Technical Note

Laparoscopic liver ALPPS - How I do it

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Abstract

In complex oncological liver resections, insufficient future liver remnant (FLR) volume may become the most challenging problem to deal with in the postoperative setting. The Associating Liver Partition and Portal Vein Ligation for Staged Hepatectomy (ALPPS) is one of the techniques described for inducing hepatic hypertrophy and achieving an adequate FLR. The technique initially described is performed by a complete bipartition of the liver in the first operation and a portal vein ligation to achieve occlusion of the intrahepatic circulation followed by a major hepatectomy in the second operation once an adequate FLR has been reached. With the introduction of minimally invasive liver surgery, these procedures can be performed by laparoscopic or robotic approach. We aim to provide a comprehensive overview of ALPPS, highlighting key technical aspects. Furthermore, the main aspects of this technique based on current evidence, such as indications, outcomes, strengths, limitations and potential complications, will be analyzed.

Keywords: Minimally invasive, ALPPS, two-stage hepatectomy, surgical oncology, surgical technique, liver hypertrophy, future liver remnant (FLR)

INTRODUCTION

Despite the extraordinary progress made in liver surgery in recent years, insufficient liver volume after hepatectomy still represents an important clinical challenge and precludes patients from upfront major liver resection, as it predisposes them to high rates of morbidity and mortality[1,2]. For years, preoperative portal vein embolization (PVE) has been the standard approach for patients undergoing major hepatectomy with

expected insufficient future liver remnant (FLR)[3]. In patients with colorectal liver metastases (CRLM) with extensive bilobar disease not amenable to curative one-stage resection due to insufficient FLR, neoadjuvant chemotherapy followed by two-stage hepatectomy (TSH) was described as a potential curative option[4-6]. In 2012, Schnitzbauer *et al.* first introduced the procedure of associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) as an alternative for FLR augmentation[7].

ALPPS is a two-stage procedure that first combines portal vein occlusion with (partial/complete) parenchymal transection to induce rapid growth of the FLR; in the second stage, usually within 7-14 days after the first stage, and when adequate FLR hypertrophy has been obtained, hepatectomy is completed[7]. It was introduced as the potential surgical response to the high dropout rates seen in other bridging strategies[8]. Most of the accumulated experience with ALPPS is described in bilobar colorectal metastases; however, some other series have shown its potential in less frequent hepatic tumors or even in hepatitis-related hepatocellular carcinoma (HCC)[9-11].

ALPPS has been described as a high-risk operation due to the high interstage morbidity, including bile leak, septicaemia and liver failure[12-14]. Initial series of ALPPS reported mortality rates of up to 25%[15]. These initial problems were the main pitfall of a technique that, conversely, eliminates the main reason for the failure of two-stage classical hepatectomies, which is disease progression during the waiting period of FLR hypertrophy. Compared to other staged approaches, ALPPS induces rapid liver hypertrophy that reduces stage intervals. In addition, it may also be an effective alternative as a rescue after PVE failure[16]. Outcomes of ALPPS have significantly improved over recent years due to meticulous patient selection, procedure technical refinements and introduction of several modifications, such as partial-ALPPS, hybrid-ALPPS, mini-ALPPS, ablation-assisted ALPPS, tourniquet-ALPPS and/or minimally invasive approaches[17-24]. More recent analyses have demonstrated that continual research, improved understanding of the physiopathology of the procedure, and technical refinements have resulted in evident benefits, with a drop in 90-day mortality from 17% to 4% and major interstage complications from 10% to 3%[25]. The achievement of satisfactory long-term results relies on a careful patient selection and attempt to reduce perioperative complications. However, in the context of ALPPS, achieving this balance can be challenging. In this regard, a prediction model identifying predisposing risk factors to futile outcomes in ALPPS has been reported[26].

MINIMALLY INVASIVE ALPPS

Minimally invasive liver surgery (MILS) is one of the most important advances in liver surgery in recent years. The first laparoscopic liver resections (LLRs) were reported 30 years ago[27,28]. Since the first Louisville Consensus, laparoscopic liver surgery has been recognized as a safe and effective approach to perform liver resections by trained surgeons. Large meta-analyses reported better results in both short- and long-term outcomes for laparoscopic and robotic approaches[29,30-34]. The progressive dissemination of MILS has led liver surgeons to perform complex liver resections with adequate results[35]. In this regard, ALPPS is not an exception. In addition to the inherent advantages of MILS, such as reduced blood loss, faster recovery and shorter hospital stay, there are specific benefits, including a diminished formation of adhesions between stages, thereby facilitating the subsequent stage of the procedure. Nonetheless, it is essential to acknowledge that this approach involves technical complexity and a challenging learning curve, and may lead to longer operative times[36].

Table 1 summarizes the outcomes from the most relevant series related to minimally invasive ALPPS (MI-ALPPS), excluding case reports. Only two of these series included robotic approaches[39,40], and only one included a minimally invasive surgery (MIS) approach in both stages[39]. Two important observations should be noted from these studies: (a) Morbidity rate reported is heterogeneous, ranging between 0%-24% for

Table 1. Summary of studies performing minimally invasive ALPPS

Author	Year	ALPPS technique		Full MIS	EBL (mL)		FLVR hypertrophy (%)	Length of hospital stay (days)		Major complications (%)		90-day mortality (%)
		Stage 1	Stage 2		Stage 1	Stage 2		Stage 1	Stage 2	Stage 1	Stage 2	
Gall et al.[37]	2015	L-RALPPS (n = 4)	O-RH (n = 4)	N	NR	NR	62	NR	NR	20	NR	0
Truant et al.[38]	2018	L-partial ALPPS (n = 5)	O-REH (n = 5)	N	250	550	60	7	12	0	40	0
Jiao et al.[39]	2019	L-RALPPS (n = 24) R-RALPPS (n = 2)	O-RH (n = 14) L-RH (n = 4) R-RH (n = 1) O-REH (n = 4) L-REH (n = 1)	N	310	300	80.7	9.5	8	3.85	15.3	3.8
Machado et al.[20]	2017	L-ALPPS (n = 10)	L-RH (n = 3) L-REH (n = 7)	Y	200	320	118	NR	NR	0	0	0
Serenari et al.[40]	2020	L-ALPPS (n = 7) L-mini-ALPPS (n = 6) R-ALPPS (n = 1)	L-RH (n = 2) L-REH (n = 5)	Y	NR	NR	62	6.5	12	14.2	8.3	0
Li et al.[41]	2021	L-RALPPS (n = 60)	O-RH (n = 32) O-REH (n = 28)	N	165	628	45.7	NR	23.4	13.3	53.3	0

Major complications were defined as Clavien–Dindo classification ≥ IIIA grade. ALPPS: Associated liver partition with portal vein ligation for staged hepatectomy; MIS: minimally invasive surgery; EBL: estimated blood loss; FLRV: future liver remnant volume; RALPPS: radiofrequency-assisted ALPPS; RH: right hepatectomy; REH: right extended hepatectomy; NR: Not Reported; N: not; Y: yes.

Clavien–Dindo ≥ IIIA grade complications in stage 1 and 0%-53% in stage 2; and (b) the highest 90-day mortality rate reported was 3.8%. Case selection and indications (HCC *vs.* CRLM) may influence these outcomes. Moreover, the approach performed during stages is biased. Only the full MIS procedure was performed in two studies[20,40]. These studies reported a 90-day mortality rate of 0% and a Clavien–Dindo ≥ IIIA grade complication rate of approximately 0%-14.2% in stage 1 and 0%-8.3% in stage 2. Therefore, the evidence supporting minimal invasiveness is weak and mainly supported by case reports or case series, which is a major limitation[42]. Additionally, the heterogeneity among the series concerning the ALPPS techniques performed, indications or approaches in different stages makes it challenging to properly evaluate postoperative clinical outcomes. Evidence about open versus modified MI-ALPPS is lacking, making the assessment of the MIS role difficult. Moreover, reports about the robotic approach are limited. Considering these issues, the influence of MIS in ALPPS procedures is still uncertain.

HOW I DO A LAPAROSCOPIC ALPPS

The ALPPS technique and technical modifications described can be mostly performed by a minimally invasive approach, always in experienced hands. A step-
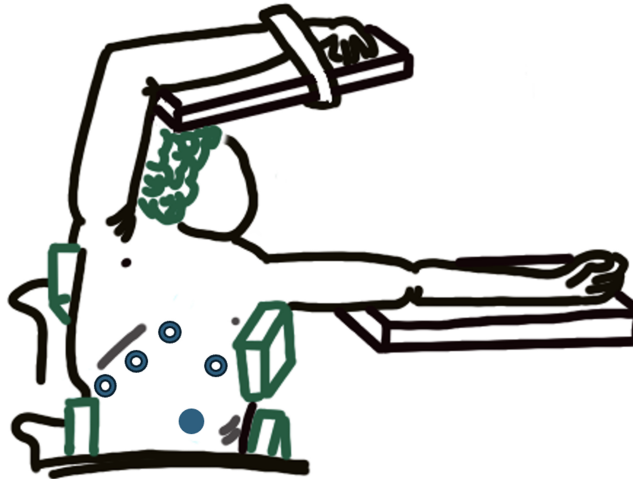
Figure 1. Patient and trocar positioning scheme.

by-step description of how different fully laparoscopic ALPPS techniques are performed is provided. Most of the modifications reported in current literature are based on full or partial parenchymal partitioning and in different vascular occlusion techniques.

Laparoscopic classic ALPPS

First stage

The patient is positioned in a 30° left decubitus tilt and in an anti-Trendelenburg position. Five access trocars are used for the procedure, keeping intraabdominal pressure around 12-14 mmHg [Figure 1]. Trocars are placed in the following locations: at the umbilical region (12 mm), subxiphoid region (5 mm), below the costal margin on the right midclavicular line (12 mm), below the costal margin on the right axillary line (5 mm), and one more trocar is inserted between the last two (5 mm).

● Similar to open ALPPS, the initial step is to explore the entire abdominal cavity. A meticulous intraoperative ultrasound (IOUS) examination of the FLR is mandatory. If there were lesions in the FLR, they must be resected. The gallbladder is removed. Liver is not mobilized and only falciform ligament is sectioned.

● The right portal vein is identified and transected extrahepatic hilar approach [Figure 2A]. This is usually performed using an endostapler. Parenchymal transection is performed by a caudal approach [Figure 2B].

● After completing the liver transection and portal vein ligation, confirming the complete deportalization of the tumor-bearing liver using IOUS is crucial.

● Since liver atrophy and contralateral hypertrophy may frequently alter the porta hepatis anatomy after stage 1, it is strongly recommended to mark the vasculobiliary structures of the tumor-bearing liver with vessel loops to facilitate their identification during stage 2 [Figure 2C and D]. It is also advisable but not mandatory to place vessel loops surrounding the right and middle hepatic veins.

● A hemostatic patch is placed on the transection surface to minimize adhesion between the divided sections of the liver and a Jackson-Pratt drain is placed between partitioned livers. Hemostasis control must be rigorous.

Second stage

Although variable, it is our routine practice to perform a computed tomography (CT) scan on days 10-14 after the first procedures to check volumetric status. If adequate growth is observed, the patient undergoes
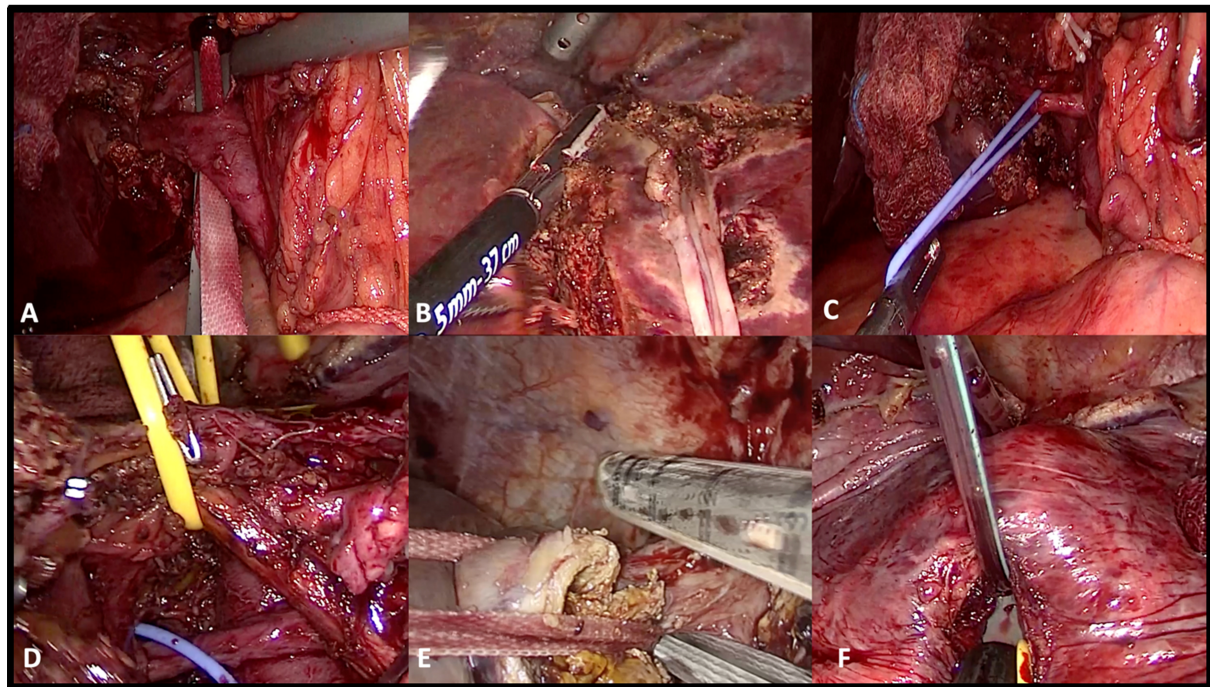
Figure 2. Different steps of the classic laparoscopic ALPPS; some of them are common with the ALPPS tourniquet. (A) Dissection of the right portal pedicle through Sugioka Gates; (B) Transection of liver parenchyma; (C) Right hepatic artery identification and referral; (D) Identification of right bile duct; (E) Right hepatic vein section with endostapler; (F) Hanging manoeuvre. ALPPS: Associating liver partition and portal vein ligation for staged hepatectomy.

the second stage of ALPPS. Usually, area surrounding parenchymal transection is affected by adhesions and clots which can be dissected. Vascular structures at the hilum of the affected hemiliver are identified by locating the vessel loops surrounding them. Subsequently, endostaplers are employed to transect the right hepatic vein and the middle hepatic vein if indicated [Figure 2E]. Ultrasonography (US) is used to assess liver perfusion and discard lesions in the future liver parenchyma.

Laparoscopic tourniquet ALPPS

First stage

This technique was initially described by Robles *et al.*[43]. In contrast to classical ALPPS, there is no bipartition of the parenchyma. A refined and updated version of this technique has been reported recently by our group including advanced laparoscopic techniques such as pure hanging maneuver and access throughout the liver gates reported by Sugioka *et al.*[17,44-46]. Figure 3 illustrates the first part of the ALPPS tourniquet procedure. In addition, our group published this technique in a step-by-step video to help the understanding of the technique due to its complexity[45].

Tourniquet ALPPS avoids liver splitting in the initial stage, resulting in a more conservative intervention. This leads to avoiding potential complications such as blood loss and bile leak associated with the initial stage of classic ALPPS. Moreover, segment IV remains connected to the hilar bifurcation, preventing ischemic necrosis. Patients undergoing laparoscopic Tourniquet ALPPS may benefit from early discharge after the first stage. In the second stage, minimal adhesions are observed, facilitating the liver transection along the tourniquet-induced ischemic line, with limited bleeding[18,45].
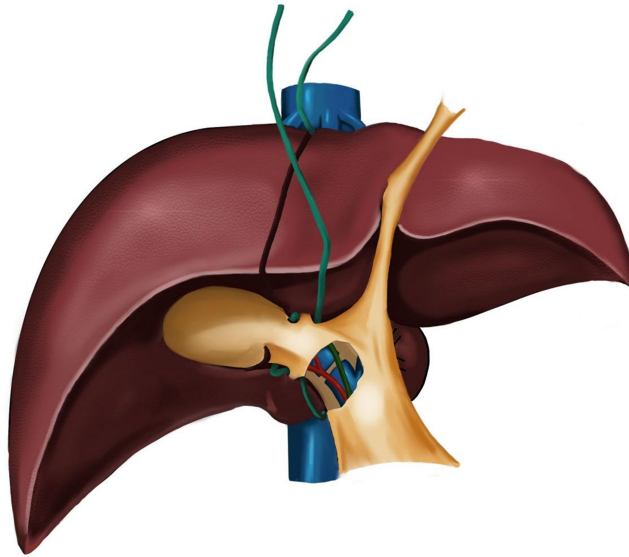
Figure 3. First part of ALPPS tourniquet procedure. The green tape shows the position of the tourniquet; after placement, it is tightened along the marked transection line, approximately 1 cm deep. It can be seen how it should pass between the right and middle suprahepatic vein and the passages made through Sugioka's gates. The section of the right portal vein is also shown. ALPPS: Associating liver partition and portal vein ligation for staged hepatectomy.

The patient is placed in the 30º semi-left lateral decubitus and reverse Trendelenburg position. Five trocars are placed. Pneumoperitoneum pressure is set at 12-14 mmHg. Trocars are placed in the following locations: at the umbilical region (12 mm), subxiphoid region (5 mm), below the costal margin on the right midclavicular line (12 mm), below the costal margin on the right axillary line (5 mm), and one more trocar is inserted between the last two (5 mm). Resection of the lesions located in the FLR is guided by ultrasound, if necessary, without mobilizing the liver. Cholecystectomy is performed.

● Similar to classic ALPPS, the right portal vein is identified and transected by extrahepatic hilar approach, as previously described.
● In our technique, a careful dissection of the retrohepatic tunnel is conducted to finally perform a hanging maneuver [Figure 2F][47]. In the case of a right hepatectomy in the second stage, the tourniquet is placed in the main portal fissure between the right and middle hepatic suprahepatic vein (Cantlie's line) using the hanging maneuver. Then, the tape is passed posterior to the right portal pedicle using extraglissonean approach to prevent occlusion of the right artery and right bile duct. In the case of a right trisectionectomy in the second stage, the tourniquet is placed in the umbilical fissure, passed between the left and middle suprahepatic veins, passed through Rex's recess and continued posterior to left portal pedicle. The left portal pedicle is identified and encircled by an extraglissonean approach to prevent an occlusion of the left artery and left bile duct.
● We have described a technical variant in case of ALPPS through the Cantlie's line. The Sugioka Gates G4, G5 and G6 are identified. The hanging tape is passed from G6 to G5 and then throughout G4 in case of a right hepatectomy. The Sugioka gates approach avoids uncontrolled damage, especially on the bile duct bifurcation, and facilitates subsequent second stage right hemihepatectomy.
● A 1-2 cm deep liver parenchyma transection is performed using bipolar and sealing devices combined with an ultrasonic dissector. Exhaustive hemostasis is mandatory.
● The tape is then tightened firmly. We strongly recommend to check with doppler IOUS that collaterals from MHV in the case of a right hepatectomy are collapsed and that main trunk of the MHV is kept intact to avoid congestion in the remnant.

Second stage
Similarly to classic ALPPS, a CT scan on days 10-14 after the first procedure to check volumetric status is performed. If adequate remnant volume is achieved, the procedure is finalized by a laparoscopic right hepatectomy or right trisectionectomy. In case of insufficient liver hypertrophy, the embolization of right hepatic vein or both middle and right hepatic vein to obtain a complete Liver venous deprivation (or "double vein embolization") may be performed to increase FLR. In case of insufficient liver hypertrophy or disease progression, the tourniquet should ideally be removed by a minimally invasive approach. Blunt dissection and the use of saline irrigation may facilitate removal of adhesions during tourniquet removal. However, this procedure should not be underestimated as iatrogenic injury may occur during surgery. In our experience, we only had to remove one tourniquet and there were no incidences.

The positioning and access trocars are the same as those used in the first stage. In the liver surface, the tape and the knot will be observed. By releasing the knot, an ischemic line is observed and transection in this area becomes easier. The tape is employed to perform a hanging maneuver that facilitates the transection plane. By pulling up the tape, access to the transection plane is easily gained towards the anterior surface of the inferior vena cava (IVC). However, it should noted that the tape may cause tight adhesions in the anterior surface of IVC that might be dissected with caution. The last step includes hepatic veins and Glissonean pedicles section using endostaplers.

CONCLUSION

MI-ALPPS is a technique with a high degree of complexity and must be performed by surgeons with expertise in MILS. The preliminary evidence suggests that it may be safe with a lower morbidity and mortality rate relative to open series. However, the number of series is limited, and caution should be taken to get powerful conclusions regarding the application of this technique.

DECLARATIONS

Authors' contributions
Conception and design of the study: Ciria R
Data review: Durán M, Calleja R, Pérez-de-Villar JM
Draft manuscript preparation: Durán M, Calleja R, Pérez-de-Villar JM
Critical review: Ciria R, Briceño J
All authors reviewed the results and approved the final version of the manuscript.

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Not applicable.

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All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate
As this is a technical review article and no patient data is presented, it did not need to be submitted to an ethics committee. Informed consent was obtained from the patient for the publication of the images.

Consent for publication
Not applicable.

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