; TSH, two stage hepatectopmy .

procedure on patient recovery and resectability. Long-term outcomes reported in the selected studies are OS, DFS, recurrence and morbidity. These indicators provide insight into the effectiveness of these interventions in improving survival and reducing disease progression over time. Together, these short- and long-term measures provide a comprehensive assessment of both the immediate and long-term benefits of the approaches being compared.

Portal vein embolisation versus associating liver partition and portal vein ligation for staged hepatectomy

Four articles evaluated outcomes in patients who went through the PVEfLR and ALPPS. The median OS between PVEfLR and ALPPS varied between studies. In one study, ALPPS had a higher median OS than PVEfLR (34 months vs 28 months), while another study reported the opposite with PVEfLR having a higher median OS than ALPPS (33 months vs 29 months). However, these differences were not statistically significant (p values=0.297–0.507).[22 31] Meanwhile, the median DFS in the PVE group was lower than that of the ALPPS group (10 months vs 19 months). The difference is statistically insignificant (p value=0.05)[31] (table 2).

In one study, the completion rate was lower for the patients who applied PVE as part of two stage hepatectomy (TSH) compared with ALPPS but not significantly (PVEfLR: 73.3% (11/15), ALPPS: 100% (10/10), p value=0.075).[24] However, another study reported that 27% (14/52) patients in the PVE group did not complete the second step and 11 of these patients received salvage ALPPS.[22] The in-hospital mortality rates of the PVE group and ALPPS group were 6.0–18.2% and 10.0–21.7%, respectively, with no significant difference (p value=0.577–0.810).[30 31] The overall mortality rates in the ALPPS group were nearly double, although there was no significant difference between the two treatment modalities (PVEfLR:

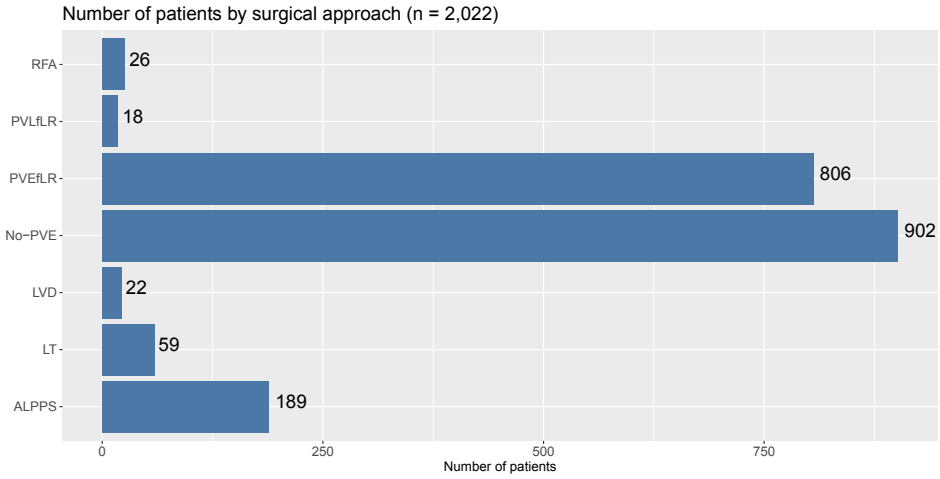

Figure 2 Distribution of patients by the techniques of surgery. ALPPS, associating liver partition and portal vein ligation for staged hepatectomy; PVE, portal vein embolisation; PVEfLR, portal vein embolisation followed by liver resection; PVLfLR, portal vein ligation followed by liver resection; LT, liver transplant; LVD, liver venous deprivation; RFA, radiofrequency ablation.

Table 2 Summary of comparative outcomes of PVE and other techniques

	Outcomes	ALPPS	LT	PVLfLR	LVD	No-PVE	
Survival	Overall survival (median survival time in month)	28: 34 (31) 33: 29 (22)	41: 19*(25)	NR	NR	59: 36 (32) 45: 49 (27)	PVEfLR
	Disease-free survival (median survival time in month)	10: 19 (31)	NR	NR	NR	23: 33 (27)	
Mortality	Mortality (%)	10: 5 (22)	NR	NR	NR	NR	
	In-hospital mortality (%)	10: 6 (31) 22: 18 (30)	NR	NR	NR	NR	
	90-day mortality (%)	9:5 (33)	NR	NR	0:0 (34)	5: 11* (29)	
Complications	Postoperative complications (%)	65: 27* (30)	22: 27 (30)	17: 3 (26)	NR	36: 51* (29)	
	Post-hepatectomy liver failure grade B (%)	30: 27 (30) 7: 5 (33)	NR	NR	NR	NR	
Other	Completion rate (%)	100:73 (24)	100:72 (25)	61:81 (26)	68:68 (34)	100:80* (27)	
	FLR growth (%)	155: 159 (30)	174: 159 (30)	33: 35 (26)	46:40 (34)	96: 46 (28)	
	Degree of hypertrophy (%)	NR	NR	NR	NR	15.7: 10.5* (34)	
	Kinetic growth rate	NR	NR	NR	NR	3.9: 2.4* (34)	
	Hospital stays (median number of days)	NR	NR	6: 2* (26)	NR	9: 8* (32)	
	Resection rate (%)	R0: 100: 88 (31) R1: 35: 40 (33)	NR	NR	NR	NR	
	Recurrence rate (<6 months)	31: 22 (33)	NR	NR	NR	NR	

Note: the estimates correspond to the order—other methods: PVE.
*Statistically significant differences with p<0.005.
ALLPPS, associating liver partition and portal vein ligation for staged hepatectomy; FLR, future liver remnant; LT, liver transplantation; LVD, liver venous deprivation ; NR, not reported; PVE, portal vein embolisation; PVEfLR, portal vein embolisation followed by liver resection; PVLfLR, portal vein ligation followed by liver resection.

4.9% (2/41) and ALPPS: 9.5% (2/21), p value=0.481).[22] ALPPS was associated with a higher R0 resection rate (100% (20/20) vs 88.2% (30/34)) compared with the PVE group (p value=0.116)[31] (table 2).

Patients who underwent the ALPPS experienced a higher rate of complications. 65.2% (15/23) of patients undergoing ALPPS had postoperative complications, of which 30.4% (7/23) had post-hepatectomy liver failure (PHLF) from grade B, while the rates in the PVE group were 27.3% (3/11) and 27.3% (3/11) had PHLF from grade B.[30] The comprehensive complication index was also reported to be higher in the ALPPS group compared with the PVE group (mean (SD): 41 (25) vs 25 (25); p value=0.021).[22] Interestingly, one study reported no difference in both total and serious complications (p value>0.99 and p value=0.84, respectively).[24] The same study also observed a higher recurrence rate in the PVE group (PVEfLR: 36% vs ALPPS: 10%; p value=0.16).[24]

PVEfLR outperformed the ALPPS in terms of percentage gain in future residual liver volume (158.7%, compared with 154.8%)[30] and the degree of hypertrophy (45% compared with 35%, p value=0.803).[31] However, a study has reported that ALPPS achieves larger and faster volumes of the standardised FLR compared with the PVEfLR (89% compared with 52%)[24] (table 2).

Portal vein embolisation followed by liver resection versus liver transplantation

Two of the selected studies reported superior performance of two-stage LT technique compared with PVEfLR in terms of survival outcome, FLR increase ratio and postoperative complication.[1 25 30] In a study examining survival outcomes between PVEfLR and LT with high and low tumour load, the LT group had a higher survival rate.[25] The LT group had a 5-year OS rate of 72.4% among the low tumour load patients, while the rate was 53.1% among the PVE group (p value=0.08).[25] Similarly, in the high tumour load group, the median OS time in the LT group was 40.5 months, which was almost half in the PVE group (median OS time 19.2 months, p value=0.007).[25] 28% (15/53) of patients did not undergo LR after PVE.[25] The FLR volume increase ratio of the LT method was 173.8% compared with 158.7% in the PVE group.[30] The rate of postoperative complications in the LT group was also reported to be slightly lower than the PVE group (PVEfLR: 27.3% vs LT: 22.2%, p value=0.795)[30] (table 2).

Portal vein embolisation versus portal vein ligation followed by liver resection

Studies comparing the results between the two techniques, right PVL and right PVE with LR, showed no statistically significant difference in the mean FLR growth percentage with 32.5% (IQR 36.7%) and 34.5% (IQR 26.8%), respectively, (p value before and after matching by propensity score criteria=0.221–0.859).[21 26] 61% (11/18) of patients in the PVL group underwent LR while this rate was 81% (29/35) in the PVE group (p value=0.081).[26] Median post-procedure hospital stay for the patients in the PVE group was significantly shorter (PVEfLR: median 2 days, IQR: 1 day vs PVL: median 6 days, IQR 5.75 days, p value<0.01)[26] (table 2). However, the median length of stay after the right hepatectomy in the PVL group (median 7 days, IQR=10 days) was shorter than that of PVE (median 10 days, IQR=7.5) but not statistically significant (p value=0.107).[26] The post-procedure major complication rate in the PVL group was 16.7% (3/18), which is higher than the rate in the PVE group (2.8%, 1/36); however, the difference was not statistically significant (p value=0.107).[26] Although the postoperative major complications in the PVL group were higher than the PVE group, 27.3% (3/11) and 17.4% (4/23), respectively, the difference was not statistically significant (p value=0.347)[26] (table 2).

Portal vein embolisation followed by liver resection versus LVD

One article using propensity scores noted a completion rate of 68% and did not record mortality rates within 90 days for the two procedures, PVEfLR and PVD. No patients in the PVEfLR group had any adverse events, while the liver venous deprivation (LVD) group had four mild or moderate adverse events. The LVD group had significantly higher degrees of hypertrophy (DH) and kinetic growth rate (KGR) scores compared with the PVE group (DH: median 15.7% vs 10.5%, p=0.017, KGR: median 3.9% vs 2.4% per week; p=0.006). While the pre-intervention standardized future liver remnant (sFLR) index was approximately 29% in both groups, the post-intervention sFLR index was higher in the LVD group but not statistically significant (46.1% vs 39.8%, p=0.214). There is no comparison between OS and DFS in this article[34] (table 2).

Portal vein embolisation followed by liver resection versus no-portal vein embolisation

When comparing PVEfLR to LR without PVE, it is important to note that these groups differ fundamentally at baseline, with the PVEfLR cohort typically having more advanced or complex disease. Despite this, four studies reported similar OS rates between the groups.[23 27 29 32] Findings for DFS were heterogeneous, with one large study noting significantly worse DFS in the PVEfLR group.[29] Postoperative complications and 90-day mortality were generally higher in the PVEfLR group, which is consistent with their more complex preoperative status.[23 29] However, hospital stay was significantly shorter in the PVEfLR group in one study[32] (table 2).

DISCUSSION

Although LR is the only curative treatment currently available for patients with CRLM, less than 25% of patients are initially resectable.[3 4 6] PVE, one of the first preoperative procedures invented with the aim of increasing FLR, making more patients eligible, aims to address this issue.[7] Meanwhile, other techniques such as ALPPS, PVL and LT

have been developed and provide more options for this cohort of patients.[35 36] Depending on the availability of a donor liver, patient characteristics, treatment regimen or other influencing factors, the outcomes of the above procedures will vary. This rapid review compared the short- and long-term outcomes of each technique with PVEfLR. It also highlights the role of PVE as an intervention to prepare patients with CRLM for potentially curative LR based on a narrative synthesis of fourteen research articles published from 2014 to 2025.

In terms of short-term outcomes, the PVEfLR group showed lower inpatient and 90-day mortality rates than the ALPPS group, although the differences were not statistically significant. In contrast, the 90-day mortality rate was significantly higher in the PVEfLR group compared with the no-PVE group. Regarding postoperative complications, the PVEfLR group had a significantly higher rate of complications compared with the no-PVE group, while showing a similar rate with the LT group. Notably, the PVEfLR group experienced fewer complications than the ALPPS and PVL groups, with the difference only reaching statistical significance when compared with ALPPS. The number of patients with grade B PHLF was similar in the ALPPS and PVEfLR groups. With negative margins as the surgical goal, the ALPPS group had better results than the PVEfLR group, although the difference was not significant.[37] This review noted that with the advantage of significantly shorter hospital stay compared with the PVL group and no PVE, as well as no difference in mean FLR growth rate when compared with ALPPS and PVLfLR, PVEfLR may be the preferred method in clinical practice. Part of this is consistent with findings of a systematic review, which reported comparable FLR volumes and complication rates between PVLfLR and PVEfLR.[38] However, the FLR growth rates in ALPPS and PVEfLR were reported inversely. In the scandinavian multicenter randomized controlled trial, ALPPS is the technique with the significantly higher rate of FLR gain than TSH with PVEfLR, 68% versus 36%, p value<0.0001.[39] Being a less invasive procedure, PVEfLR is also more widely used, as reflected in the number of patients (PVEfLR: 1953 patients, PVL: 123 patients in 21 studies).[40] Overall, PVEfLR has shown favourable short-term outcomes compared with PVLfLR and especially ALPPS, while maintaining comparable performance to LT. PVEfLR remains a valuable option, particularly for patients at a higher risk of complications or when slower enlargement is clinically acceptable. Because it is not donor-dependent, this preoperative technique offers a more accessible and less expensive option, making it more widely applicable to a wider range of patients.

A key challenge in interpreting these results, particularly the comparison between PVEfLR and strategies such as ALPPS or LT, is the handling of 'drop-out' patients. In the PVEfLR series, a significant proportion of patients (up to 28% in one study[25]) do not proceed to resection due to inadequate hypertrophy or disease progression and are often analysed on an 'intent-to-treat' basis. In contrast, outcomes for ALPPS and LT are frequently reported on a 'per-protocol' basis, including only those who completed the entire procedure. This fundamental difference in cohort analysis can bias outcomes in favour of techniques with higher completion rates and must be considered when comparing their efficacy.[2 4 25]

In the long-term outcome measurements, only the LT group showed significantly better OS than the PVEfLR group. For the other groups, including ALPPS and no-PVE, the OS and DFS results were inconsistent, with no statistically significant differences observed. These heterogeneous findings reflect the diversity in study size, treatment regimens, patient selection criteria and baseline characteristics across the studies. Despite being an older technique, PVEfLR achieved OS rates comparable to the more modern ALPPS method, emphasising its value in clinical practice. While PVE is a technique to convert unresectable patients into surgical candidates, the characteristics of PVEfLR and no-PVE patients are dissimilar. When comparing the results of these two groups, PVEfLR still achieved similar results in terms of OS and DFS rates, while having a shorter hospital stay. Therefore, PVEfLR is an approach that can help patients with more complex features achieve survival outcomes nearly equivalent to those with less complex features, suggesting that PVE helps close the gap in patients with inadequate FLR. Among the techniques compared, PVEfLR maintained a favourable safety profile. It is important to realise that PVE converted initially unresectable patients into surgical candidates and maintained the same survival rate as the hepatectomy-alone group.

CONCLUSION

This review synthesised research published over the past decade to compare the outcomes of PVEfLR with other surgical and intervention treatments for patients with CRLM. The findings highlight the impact of PVE on the treatment of patients with unresectable CRLM by converting them into surgical candidates while maintaining survival with lower complication rates. Further research should focus on combining PVE with other methods, such as chemotherapy or immunotherapy, to yield better results. The current authors are designing a retrospective cohort study of an international sample of patients with CRLM to investigate the impact of PVEfLR on treating patients with CRLM. In a nutshell, PVE remains the appropriate approach for initially unresectable patients.

Some limitations should be considered alongside the strengths of this rapid review while interpreting the findings. Many studies had small sample sizes and retrospective designs, limiting the strength of the evidence. Furthermore, the lack of RCTs directly comparing PVE with alternative techniques limits the ability to conclude these interventions' relative efficacy and safety.

One limitation of this review was the inability to access full text in a study as it is a conference abstract.[21–24]

Although we still have sufficient data to conduct the review, the lack of specific patient selection criteria, statistical analysis and outcome measures makes the review incomplete. Therefore, the accuracy of the results extracted from such studies may impact the reliability of the review's findings.

Implications

The findings of this rapid review suggest that PVEfLR is a valuable preoperative intervention to increase FLR and enable LR. In addition, PVEfLR showed a slower time to achieve hypertrophy compared with ALPPS and a lower survival rate compared with LT in patients with high tumour volume. These findings indicate that with each patient's characteristics, the methods will have a certain suitability. Therefore, physicians need to rely on tumour burden, FLR volume and risk assessment of complications to determine the appropriate treatment strategy.

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ORCID iD

Mohammed Moinuddin https://orcid.org/0000-0001-9364-390X

REFERENCES

1 Akgül Ö, Çetinkaya E, Ersöz Ş, *et al*. Role of surgery in colorectal cancer liver metastases. *World J Gastroenterol* 2014;20:6113–22.
2 Kron P, Lodge JPA. Changing perspectives in the treatment of colorectal liver metastases. *Br J Surg* 2024;111:znad431.
3 Ivey GD, Johnston FM, Azad NS, *et al*. Current Surgical Management Strategies for Colorectal Cancer Liver Metastases. *Cancers (Basel)* 2022;14:1063.
4 Marcus RK, Aloia TA. Defining Resectability of Colorectal Cancer Liver Metastases: Technical and Oncologic Perspectives, in Colorectal Cancer Liver Metastases: A Comprehensive Guide to Management. Cham: Springer International Publishing, 2020:129–44.
5 Wang Y, Zhong X, He X, *et al*. Liver metastasis from colorectal cancer: pathogenetic development, immune landscape of the tumour microenvironment and therapeutic approaches. *J Exp Clin Cancer Res* 2023;42:177.
6 Zhai S, Sun X, Du L, *et al*. Role of Surgical Approach to Synchronous Colorectal Liver Metastases: A Retrospective Analysis. *Cancer Manag Res* 2021;13:3699–711.
7 Madoff DC, Abdalla EK, Vauthey JN. Portal vein embolization in preparation for major hepatic resection: evolution of a new standard of care. *J Vasc Interv Radiol* 2005;16:779–90.
8 Luz JHM, Gomes FV, Coimbra E, *et al*. Preoperative Portal Vein Embolization in Hepatic Surgery: A Review about the Embolic Materials and Their Effects on Liver Regeneration and Outcome. *Radiol Res Pract* 2020;2020:9295852.
9 Heil J, Schadde E. Simultaneous portal and hepatic vein embolization before major liver resection. *Langenbecks Arch Surg* 2021;406:1295–305.
10 Shindoh J, Tzeng C-WD, Aloia TA, *et al*. Safety and efficacy of portal vein embolization before planned major or extended hepatectomy: an institutional experience of 358 patients. *J Gastrointest Surg* 2014;18:45–51.
11 Chansangrat J, Keeratibharat N. Portal vein embolization: rationale, techniques, outcomes and novel strategies. *Hepat Oncol* 2021;8:HEP42.
12 Schnitzbauer AA, Lang SA, Goessmann H, *et al*. Right portal vein ligation combined with in situ splitting induces rapid left lateral liver lobe hypertrophy enabling 2-staged extended right hepatic resection in small-for-size settings. *Ann Surg* 2012;255:405–14.
13 Hasselgren K, Røsok BI, Larsen PN, *et al*. ALPPS Improves Survival Compared With TSH in Patients Affected of CRLM: Survival Analysis From the Randomized Controlled Trial LIGRO. *Ann Surg* 2021;273:442–8.
14 Vyas S, Markar S, Partelli S, *et al*. Portal vein embolization and ligation for extended hepatectomy. *Indian J Surg Oncol* 2014;5:30–42.
15 Abdalla M, Collings AT, Dirks R, *et al*. Surgical approach to microwave and radiofrequency liver ablation for hepatocellular carcinoma and colorectal liver metastases less than 5 cm: a systematic review and meta-analysis. *Surg Endosc* 2023;37:3340–53.
16 Abreu P, Gorgen A, Oldani G, *et al*. Recent advances in liver transplantation for cancer: The future of transplant oncology. *JHEP Rep* 2019;1:377–91.
17 Tricco AC, Antony J, Zarin W, *et al*. A scoping review of rapid review methods. *BMC Med* 2015;13:224.
18 Institute, J.B. The joanna briggs institute critical appraisal tools for use in jbi systematic reviews. *Critical Appraisal Checklist for Cohort Studies*; 2017.
19 Phillips B. Oxford Center for Evidence-based Medicine. Levels of Evidence, Available: http://www. cebm
20 Wells GA. The newcastle-ottawa scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. 2000.
21 Werey F, Dembinski J, Yzet T, *et al*. Left Hemi-liver Hypertrophy after Right Portal Vein Ligation versus Embolization: A Comparative Study. *HPB (Oxford)* 2023;25:S361–2.
22 Bednarsch J, Ulmer TF, Czigany Z, *et al*. Oncologic outcome analysis of two-stage hepatectomy with portal vein embolization versus associating liver partition and portal vein ligation for patients with colorectal liver metastases. *HPB (Oxford)* 2018;20:S412–3.
23 Collin Y. SURVIVAL OF PATIENTS AFTER PORTAL EMBOLIZATION FOR LIVER METASTASES OF COLORECTAL CANCER. *HPB (Oxford)* 2015;17:19.
24 Saturday, February 22, 2014, 2:30pm–4:30pm Parallel Oral Abstract G Liver/Other. *HPB (Oxford)* 2014;16:45–52.
25 Dueland S, Yaqub S, Syversveen T, *et al*. Survival Outcomes After Portal Vein Embolization and Liver Resection Compared With Liver Transplant for Patients With Extensive Colorectal Cancer Liver Metastases. *JAMA Surg* 2021;156:550–7.
26 Werey F, Dembinski J, Michaud A, *et al*. Right portal vein ligation is still relevant for left hemi-liver hypertrophy: results of a comparative study using a propensity score between right portal vein ligation and embolization. *Langenbecks Arch Surg* 2023;409:25.
27 Collin Y, Paré A, Belblidia A, *et al*. Portal vein embolization does not affect the long-term survival and risk of cancer recurrence among

colorectal liver metastases patients: A prospective cohort study. *Int J Surg* 2019;61:42–7.
28 Simoneau E, Alanazi R, Alshenaifi J, *et al*. Neoadjuvant chemotherapy does not impair liver regeneration following hepatectomy or portal vein embolization for colorectal cancer liver metastases. *J Surg Oncol* 2016;113:449–55.
29 Huiskens J, Olthof PB, van der Stok EP, *et al*. Does portal vein embolization prior to liver resection influence the oncological outcomes - A propensity score matched comparison. *Eur J Surg Oncol* 2018;44:108–14.
30 Ali Deeb A, Rauchfuß F, Gaßler N, *et al*. Liver regeneration after two-stage liver transplantation is more effective than after other preconditioning procedures in colorectal liver metastases. *J Hepatobiliary Pancreat Sci* 2023;30:615–24.
31 Bednarsch J, Czigany Z, Sharmeen S, *et al*. ALPPS versus two-stage hepatectomy for colorectal liver metastases--a comparative retrospective cohort study. *World J Surg Oncol* 2020;18:140.
32 Reissfelder C, Rahbari NN, Bejarano LU, *et al*. Comparison of various surgical approaches for extensive bilateral colorectal liver metastases. *Langenbecks Arch Surg* 2014;399:481–91.
33 Reese T, Björk D, Longva AMH, *et al*. Oncological safety of portal vein embolization without prior tumour clearance in the future liver remnant followed by one-stage hepatectomy for bilateral colorectal liver metastases. *Br J Surg* 2025;112:znaf198.
34 Haddad A, Khavandi MM, Lendoire M, *et al*. Propensity Score-Matched Analysis of Liver Venous Deprivation and Portal Vein Embolization Before Planned Hepatectomy in Patients with Extensive Colorectal Liver Metastases and High-Risk Factors for Inadequate Regeneration. *Ann Surg Oncol* 2025;32:1752–61.
35 Foss A, Adam R, Dueland S. Liver transplantation for colorectal liver metastases: revisiting the concept. *Transpl Int* 2010;23:679–85.
36 Yi F, Zhang W, Feng L. Efficacy and safety of different options for liver regeneration of future liver remnant in patients with liver malignancies: a systematic review and network meta-analysis. *World J Surg Oncol* 2022;20:399.
37 Symeonidis D, Tepetes K, Tzovaras G, *et al*. Colorectal Cancer Liver Metastases: Is an R1 Hepatic Resection Accepted? *Clin Pract* 2022;12:1102–10.
38 Pandanaboyana S, Bell R, Hidalgo E, *et al*. A systematic review and meta-analysis of portal vein ligation versus portal vein embolization for elective liver resection. *Surgery* 2015;157:690–8.
39 Sandström P, Røsok BI, Sparrelid E, *et al*. ALPPS Improves Resectability Compared With Conventional Two-stage Hepatectomy in Patients With Advanced Colorectal Liver Metastasis: Results From a Scandinavian Multicenter Randomized Controlled Trial (LIGRO Trial). *Ann Surg* 2018;267:833–40.
40 Isfordink CJ, Samim M, Braat M, *et al*. Portal vein ligation versus portal vein embolization for induction of hypertrophy of the future liver remnant: A systematic review and meta-analysis. *Surg Oncol* 2017;26:257–67.