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ORIGINAL RESEARCH

Simultaneous Liver Venous Deprivation Following Hepatic Arterial Chemoembolization Before Major Hepatectomy for Hepatocellular Carcinoma: A New Methods to Achieve Hypertrophy Liver Remnant

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Purpose: Liver venous deprivation (LVD; simultaneous portal vein embolization and hepatic vein embolization) has been the latest surgical strategy for rapid future liver remnant (FLR) hypertrophy. The aim of this study was to assess the feasibility, safety, and efficacy of simultaneous LVD following hepatic arterial chemoembolization (TACE-LVD) before major hepatectomy for hepatocellular carcinoma (HCC).

Patients and Methods: A retrospective analysis of the outcomes of 23 HCC patients who underwent TACE-LVD at our center between October 2019 and October 2023 was conducted. An assessment of postoperative complications, FLR volume, liver function, and tumor response was performed.

Results: All patients successfully underwent TACE-LVD. No other serious complications occurred except in 1 patient who underwent puncture drainage due to excessive pleural effusion. Following TACE-LVD, transaminase levels peak two days before rapidly decreasing and return to preoperative levels within one week. The ratio of FLR to standardized liver volume increased from 35.9% (interquartile range [IQR], 8.6) to 46.4% (IQR, 8.2), with a mean degree of hypertrophy and kinetic growth rate of 13.2% (IQR, 5.4) and 4.4% (IQR, 1.8) per week, respectively. At the first assessment after TACE-LVD, most patients exhibited sufficient FLR for hepatectomy, except for 4 patients with cirrhosis. The modified response evaluation criteria for solid tumor assessment revealed a disease control rate of 95.7%, with only 1 patient (Barcelona Clinic Liver Cancer stage C) developing intrahepatic disease progression.

Conclusion: TACE-LVD seems to be a feasible, safe, and effective strategy for rapid FLR hypertrophy. Moreover, TACE-LVD may be a therapeutic choice if insufficient FLR hypertrophy precludes resection. This strategy warrants further exploration.

Keywords: hepatocellular carcinoma, hepatectomy, liver hypertrophy, liver venous deprivation, arterial chemoembolization

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Introduction

Hepatectomy remains the primary therapeutic modality for patients with hepatocellular carcinoma (HCC); however, its application is limited by factors such as tumor size, number, location, hepatic function, and the general physical condition of the patient, and only a minority of patients can tolerate surgical intervention.[1] With advancements in surgical techniques and perioperative management, the indications for hepatectomy have progressively expanded, permitting a broader population of patients to benefit from this intervention. Nevertheless, an insufficient future liver remnant (FLR) volume consistently serves as a major factor restricting hepatectomy and constitutes a significant contributor to postoperative hepatic dysfunction.[2,3]

Currently, the cornerstone of surgical intervention is parenchymal-sparing hepatectomy, which aims to eradicate target lesions while ensuring the integrity of the remaining liver structure and maximizing its functional volume. Over the past three decades, several strategies have been developed to optimize the FLR to improve patient prognosis. From the initial use of the portal vein embolization (PVE) technique to the subsequent advent of associating liver partition and portal vein ligation for staged hepatectomy (ALPPS), these strategies have facilitated rapid hypertrophy of the FLR by altering portal vein blood flow distribution, resulting in maximum benefit for patients.[4–7] Preoperative PVE, as a traditional and safe procedure, has been widely employed in patients undergoing extended hepatectomy; however, PVE, as a standalone method, sometimes induces sufficient liver regeneration within a short timeframe but leads to the inability to perform hepatectomy in more than 20% of PVE patients due to inadequate FLR hypertrophy or tumor progression.[2] In contrast, the ALPPS technique, involving staged hepatectomy with liver parenchymal transection and portal vein ligation, has achieved satisfactory FLR hypertrophy through more thorough liver parenchymal division. Nevertheless, this strategy is accompanied by increased postoperative morbidity and mortality.[8]

In the pursuit of more efficient and safer alternatives, Hwang et al reported in 2009 that sequential hepatic venous embolization (HVE) following PVE had an incremental effect on FLR hypertrophy.[9,10] Building upon this foundation and aiming to streamline and optimize the preoperative liver preparation phase, Boris et al were the first to combine PVE and HVE in a single surgical procedure, formally termed liver venous deprivation (LVD).[11] LVD partially addresses the limitations of PVE and ALPPS; however, the current literature on this strategy is predominantly focused on the treatment of liver tumors without concomitant cirrhosis, such as colorectal liver metastases or biliary tumors.[2,12] Limited information is available regarding its application in HCC patients with cirrhosis. However, despite the excellent clinical outcomes of LVD, proactive measures are still needed to address situations of inadequate FLR growth or challenges arising from tumor progression during the waiting period. In other words, the control of tumor progression must be viewed as equally important to the promotion of rapid FLR hypertrophy. In the past, sequential arterial and portal vein embolization (TACE-PVE) has been explored for the treatment of HCC patients with cirrhosis before hepatectomy. This strategy facilitates rapid FLR hypertrophy and achieves additional efficacy in controlling tumor progression.[13–16] Additionally, in the era of a lack of powerful systemic therapy, TACE is the main means of conversion therapy for HCC. Early on, the results of several RCTs showed that TACE has the potential for surgical resection in patients with initially unresectable HCC and translates into a survival benefit.[17,18] However, the staged implementation of two different procedures adds to the overall surgical waiting time.

To achieve the dual objectives of promoting rapid hypertrophy of the FLR and treating tumors, our team pioneered the simultaneous application of superselective hepatic arterial chemoembolization and liver venous deprivation (TACE-LVD) for the treatment of HCC patients with insufficient FLR volume. The aim of this study was to assess the feasibility, safety, and efficacy of this combined strategy for the treatment of HCC patients with insufficient FLR volume.

Patients and Methods

This study retrospectively analyzed the outcomes of patients who underwent TACE-LVD at the First Affiliated Hospital of the University of Science and Technology of China from October 2019 to October 2023. Our center's multi-disciplinary team, consisting of liver surgeons, oncologists, hepatologists, and interventional radiologists, provided treatment plans for all patients. The determination of whether a patient had the potential to undergo hepatectomy (right hepatectomy or extended right hepatectomy) was made comprehensively based on preoperative laboratory examination and abdominal computed tomography (CT). In general, the criteria for TACE-LVD treatment were as follows: (1) Eastern Cooperative Oncology Group (ECOG) score of 0 or 1; (2) Child–Pugh class A or B7; (3) limitation

of the tumor to the right trilateral lobe, and minor vascular invasion of the right portal vein (Vp1 or Vp2) as detected by imaging was allowed; and (4) the preoperative FLR was < 30% of the standardized liver volume (SLV) in patients with no basis for liver disease and < 40% of the SLV in patients with chronic liver disease or liver parenchymal injury.

Operative Procedure

TACE-LVD is performed in the following order: TACE, PVE, and HVE (Figure 1). The aforementioned procedures were performed by a single experienced interventionalist at the senior level.

Transarterial Chemoembolization

Under local anesthesia, a 5-French RH catheter (Terumo, Tokyo, Japan) was introduced through the femoral artery puncture pathway. The catheter was individually inserted into the celiac trunk, superior mesenteric artery, right renal artery, and inferior phrenic artery for vascular angiography to identify the arterial blood supply to the hepatic tumor. Using a 2.7- or 3-French microcatheter, selective catheterization was subsequently performed into the arterial supply of the tumor. In conjunction with intraoperative digital subtraction angiography, the position of the microcatheter was confirmed. A mixture of pirarubicin (30 mg) and an appropriate amount of iodized oil was injected through the microcatheter to embolize the supplying arteries, followed by the administration of gelatin sponge particles to enhance the embolization process until blood flow ceased, thereby achieving maximal blockade of the tumor's blood supply. The dose of iodized oil was determined based on the tumor size and liver function, with a maximum dose not exceeding 15 mL. For giant tumors, we prioritized embolizing all tumoral arteries near the FLR to avoid tumor spread while waiting for hepatectomy.

Liver Venous Deprivation

Owing to the association between the tumor and portal vein, the tumor's ipsilateral or contralateral portal vein was subjected to intraoperative ultrasound-guided percutaneous puncture, followed by catheter placement into the central portal vein for angiography. This procedure aimed to ascertain the absence of cancer thrombus or thrombus in the healthy portal vein branch (specifically, the left branch) and evaluate the blood flow velocity in the portal vein. The catheter was subsequently meticulously inserted into the right branch of the affected lateral portal vein. The catheter was then superselectively inserted into the right branch of the affected lateral portal vein. Based on the blood flow velocity analysis of the portal vein, the right branch of the portal vein was effectively embolized via a combination of medical glue and iodized oil at a ratio of 1:3/4. The completeness of the embolization was verified through angiography, which

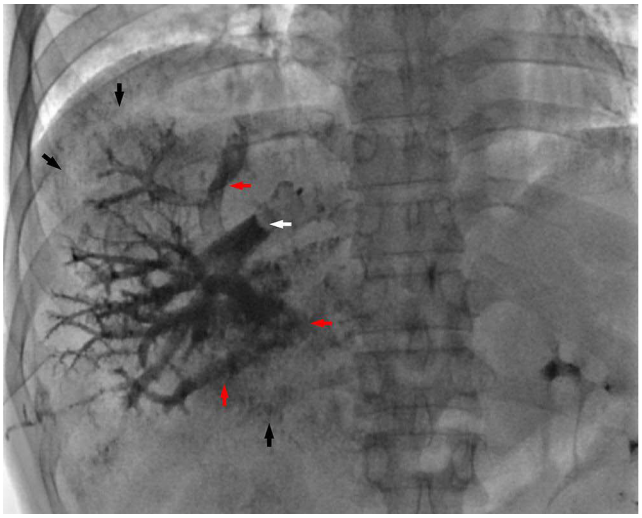

Figure 1 Digital subtraction angiography after TACE-LVD. Right branch of portal vein (red arrow); right hepatic vein (white arrow); iodized oil deposition (black arrow).

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also confirmed the unobstructed flow in the primary and left branches. To mitigate the risk of bleeding, the intrahepatic puncture pathway was securely sealed using either a spring ring or medical glue.

Based on the correlation between the tumor and the right hepatic vein, the procedure involved ultrasound-guided percutaneous puncture of the right hepatic vein or the jugular strategy to access the right hepatic vein and insert a 10F vascular sheath. A catheter was inserted into a 10F vascular sheath placed within the right hepatic vein. Angiography was employed to determine the diameter of the right hepatic vein and identify the distal branch and potential communicating branch of the vein. A vascular occluder with a diameter 50% greater than the diameter of the placed hepatic vein was chosen. After a guidewire was secured, the vascular occluder delivery system was introduced through the vascular sheath. The vascular occluder was inserted through the vascular sheath and positioned at least 10 mm from the proximal cardiac end of the occluder to the junction of the hepatic vein and inferior vena cava. Once the hepatic vein is successfully obstructed, blood flow becomes sluggish and stagnant. A catheter was subsequently introduced through the previously preserved guidewire, and a mixture of medical glue and iodized oil (at a ratio of 1:2) was injected through the catheter to embolize the distal and communicating branches of the right hepatic vein.

Liver Volumetric Analysis

Abdominal CT was performed before and three weeks after TACE-LVD. The CT images were reconstructed via the IQQA Intelligent Image Interpretation and Analysis System (EDDA Technologies, Princeton, NJ) using various measurements, including total liver volume excluding tumor volume (TLV) and FLR volume. As previously described, the SLV was calculated by the formula −404.8+961.3×body surface area.[19]

The ratios of the FLR volume to the TLV and SLV were defined as the actual future liver remnant (aFLR) and the standardized future liver remnant (sFLR), respectively. Additionally, calculations were performed to determine the degree of FLR hypertrophy, hypertrophy rate, and kinetic growth rate (KGR). The degree of FLR hypertrophy was determined by subtracting the presFLR from the postsFLR, while the hypertrophy rate was calculated as (post-FLR−pre-FLR) ×100%/pre-FLR. The KGR was calculated by dividing the degree of FLR hypertrophy by the number of weeks.

Postoperative Follow-Up

The laboratory outcomes of the patients were continuously monitored both preoperatively and at specific intervals postoperatively (1, 2, 3, and 7 days and three weeks) to assess alanine aminotransferase (ALT), aspartate aminotransferase (AST), total bilirubin (TBIL), albumin (ALB), and creatinine (Cr) levels and platelet (PLT) counts. The classification of postoperative complications was based on the Clavien–Dindo classification system to evaluate the efficacy of TACE-LVD for HCC patients with respect to the modified Response Evaluation Criteria in Solid Tumors (mRECIST).[20]

Statistical Analysis

The median (interquartile range [IQR]) or percentages (%) of the baseline characteristics of the patients were reported, depending on the retrospective nature of the data. Continuous variables were analyzed using Mann–Whitney *U*-test. P values < 0.05 were considered to indicate statistical significance. The statistical analysis was conducted via SPSS 26.0 software (SPSS, Inc., Chicago, IL). The reporting of this study conforms to the STROCESS criteria.[21]

Results

Patient Characteristics

A total of 23 patients (19 males and 4 females) underwent TACE-LVD at our hospital from October 2019 to October 2023. The preoperative characteristics of these patients are presented in Table 1. The median age of the patients was 62.0 (IQR, 19) years. The majority of the patients had chronic liver disease, specifically HBV-viral hepatitis (n=21) and cirrhosis (n=17), and presented with a significant median tumor burden of 14.0 (IQR, 4.6) cm. A few patients (n=8) had minor vascular invasion of the right portal vein (Vp1 or Vp2). The prospective surgical plan included a right hepatectomy (n=11) and an extended right hepatectomy (n=12).

Table 1 Patients and Tumor Characteristics

Variables	TACE-LVD (n=23)
Age (years), median (IQR)	62.0 (19)
Sex	
Male, n (%)	19 (82.6%)
Female, n (%)	4 (17.4%)
BMI (kg/m^2), median (IQR)	21.8 (3.0)
BSA (m^2), median (IQR)	1.67 (0.22)
ALT (U/L), median (IQR)	40.0 (29.5)
AST (U/L), median (IQR)	87.0 (68.2)
TBIL (μmol/L), median (IQR)	15.0 (12.2)
ALB (g/L), median (IQR)	38.1 (7.5)
HBV	
Yes, n (%)	21 (91.3%)
No, n (%)	2 (8.7%)
Cirrhosis	
Yes, n (%)	17 (73.9%)
No, n (%)	6 (26.1%)
Tumor size (cm), median (IQR)	14.0 (4.6)
Tumor number	
1, n (%)	20 (87.0%)
> 1, n (%)	3 (13.0%)
BCLC stage	
A/B, n (%)	15 (65.2%)
C, n (%)	8 (34.8%)
Prospective surgical plan	
Right hepatectomy, n (%)	11 (47.8%)
Extended right hepatectomy, n (%)	12 (52.2%)

Abbreviations: IQR, interquartile range; BMI, body mass index; BSA, body surface area; ALBI, bilirubin-albumin; HBV, hepatitis B virus; ALT, alanine aminotransferase; AST, aspartate aminotransferase; TBIL, total bilirubin; ALB, albumin; BCLC, Barcelona Clinic Liver Cancer.

Outcomes After TACE-LVD

All patients successfully underwent TACE-LVD, and no patients died. After TACE-LVD, one patient received whole blood for coagulation dysfunction. Additionally, one patient developed bacteremia, and another developed excessive pleural effusion, necessitating puncture drainage. No patients had peritonitis, liver abscess, or acute liver dysfunction. The intraoperative and postoperative outcomes are shown in Table 2. After TACE-LVD, patients experienced significant increases in ALT and AST levels, reaching a peak 2 days later. These levels subsequently rapidly decreased, and returned to their baseline levels before TACE-LVD within 3 weeks (Median ALT, AST were 28.0 [IQR, 26.0], 60.0 [IQR, 48.0] U/L, respectively). ALB and ALT decreased slightly after TACE-LVD but returned to normal at 3 weeks, whereas TBIL (23.5 [IQR, 25.3] μmol/L) was slightly elevated. In addition, Cr remained stable Liver enzyme profiles after surgery are shown in Figure 2.

Table 2 Outcomes After TACE-LVD

Variables	TACE-LVD (n=23)
Operation time (minutes), median (IQR)	120.0 (62.5)
Postoperative hospital stays, days	8.0 (0.5)
Postoperative transfusion of blood products, n (%)	1 (3.8%)
Infection, n (%)	1 (3.8%)
Puncture drainage, n (%)	1 (3.8%)
Clavien-Dindo ≥ 3, n (%)	1 (3.8%)

Abbreviation: IQR, interquartile range.

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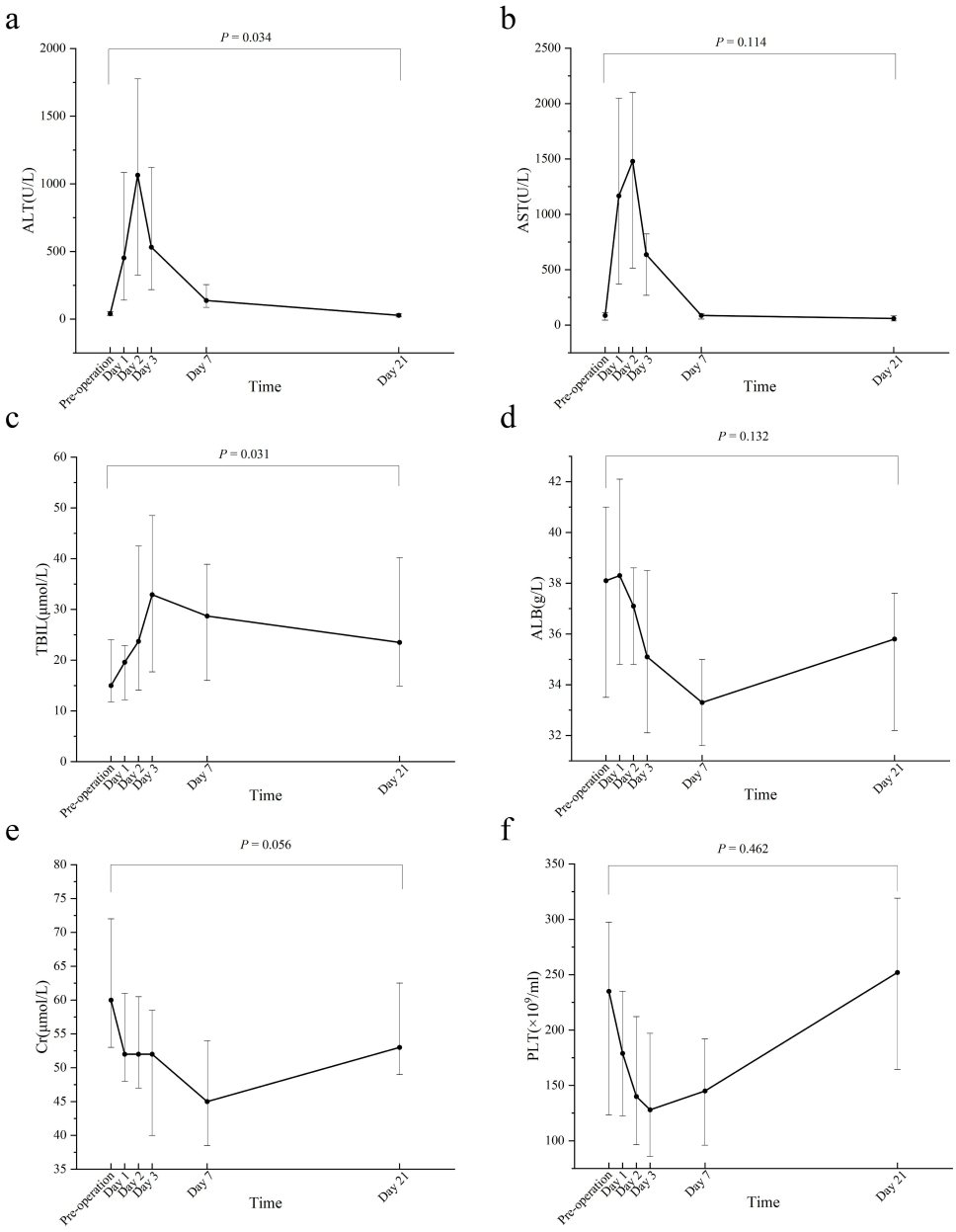

Figure 2 The laboratory examination results before and 1, 3, 5, 7 and 21 days after TACE-LVD. (**a**) alanine aminotransferase; (**b**) aspartate aminotransferase; (**c**) total bilirubin; (**d**) albumin; (**e**) creatinine and (**f**) platelet counts. Values are expressed as median (IQR).

Volumetric Analysis and Outcomes

The liver volume characteristics are outlined in Table 3. The median SLV of the patients was 1229.0 (209.5) mL, and they all underwent TACE-LVD due to a small FLR volume. After three weeks, the median FLR volume significantly increased from 402.0 (IQR, 111.0) mL at baseline to 553.0 (IQR, 131.0) mL. Concurrently, the median TLV increased from 1183.0 (IQR, 237.5) mL to 1311.0 (IQR, 315.5) mL. The sFRL also increased significantly from 35.9% (IQR, 8.6) to 46.4% (IQR, 8.2). The KGR of FLR was 4.4% (IQR, 1.8) /week, resulting in a median degree of FLR hypertrophy of 13.2% (IQR, 5.4).

A notable increase in the volume of the FLR was evident following abdominal CT in most patients with sufficient FLR for hepatectomy (Figure 3); however, this was not the case for 4 patients with cirrhosis. In instances where FLR was still inadequate or the patient declined surgery, repeat TACEs were commonly arranged and combined with systemic therapy to control tumor progression.

Table 3 Volumetric Analysis and Outcomes

Variables	TACE-LVD (n=23)
Preoperative	
SLV (mL), median (IQR)	1229.0 (209.5)
TLV (mL), median (IQR)	1183.0 (237.5)
FLR volume (mL), median (IQR)	402.0 (111.0)
sFLR (%), median (IQR)	35.9 (8.6)
aFLR (%), median (IQR)	35.2 (8.9)
Three weeks after TACE-LVD	
TLV (mL), median (IQR)	1311.0 (315.5)
FLR volume (mL), median (IQR)	553.0 (131.0)
Post FLR – pre FLR (mL), median (IQR)	153.0 (64.0)
sFLR (%), median (IQR)	46.4 (8.2)
aFLR (%), median (IQR)	44.7 (8.0)
Degree of hypertrophy (%), median (IQR)	13.2 (5.4)
The FLR hypertrophy rate (%), median (IQR)	36.2 (13.9)
KGR (%), median (IQR)	4.4 (1.8)

Abbreviations: IQR, interquartile range; SLV, standardized liver volume; TLV, total liver volume excluding tumor volume; FLR, future liver remnant; sFLR, standardized future liver remnant; aFLR, actual future liver remnant; KGR, kinetic growth rate.

Tumor Outcomes

Despite challenges in inducing significant tumor shrinkage within a limited timeframe, most patients exhibit dense iodized oil deposits and extensive necrosis (either spontaneous necrosis or necrosis induced by TACE-LVD) within the

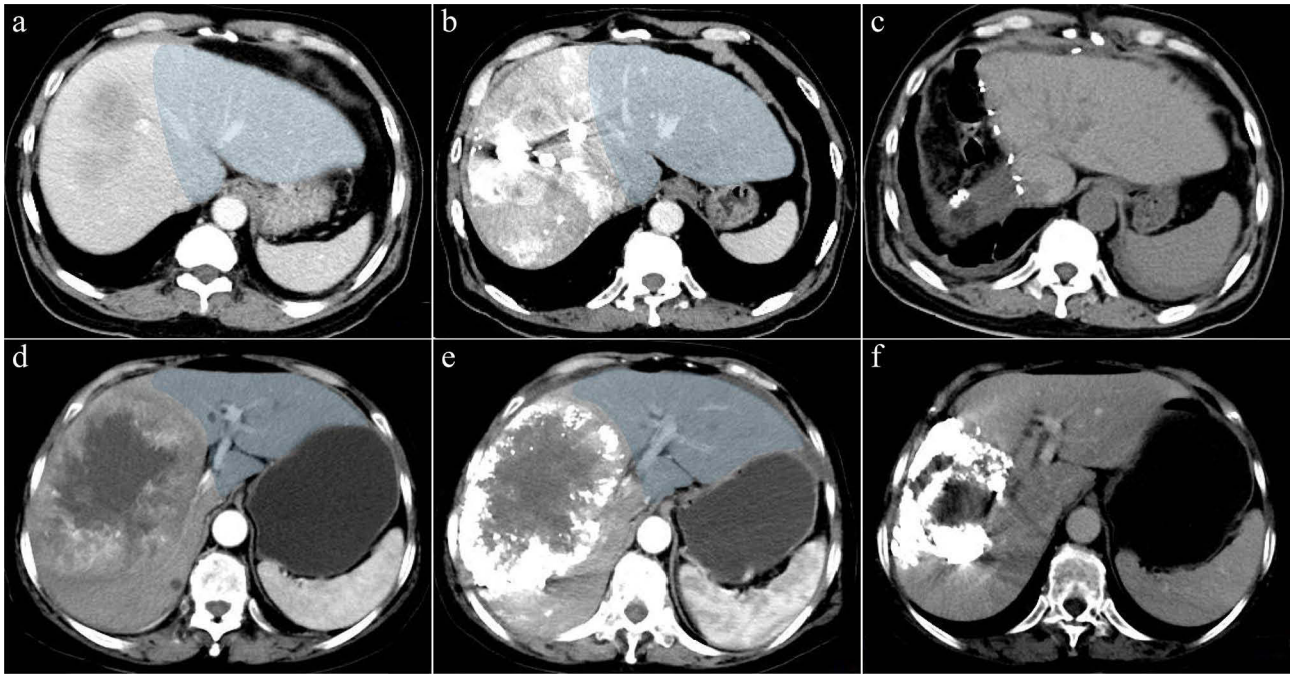

Figure 3 Abdominal CT before and after TACE-LVD. A male patient presented with a solitary giant tumor (16.1 cm) in the right lobe with a sFLR of 33.2% and cirrhosis. Following assessment by a multidisciplinary team, the patient was deemed a candidate for right hepatectomy (**a**). Three weeks after TACE-LVD, his sFRL increased to 46.4%, and the disease remained stable (**b**). Finally, the patient underwent a right hepatectomy on the 26th day post-TACE-LVD (**c**). A female patient presented with a solitary giant tumor (13.7 cm) in the right lobe, with an sFLR of 28.7%. Following assessment by a multidisciplinary team, she was deemed a candidate for extended right hepatectomy (**d**). Three weeks after TACE-LVD, she had sufficient sFLR (43.0%) to undergo hepatectomy. Additionally, dense iodized oil deposits and a significant expansion of internal tumor necrosis areas were observed, leading to a partial response according to mRECIST (**e**). Despite these positive outcomes, she refused surgical intervention and opted to continue TACE. After five months, significant tumor shrinkage was observed (**f**).

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tumor, with some regions retaining viability. When the baseline measurement of the longest diameter was captured, areas with dense iodized oil deposits and necrosis within the tumor were excluded. The mRECIST assessment revealed a disease control rate of 95.7%, with 7 patients experiencing a partial response and the disease of 15 patients remaining stable In addition, 1 patient classified as Barcelona Clinic Liver Cancer Stage C developed new lesions.

Discussion

In recent years, various strategies have been employed to improve surgical outcomes for patients who are anticipated to have insufficient FLR. The central theme of these strategies involves promoting compensatory hypertrophy in the healthy liver by altering the hepatic blood flow distribution. To our knowledge, the present study represents the first attempt to combine both TACE and LVD during the same procedure.

Generally, strategies to promote FLR hypertrophy may encounter obstacles and potential setbacks, including unsatisfactory FLR hypertrophy within a limited period, tumor progression, or severe complications. Previously, PVE served as the primary method for preoperative FLR hypertrophy, and ample data confirming its safety and efficacy have been obtained.[22–24] Nevertheless, it is worth noting that relying solely on PVE may not consistently yield favorable results. In addition to the slow pace of FLR hypertrophy, a commonly cited limitation of PVE is the potential for tumor progression during the preoperative liver preparation phase.[25,26] Theoretically, cessation of portal vein blood flow may lead to a compensatory increase in arterial blood supply to the tumor-bearing liver segment, referred to as the hepatic arterial buffer response, potentially accelerating tumor progression. In an effort to promote FLR hypertrophy while maintaining optimal control over tumor progression, researchers have attempted to combine TACE with PVE.[13–16] By simultaneously occluding the blood supply to the tumor-bearing liver segment, TACE-PVE eradicates the hepatic arterial buffer response, intensifies the ischemic conditions within the tumor-bearing liver segment, and stimulates accelerated FLR hypertrophy.[15,16] Additionally, TACE has potent antitumor effects, reducing the likelihood of tumor advancement. In recent studies, several scholars have reported that preoperative TACE is associated with longer overall and recurrence-free survival in patients with HCC.[27,28] Similarly, compared with PVE alone, several studies have indicated that TACE-PVE can produce more rapid and extensive FLR growth and can significantly improve the long-term prognosis of HCC patients.[13,14] Compared with TACE-PVE, LVD mitigates rather than eliminates the hepatic arterial buffer response by occluding hepatic venous outflow. Since its introduction, LVD has exhibited favorable outcomes in terms of FLR hypertrophy and has significantly reduced the duration of preoperative liver preparation.[2,11,12] However, further investigations are needed to better understand the safety and effectiveness of this innovative strategy in treating HCC patients, particularly those with concomitant cirrhosis. Additionally, there are potential questions that warrant consideration, such as what should be done if FLR hypertrophy is insufficient, and how can tumor progression be further controlled while waiting for FLR hypertrophy to occur?

Inspired by the strategies of TACE-PVE and LVD, we endeavored to answer these questions by combining both TACE and LVD during the same procedure. The basic hypotheses of the combined strategy are as follows: first, when comprehensively assessing treatment options, LVD may currently be the optimal option for promoting FLR hypertrophy through a safe and expeditious strategy; second, obstructing both the inflow and outflow channels of the tumor-bearing liver segment creates an "isolation effect", which may further enhance the control of tumor progression; and third, even if FLR hypertrophy is unsatisfactory, TACE is a suitable treatment for HCC. These hypotheses are supported by a study from Sy et al, who recently reported favorable outcomes of sequentially combining TACE and LVD for treating HCC.[29] Their combined strategy was able to safely and effectively induce FLR hypertrophy without causing tumor progression. The distinction is that we combined TACE and LVD during the same procedure, leading to substantial cost and time savings.

In our study, 18 patients met the surgical requirements after 3 weeks following TACE-LVD, with average FLR hypertrophy rates of 11.8 ± 3.7% and 35.4 ± 11.6%, respectively. Previous systematic reviews and meta-analyses reported average post-PVE hypertrophy rates of 37.9–49.4%, but these volumetric outcomes require substantial time before they occur (approximately 4–8 weeks).[22–24] Ogata et al reported a 12% increase in the FLR in HCC patients with cirrhosis after TACE-PVE, but those changes occurred over an average duration of 5.3 weeks.[13] Notably, comparing FLR hypertrophy outcomes associated with TACE-LVD with those associated with other strategies at longer intervals may not be appropriate. For HCC patients, reducing the waiting time before hepatectomy is advantageous for minimizing unforeseen events, such as tumor progression or patient withdrawal. In addition to effectively promoting FLR hypertrophy, TACE-LVD may further improve

oncological outcomes, as indicated by the reduction in viable regions observed by imaging and histological analyses. In the present study, TACE-LVD demonstrated favorable disease control rates (95.7%), with only 1 patient (BCLC-C) developing intrahepatic disease progression. The efficacy of FLR hypertrophy strategies in patients with underlying liver disease may not be satisfactory; however, they may at least provide the opportunity to completely eradicate the disease in comparison with other treatments. These strategies may be especially beneficial for patients with giant tumors. Furthermore, this combination strategy may be an appropriate treatment for HCC, even in cases where insufficient hypertrophy occurs or in which patients refuse surgery during treatment.

Rapid postoperative regeneration of liver function is crucial for the success of two-stage hepatectomy and its outcomes. It has been reported that after ALPPS, immature development of proliferated liver tissue frequently occurs, leading to delayed functional gain of the FLR.[30] Conversely, the functional and volumetric gains in the FLR following extended LVD were simultaneous.[31] In contrast to patients who underwent extended LVD, our patient cohort demonstrated a noteworthy increase in transaminase levels, suggesting a heightened severity of liver injury associated with combined TACE. Following the administration of hepatoprotective treatment, patients exhibited a relatively swift recovery of liver function, with levels returning to preoperative values at 3 weeks. For safety considerations, we employed superselective techniques. TACE-LVD exhibited favorable tolerability among all patients, with the majority experiencing only mild complications, primarily characterized by postembolization syndrome symptoms. No cases of liver abscess or bile duct injury occurred, and only one patient underwent percutaneous drainage due to excessive pleural effusion. Previously, LVD was less frequently performed in patients with cirrhosis due to concerns about potential exacerbation of portal hypertension after combined embolization. Fortunately, our findings align with those reported by Sy et al, and no significant manifestations of portal hypertension were observed in these patients.[29]

This study represents the first attempt to concurrently employ superselective TACE and LVD in the same surgical procedure for the treatment of HCC patients with insufficient FLR. Despite the initial positive outcomes, our study has certain limitations. First, this was a single center study, the small sample size may not adequately represent a broader population, and the optimal choice for promoting rapid FLR hypertrophy in HCC patients remains to be definitively established. Second, although our preliminary results did not reveal severe complications, the safety of the combined strategy requires further evaluation, particularly regarding concerns related to excessive hepatic ischemia and postoperative infection events.

Conclusion

In conclusion, these preliminary research results suggest that TACE-LVD is a safe and effective strategy for inducing rapid FLR hypertrophy. Moreover, TACE-LVD may be a suitable therapy if insufficient FLR hypertrophy precludes resection. However, the specific efficacy of this strategy requires evaluation through multi-center; larger clinical case cohorts and comparison with other strategies.

Abbreviations

HCC, Hepatocellular carcinoma; FLR, Future liver remnant; PVE, Portal vein embolization; ALPPS, Associating liver partition and portal vein ligation for staged hepatectomy; HVE, Hepatic venous embolization; LVD, Liver venous deprivation; TACE, Arterial chemoembolization; TACE-PVE, Sequential arterial and portal vein embolization; TACE-LVD, Hepatic arterial chemoembolization and liver venous deprivation; CT, Computed tomography; SLV, Standardized liver volume; TLV, Total liver volume excluding tumor volume; aFLR, Actual future liver remnant; sFLR, Standardized future liver remnant; KGR, Kinetic growth rate; ALT, Alanine aminotransferase; AST, Aspartate aminotransferase; TBIL, total bilirubin; ALB, Albumin; Cr, Creatinine; PLT, Platelet; mRECIST, Modified Response Evaluation Criteria in Solid Tumors; IQR, interquartile range.

Data Sharing Statement

Data for this study can be reasonably obtained by contacting the corresponding authors.

Ethics Approval and Informed Consent

The study was approved by the Ethics Committee of the First Affiliated Hospital of the University of Science and Technology of China (ID: 2022-KY-185) and carried out in accordance with the 1990 Declaration of Helsinki and its subsequent amendments. Given that this was a retrospective study and that patients' personal information was anonymized during data usage process, the ethics Committee waived the requirement for informed consent.

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Disclosure

The authors report no conflicts of interest in this work.

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