Chapter 2

Advances in Hepatic Surgery

Wong Hoi SHE and Kenneth SH CHOK*

Department of Surgery, The University of Hong Kong, Hong Kong Special Administrative Region,China

***Corresponding Author:** Kenneth SH CHOK, Department of Surgery, The University of Hong Kong, Hong Kong, China,, Email: chok6275@hku.hk

First Published **October 30, 2017**

Abstract

Liver surgery has been evolving over the past years, and complication and mortality rates have gone down markedly. It has become one of the safest surgeries when strict selection criteria are applied. This relies on accurate and reliable preoperative assessment of liver function and the anatomical location of tumor, as well as its relationship to important vascular structures. Precise volumetric measurement of liver segments also allows better prediction of a successful liver resection. Various ways of embolization of the right portal vein can hypertrophy the future liver remnant, increasing the safety profile markedly. At the same time, more and more evidence has shown that laparoscopic surgery can be the standard of care for most liver tumors. This can only be done with the help of advanced technologies, including different energy sources for parenchymal transection and stapling devices for major pedicle and vascular control. On the other hand, liver transplantation is the definitive treatment for liver cirrhosis and its complications. There is evidence that the application of liver transplantation can be extended to some controversial diseases, such as cholangiocarcinoma and colorectal cancers. Liver transplantation using the laparoscopic approach remains experimental and requires further research.

Principle of Liver Surgery

The morbidity and mortality of liver surgery have markedly reduced over the past two decades. Modern liver surgery is still evolving; nonetheless, the principle remains the same. The aim of liver surgery is to achieve a clear resection margin in order to achieve the best survival result. However, the patient has to be fit to undergo general anesthesia and has to have reasonable liver function and liver remnant reserve. Laparoscopic liver resection is emerging as a new modality to improve short-term outcomes, if not the long-term outcomes.

Perioperative Management

New Advances in Perioperative Assessment

Liver surgery is different from other surgical procedures involving other organs. Functional assessment of liver function is of paramount importance as poor liver function may preclude major liver operation. Preoperative assessment includes general assessment of a patient's fitness, liver function and tumor status.

Liver Function Test

Taking a thorough medical history is essential to understanding the general status of the patient. Clinical examination is composed of basic assessment of the patient's condition. We should particularly look for the patient's nutritional status and the presence of stigmata of chronic

liver disease. Splenomegaly signifies cirrhosis and severe portal hypertension, which may preclude major liver resection.

Routine liver function test allows assessment of the underlying liver condition. Serum albumin and bilirubin levels are surrogate markers of synthetic and excretory functions, respectively. Platelet and white cell counts are reflective of portal hypertension. Raised serum alanine aminotransferase and aspartate aminotransferase levels indicate ongoing hepatocyte destruction rather than actual liver function. Prothrombin time or international normalized ratio is a real-time reflection of liver function [1]. The Child-Pugh score [2] is very useful for categorizing patients based on the severity of underlying liver disease. It has five clinical and biochemical parameters measuring liver disease, and each measure is scored 1-3, with 3 indicating the most severe derangement (Table 1). The stratification of liver function allows surgeons' decision on management of the liver malignancy according to the Hong Kong liver cancer staging system [3] or the Barcelona Clinic liver cancer staging classification [4-8]. In addition to liver function, renal function has been identified as one of the prognostic factors for hepatectomy [9].

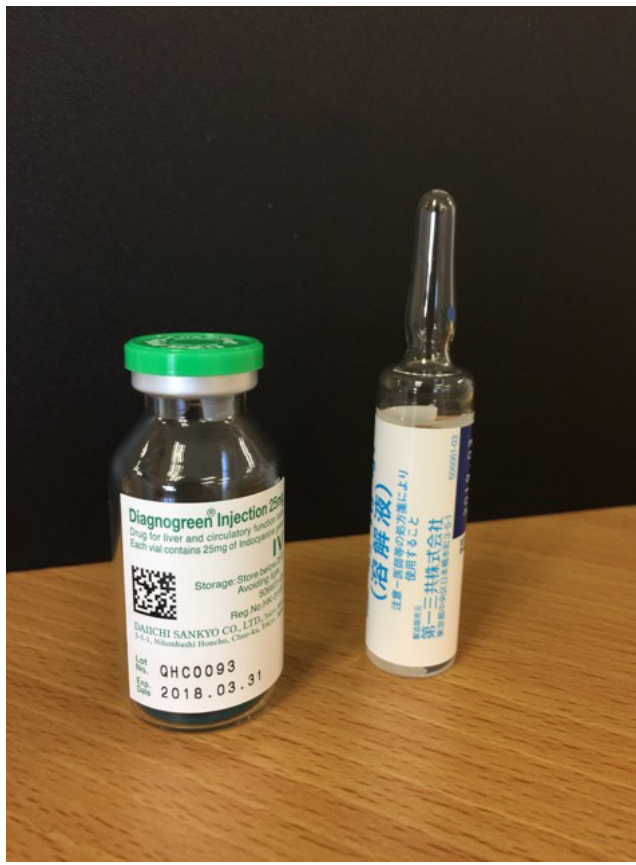
Table 1: Child-Pugh score.

Classification	1	2	3
Serum albumin (g/L)	>35	28 – 35	<28
Serum bilirubin (mmol/L)	<34	34 – 51	>51
International normalized ratio	<1.7	1.7 – 2.3	>2.3
Ascites	Absent	Controllable	Refractory
Encephalopathy	Absent	Minimal to moderate (grade 1/2)	Severe (grade 3/4)
Points	**Class**	**Severity**	**Perioperative mortality**
5 – 6	A	Least severe	10%
7 – 9	B	Moderately severe	30%
10 – 15	C	Most severe	82%

Indocyanine green (ICG) Retention Test

ICG is a non-toxic, dark bluish-green tricarbocyanine dye. After injection, it is solely cleared from the blood by hepatocytes and is excreted into the bile without intrahepatic conjugation or enterohepatic circulation [10]. ICG test is mainly a measurement of liver blood flow and a reflection of intra hepatic portovenous shunt and sinusoidal capillarization [11]. The ICG retention value at 15min (ICG R-15) after intravenous injection is about 10% in normal people. With ample experience in major hepatectomy, the cutoff value for a safe major hepatectomy can be pushed to 17% in patients with adequate liver remnant volume [12]. Limited resection would allow higher ICG R-15 values, which can be as high as 40% [13]. The ICG retention value, however, should not be used singly but

should be combined with other clinical parameters (such as presence of portal hypertension) and liver biochemistry when determining the extent of hepatectomy [14] [Figure 1].



1 (A)

1 (B)

Figure 1: Indocyanine green test(A) Medication (B)Machine.

Operative Planning

Various Imaging Techniques

Ultrasound

Ultrasound is often used as the first imaging method for evaluation or screening of the liver, despite its lower sensitivity or specificity when compared with computed tomography (CT) or magnetic resonance imaging (MRI) [15-17]. However, low radiation, easy availability and low

cost allow its wide use. Ultrasound is the recommended screening tool for detection of hepatocellular carcinoma (HCC) in patients with cirrhosis, while CT or MRI is used for further detailed characterization and confirmation for lesions bigger than 1 cm [18-21]. Intraoperative ultrasound is particularly useful; it has greater sensitivity and allows better delineation and assessment of the relationship between the tumor and intra-parenchymal vasculature [22,23].

Contrast-Enhanced Ultrasound

The use of contrast material allows dynamic images to be observed throughout the vascular phases of liver, which greatly improves the diagnostic accuracy of ultrasound. Various contrast agents are commercially available, such as Sonovue® and Sonazoid®. Sonovue is a strictly intravascular agent, while Sonazoid is cleared by Kupffer cells. They are composed of microbubbles encapsulated by a stabilizing shell such as albumin, polymer, or phospholipid. The microbubbles are miniature gas bubbles smaller than red blood cells (up to 7 micrometers in diameter) and therefore can pass through the capillary beds. The microbubbles act as blood-pool tracers, using ultrasound signals back-scattered from tissue to determine the ultrasound echogenicity [24].Contrast-enhanced ultrasound is particularly useful for clarifying obscure lesions that cannot be determined by CT or MRI. The enhancement

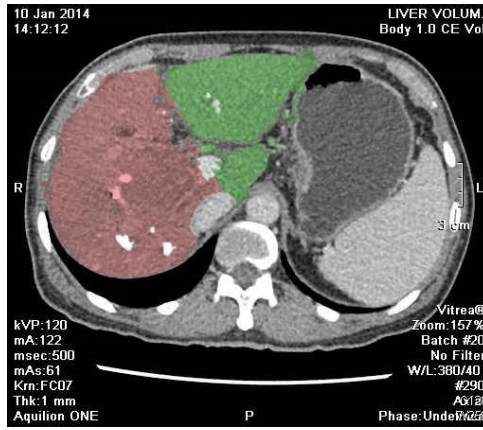
patterns depend on the microvascularization of the focal liver lesions, which can be identified as specific lesions with different characteristics based on the enhancement patterns in three vascular phases: arterial phase, portal venous phase, and late phase.

CT Scan

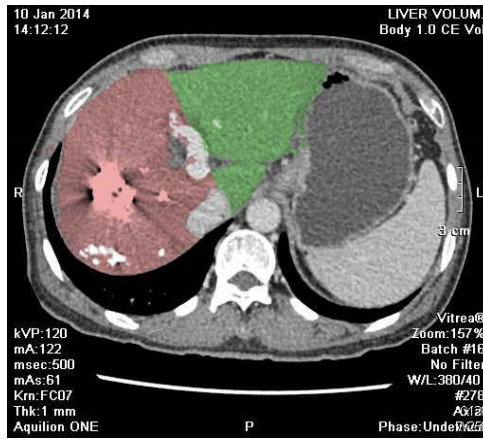
Multi-detector CT scan offers a best multiplanar and multiphasic imaging with fast scanning speed, but it carries the risk of radiation exposure [25-27]. With injection of contrast, images of the liver at different phases (arterial, venous, delayed or any other desired phase) can be captured. Currently, all major HCC guidelines recommend multiphasic CT scan as the first-line imaging modality for the diagnosis of HCC [28-32].

CT Volumetry

CT volumetry of the liver was first performed on cadavers in 1979 by Heymsield [33]. It was shown to be accurate within 5% of water displacement volumetry. CT is more commonly used than other modalities due to the relatively lower cost, greater accessibility, higher spatial resolution, and shorter acquisition time [34-36] [Figure 2].



2 (A)



2 (B)

Figure 2: CT scan of liver volumetry(A) CT volumetry of left lateral section, with tumor at right lobe (area in red) (B) CT volumetry of liver, with evidence of previous right portal vein embolization.

MRI scan

MRI scan offers multiple contrast mechanisms. It shows the vascular and biliary anatomy and can be used to assess parenchymal pathology. It provides better information of soft-tissue differentiation and tissue components, and is therefore useful in the detection and characterization of indeterminate liver nodules, especially in a background of liver cirrhosis [37]. It also minimizes the risk of nephrotoxicity and eliminates concerns of radiation exposure [38]. Three types of contrast agents are available for the evaluation of cirrhosis-associated nodules, including gadolinium-based extracellular contrast agents, super paramagnetic iron oxide (SPOI) contrast agents, and hepatobiliary contrast agents. Gadolinium-based extracellular contrast agents contain low-molecular-weight gadolinium chelates that cause T1shortening; they are useful for the evaluation of tissue vascularity [39]. SPOI and hepatobiliary contrast agents are liver-specific contrast agents. SPOI agents show uptake in the reticulo edothelial system, while hepatobiliary agents (gadobenate dimeglumine or gadoxetate disodium) show uptake in hepatocytes and demonstrate biliary excretion [40]. Diffusion-weighted imaging is a functional imaging technique and is now one of the standard imaging sequences of a liver MRI. It gives information on cellular architecture on a micrometer scale, and can evaluate the cellular density of hepatocellular nodules [37, 41].

Positron emission tomography (PET) scan

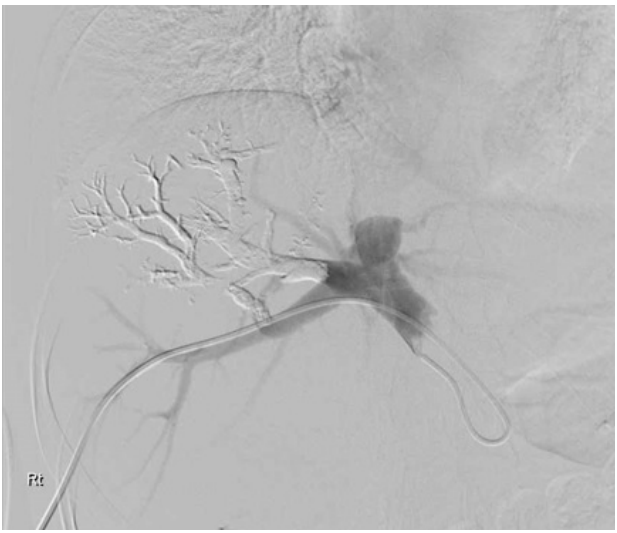
PET scan with the tracer [18F]fluorodeoxyglucose (FDG) is one of the non-invasive diagnostic tools used for detection of various malignancies, including colonic, pancreatic, and lung tumors. The use of [18F] FDG PET may predict microvascular tumor invasion in candidates for liver transplantation [42-44]. The additional use of the tracer [11C] acetate has been proven specific for primary liver cancers. It has been shown to be negative for hemangiomas, cholangiocarcinomas, secondary cancers from the colon, breasts or lungs, and carcinoids. It has been suggested that dual-tracer PET scan using [18F] FDG and [11C] acetate is incrementally better than single-tracer PET and has a complementary advantage [45,46]. The use of [18F]FDG PET may predict HCC with microvascular invasion [42,47] and allow better detection of tumors with poor differentiation. The additional use of [11C] acetate would improve the overall sensitivity of PET, allowing better selection of candidates for liver transplantation [48].

Concepts of portal vein embolization (PVE) and "associating liver partition and portal vein ligation for staged hepatectomy" (ALPPS)

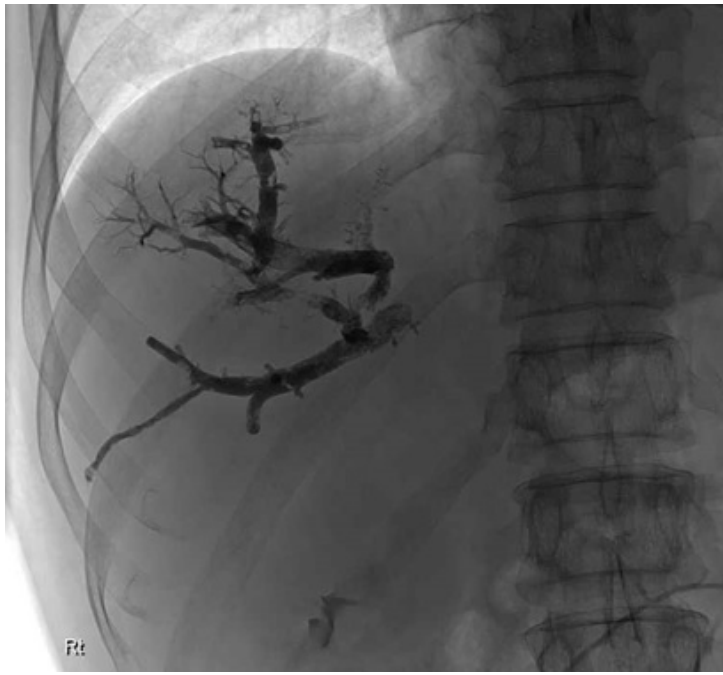
PVE

PVE is indicated when a patient needs a right or extended right hepatectomy but has a relatively small future

liver remnant (FLR). With PVE, the size of an FLR can be increased. PVE, either in an open or percutaneous manner, features embolization of the ipsilateral side of the portal vein which supplies the liver lobe harboring the tumor [49,50] [Figure 3]. To date, there is still no strict value on the minimum volume of an FLR which allows major hepatectomy to be performed safely. An FLR >35% of the estimated standard liver volume has been recommended for patients with cirrhosis, steatosis, or chronic hepatitis [51-58]. PVE is rarely required before extended left hepatectomy or left trisectionectomy, since the right posterior section usually constitutes about 30% of the total liver volume [59,60]. The technique for embolizing the segment-4 portal vein is crucial. If the vein is not properly blocked, suboptimal hypertrophy may result.



3(A)



3 (B)

Figure 3: Percutaneous portal vein embolization(A) Portal vein embolization in action (B) X-ray after portal vein embolization.

Liver Volume Assessment after PVE

The FLR volume will be reassessed 4-8 weeks after PVE [61,62]. Rapid growth of the FLR in the first 3-4 weeks is anticipated. Generally, an 8-30% enlargement over 2-6 weeks is expected [50,62-65]. Hypertrophy is usually slower in the presence of cirrhosis [66]. Studies comparing major hepatectomy with and without preceding PVE reported that comparable and even superior

long-term outcomes were achieved with PVE [55,67-73]. With PVE, patients who would have been considered inoperable in the past because of their small FLR have the option of hepatectomy with reasonable long-term surgical outcomes.

Complications of PVE

PVE can be performed in an open or percutaneous manner. Open right portal vein ligation often renders the subsequent surgery difficult due to vascular or fibrotic adhesions around the hilar structure. Open trans-ileocolic PVE features cannulation of the ileocolic vein with antegrade PVE. Percutaneous portal vein cannulation with retrograde embolization is another option. Ipsilateral percutaneous PVE is generally preferred because of the less invasiveness and an easier access to segment-4 portal vein branches [74,75]. Different ways of PVE all carry a risk of complication, such as main portal vein thrombosis. Prompt surgical intervention or anticoagulation is needed if the embolic agent crosses the contralateral side of the portal vein, which would cause liver failure in the case of bilateral PVE, resulting in death [76]. Hemorrhage or catastrophic bleeding at the puncture site may also occur, which also requires prompt surgical intervention. In addition, PVE induces inflammatory response near the hilar structure, which may increase the difficulty in dissection in the subsequent hepatectomy and raise the surgical risk.

Sequential Transarterial Chemoembolization and PVE

PVE can be given to HCC patients with underlying cirrhosis, but hepatic regeneration and thus hypertrophy of the FLR would be impaired in the presence of cirrhosis [77-79]. On the other hand, it is likely that the arterial flow in the segment with PVE will increase compensatorily, thereby stimulating tumor progression, as HCC is a hypervascular tumor mainly supplied by the hepatic artery blood flow [80-82]. To augment the effect of PVE and prevent tumor progression, the treatment "sequential transarterial chemoembolization and PVE" is used [67]. Studies comparing patients with and without this treatment showed that patients with the treatment had a higher rate of hypertrophy of FLR and a bigger increase of their FLR [67,68], and they also had a lower rate of tumor progression as tumor necrosis was evident [83]. This treatment is not without risk; it could cause ischemic parenchymal damage [84]. In general, however, it is feasible and safe, and it allows HCC patients who would otherwise be denied hepatectomy to undergo curative resection with reasonable postoperative 5-year overall and disease-free survival [66-68,85].

ALPPS

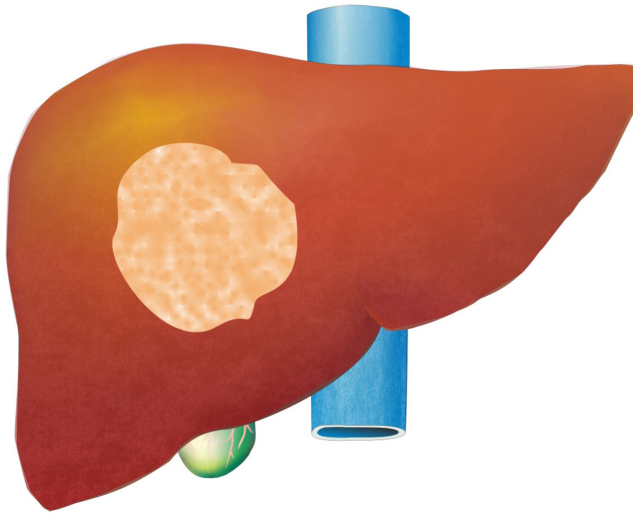
For hepatectomy, one of the limiting factors is inadequate volume of the FLR. Although the aforesaid meth-

ods are effective in inducing hypertrophy of the FLR, it takes several weeks for it to reach a satisfactory volume [50]. Tumor progression may occur before the FLR is large enough for hepatectomy. If a major vessel (such as the ipsilateral portal vein) is invaded by tumor, the tumor will progress in terms of days, and contralateral deposition and metastasis of the tumor will occur, rendering the tumor inoperable [81,82,86]. ALPPS is one of the main surgical innovations in recent years. The procedure, which was invented by chance, was initially carried out by Dr. Hans Schlitt from Germany in an intended extended right hepatectomy for hilar cholangiocarcinoma [87]. The patient had a small FLR, so palliative left hepaticojejunostomy was performed, with division of the liver parenchyma along the falciform ligament and ligation of the right portal vein. On day 8 after the surgery, CT was performed. To Dr. Schlitt's surprise, the left lateral section had grown enormously in size. The diseased portion of the liver was subsequently removed in another surgery. This novel technique was later termed "ALPPS" [88]. The idea of ALPPS is to speed up hypertrophy of the FLR (the left lobe or the left lateral section) by right portal vein ligation and in-situ splitting of the intended transection surface down to the inferior vena cava. Generally, the FLR regenerates to a volume adequate for a safe hepatectomy in days.

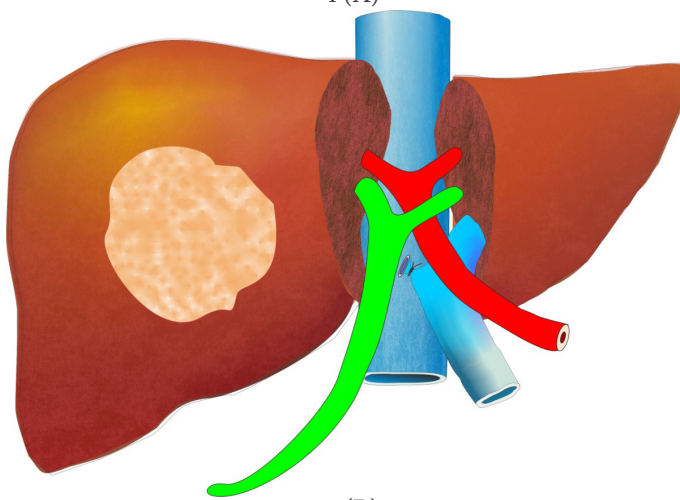
ALPPS was initially applied to relatively normal livers, such as in the case of colorectal liver metastasis. Lat-

er it was also applied to livers with steatosis or cirrhosis [87,89-93]. A 70% increase in FLR volume has been reported [94]. ALPPS is better than conventional PVE when the rate and the percentage of hypertrophy are concerned [95,96]. The shorter the interval between the two operations is, the less mature the adhesions will be, and hence the second operation will also be easier.

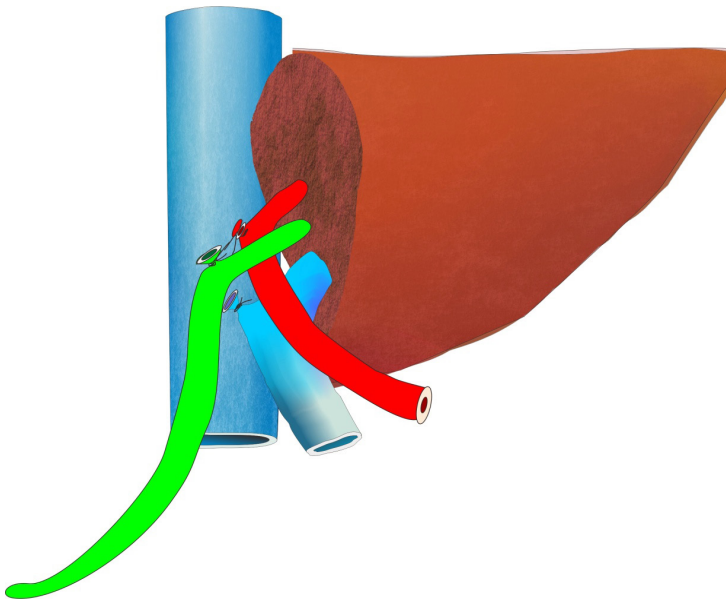
Most of the reported cases of ALPPS were on non-cirrhotic livers, and there has not been any report on the rate of hypertrophy in cirrhotic livers. However, one would anticipate that some patients would not have adequate hypertrophy of the contralateral side, rendering the second-stage operation impossible. ALPPS carries certain risks. The right hepatic artery could be injured, and liver failure could occur after right portal vein ligation. The Pringle maneuver would pose a further risk of liver injury and is thus not recommended. In the first-stage operation, adoption of the anterior approach allows liver transection without mobilization of the right lobe, thereby minimizing adhesion formation [97], and the hilar plate is left untouched so as to minimize the chance of biliary complication. Bile leakage from the transection surface can result in biloma and increases the chance of infection and thus the risk of sepsis, which may forbid the second-stage operation. ALPPS is very technically challenging and demanding, and therefore should not be carried out by inexperienced surgeons [Figure 4].



4 (A)



4 (B)



4 (C)

Figure 4: Procedure of ALPPS (A) Tumor at right lobe with small future left lobe remnant (B) Right portal vein ligation with in-situ split (C) Completion right hepatectomy.
Courtesy of World Journal of Hepatology. [World J Hepatol. 2015 Aug 28;7(18):2147-54.]

Indications for ALPPS

ALPPS should be carried out with a curative intent. It is indicated for patients who have a large tumor load and a marginal FLR [95], even with tumor invasion of major vessels, such as the portal vein [91]. ALPPS renders some inoperable tumors potentially operable.

Morbidity and Mortality after ALPPS

Risks of complication and mortality are inevitable with any surgery; ALPPS is no exception. Perioperative mortality rates of 12-28% have been reported, which are overall higher than those of conventional major hepatectomy [94,95,98,99]. A complication rate high at 50% has been recorded [98,100]. Complications include ascites, bile leakage, persisting cholestasis and sepsis, wound infection, and other inflammatory and infective complications. ALPPS increases operability at the price of heightened morbidity and mortality. Keeping morbidity and mortality at the minimum requires careful patient selection, meticulous surgical technique, and accurate decision as to proceeding to the second-stage operation or not.

The long-term outcome of ALPPS is still unknown. Long-term overall survival and disease-free survival are still pending. Further studies as well as input from different centers are required but not yet available. However, ALPPS has improved the operative rate, and it is hoped that it will improve the overall and disease-free survival of patients. Nonetheless, larger trials are needed to document its efficacy, especially for HCC patients with background cirrhosis.

Operative Advances: Laparoscopic Hepatectomy

Since the introduction of laparoscopic cholecystectomy in 1987 [101], the advantages of laparoscopic surgery

have been proven, which include less pain, more rapid recovery, earlier discharge, and a better cosmetic outcome [102,103]. The first anatomical laparoscopic hepatectomy was performed in 1996 for the resection of hepatic adenoma [104]. Since then, the number of laparoscopic hepatectomy has been increasing tremendously. When compared with open hepatectomy, laparoscopic hepatectomy has the advantages of less blood loss [105-107], shorter clamping duration, smaller chance of postoperative complications [108,109] and ascites [108,110], and shorter hospital stay [109,111].Laparoscopic major hepatectomy is a challenging procedure. However, as skills improve during its development, the more difficult types of hepatectomy are being overcome. Use of the laparoscopic approach has been extended from resection of the left lateral section to hemi-hepatectomy, sectionectomy, segmentectomy, partial resection of postero-superior segments, mono-segmentectomy, and extended anatomical resection. Before hepatectomy could be purely done by the laparoscopic approach, the hand assisted procedure and the hybrid (laparoscopic assisted) procedure were advocated to reduce the technical difficulty of pure laparoscopic hepatectomy [112-115]. Eventually, pure laparoscopic hepatectomy has been proven to be feasible in almost all segments [116-126]. Nowadays, laparoscopic left lateral sectionectomy is regarded as a standard treatment option, and it will take some years for laparoscopic hepatectomy to become a standard procedure for treating all kinds of liver tumor [127,128].

A 10-level difficulty index system introduced by the Keio University group [129] provides a comprehensive stratification of HCC for pure laparoscopic hepatectomy, taking tumor size, tumor location, extent of resection, degree of cirrhosis and proximity to major vessels into consideration. Although all the procedures have been made feasible and easier due to the advancement of surgical skills and surgical equipment, operations with a high difficulty index should only be performed by experienced laparoscopic surgeons, while those with a low difficulty index are suitable for novices in laparoscopic hepatectomy (Figure 5).

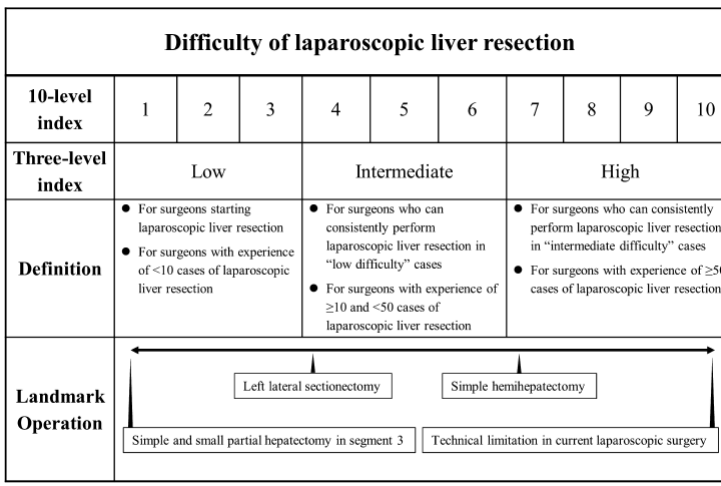


Figure 5: Ten-level difficulty index system. [J Hepatobiliary Pancreat Sci. 2014 Oct;21(10):745-53.] (License for the current use purchased from John Wiley & Sons. License number 4233621391436).

Surgical Adjunct

Pneumoperitoneum is one of the most important elements in laparoscopic hepatectomy. The inflated pressure together with application of the Pringle maneuver reduces bleeding from the hepatic vein [130,131]. The dry operative field enables better visualization of vital structures and allows precise control of vessels and bile ducts.

Energy Sources and Surgical Devices

Modern dissecting tools with energy source allow careful and precise manipulation of liver tissue [132]. Examples of energy devices include Cavitron ultrasonic surgical aspirator (CUSA), water jet, ultrasonic scalpel, diathermy, monopolar sealer, bipolar diathermy, argon beam coagulator, radiofrequency pre-coagulator and microwave pre-coagulator (Figure 6). Caution must be taken while deeper liver parenchymal transection is taking place, as excessive bleeding may occur if major vascular or biliary structure is encountered. This area is better dealt with a CUSA, the crush-clamp technique, or water-jet dissection with or without pre-coagulation using a monopolar or bipolar device [133]. Up to date, no specific type of energy device has clearly emerged and none is recommended over another. The use of energy device is to provide a precise dissection to separate vascular structures in a controlled fashion, and the different devices seem to be equally efficient in vessel hemostasis until 5 mm diameter is reached [134].

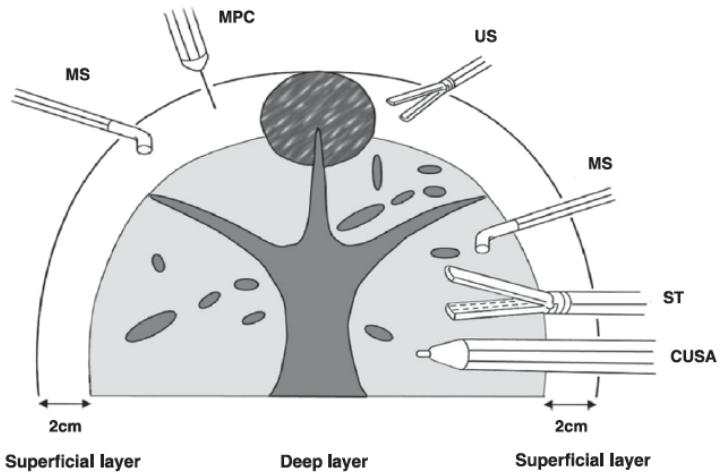


Figure 6: Use of surgical equipment. CUSA, Cavitron ultrasonic surgical aspirator; MPC, microwave pre-coagulator; MS, monopolar sealer; ST, stapler; US, ultrasonic scalpel. [J Hepatobiliary Pancreat Sci. 2015 May;22(5):363-70.] (License for the current use purchased from John Wiley & Sons. License number 4233630434721)

CUSA

CUSA is specialized for isolation of intra hepatic vasculatures. Small vessels are eligible to be sealed and transected with an ultrasonic scalpel or cautery-based vessel sealer, whereas stapler hepatectomy can be used for major vessel sealing including division of the Glissonian sheath. Clips are acceptable for division of large vessels, with the warning of potential stapler misfire when crossing a prior clip placed in the liver parenchyma. Stapler hepatectomy

is usually limited to vascular pedicles, while it can be used as a major division device. Newly designed laparoscopic clips and electricity driver staplers allow smooth and non-jerky motions of hemostasis, giving the operating surgeons full control [135,136].However, blind parenchymal transection using the stapler or an energy device without a clear operative field may lead to major bleeding and should therefore be avoided [137,138] [Figure 7].

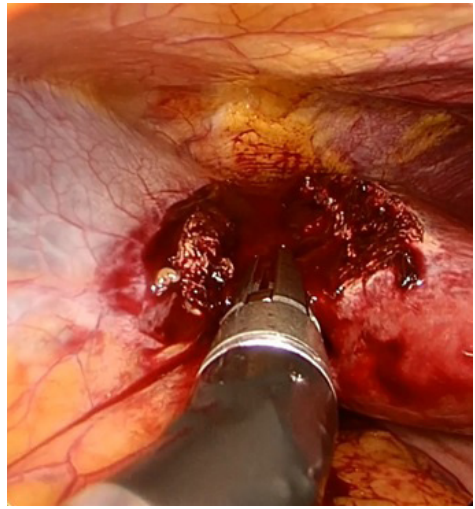


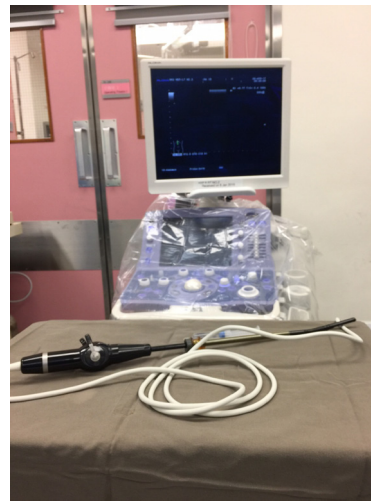
Figure 7: Intraoperative use of stapling technique.

3D Imaging

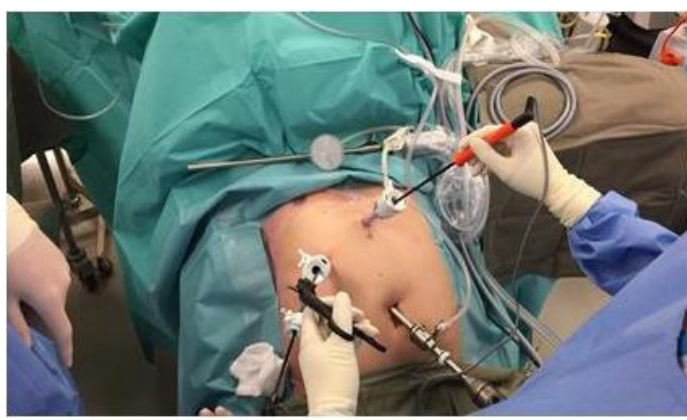
Magnification with a high-definition video camera with a large display unit provides unprecedented clarity. With such clarity, small vessels and the bile duct can be clipped as in open surgery. One of the major limitations

of conventional laparoscopy is the lack of depth perception and tactile feedback. 3D reproduction of the operative field is supposed to overcome most of the limitations of conventional laparoscopy [139-141].It may allow better depth perception and hand eye coordination, and therefore may enable accurate and swift dissection as well as better intra-corporal knotting for bleeding control or biliary suture. Nonetheless, whether a 3D laparoscopic system really benefits laparoscopic hepatectomy requires further evidence [Figure 8].

8(A)



8 (B)



8 (C)

Figure 8: Laparoscopic hepatectomy (A) 3D laparoscopic system (B) Laparoscopic ultrasound system (C) Performing laparoscopic right hepatectomy.

Laparoscopic Imaging System: Intraoperative ICG-Fluorescence Imaging

Intraoperative ICG-fluorescence imaging allows further identification of liver lesions as well as detection of complications. A laparoscopic imaging system that allows fusion ICG-fluorescence imaging enables identification of hepatic segmental boundaries and location of hepatic tumors. Tumors in the subcapsular region may not be located by conventional imaging modalities preoperatively or intraoperatively. Intraoperative ICG-fluorescence imaging also allows detection of metastatic nodules that have regressed in size after neoadjuvant chemotherapy, as in the case of colorectal liver metastasis [142-145]. Unfortunately, ICG-fluorescence imaging is limited by the depth of lesions; intraoperative ultrasonography with enhanced contrast should be used to detect deeply seated lesions [146,147].The contrast difference seen on ICG-fluorescence imaging allows identification of segmental boundaries of the hepatic parenchyma with and without blood perfusion, which guides surgeons in laparoscopic anatomical resection [148]. Furthermore, ICG-fluorescence imaging can be used as a form of intraoperative cholangiography to delineate the bile duct anatomy at the hepatic hilum and to detect the presence of bile leakage [149] [Figure 9].

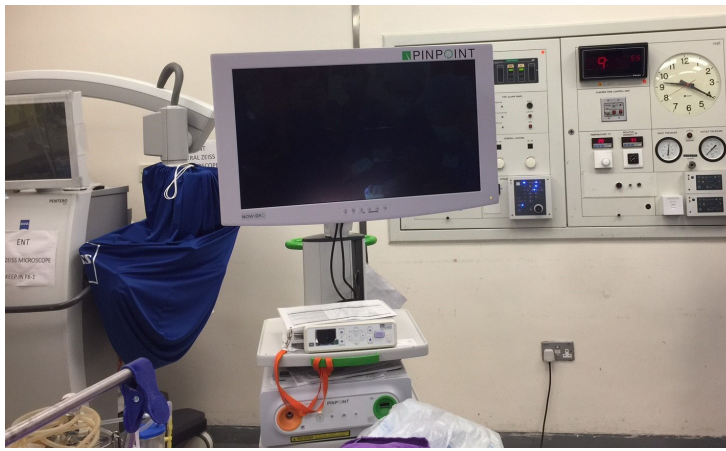
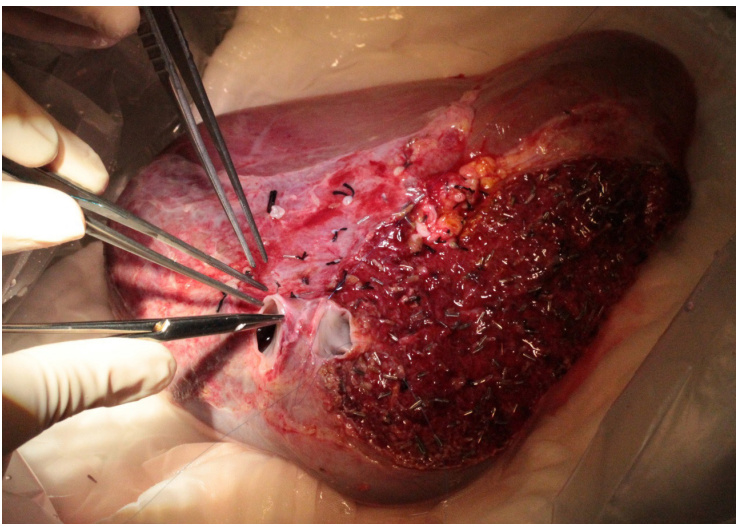


Figure 9: Machine for intraoperative laparoscopic indocyanine green test.

Liver Transplantation

Liver transplantation is the only life-saving procedure for patients with acute or chronic liver failure [150-152]. The long-term survival of HCC patients within well-established criteria (such as the Milan criteria and the UCSF criteria) after liver transplantation has been proven [153-155]. The outcome of liver transplantation for hilar cholangiocarcinoma is also promising. The Mayo pre-transplantation chemotherapy protocol has been shown to be beneficial to selected patients, with a 4-year recurrence-free survival rate of 65-70% [156-160].This protocol features external beam radiotherapy with 5-fluorouracil

chemotherapy for three weeks, followed by intraluminal brachy therapy by iridium irradiation and maintenance chemotherapy (oral capecitabine). It aims to control disease progression and prevent metastasis before transplantation. Patients with better tumor biology may be selected so that a better survival outcome of transplantation can be achieved. The idea of liver transplantation for colorectal liver metastasis was advocated by Hagness et al [161] and remains controversial as liver graft is generally a scarce resource. The idea can be implemented without sparking controversy only when the supply of liver grafts outstrips demand, such as in Norway, where there is a surplus of deceased-donor organs [162,163] [Figure 10].



10 (A)

10 (B)

Figure 10: Hepatic venoplasty in liver transplantation (A) Middle and right hepatic veins (B) Completion of venoplasty of the middle and right hepatic veins.

Laparoscopic donor hepatectomy

Laparoscopic donor hepatectomy was first developed as left lateral sectionectomy for pediatric transplant patients [164]. Although being a minimally invasive surgery, its safety profile was not different from the traditional open surgery [128]. However, with evolution and advancement of the procedure, pure laparoscopic full left [165-167] and right hepatectomies[168-170] with success were reported. The short-term outcomes in donors have markedly improved by the laparoscopic means. However, the benefit of laparoscopic donor hepatectomy for recipients needs further validation.

Conclusion

Modern liver surgery has become safer. It is also becoming more aggressive, yet relatively minimally invasive. Proper preoperative assessment of the patients' general condition, liver function and tumor status is essential for better decision making in liver surgery.

References

1. Fan ST. Liver functional reserve estimation: state of the art and relevance for local treatments: the Eastern perspective. J Hepatobiliary Pancreat Sci. 2010; 17: 380-384.
2. Pugh RN, Murray-Lyon IM, Dawson JL, Pietroni MC, Williams R. Transection of the oesophagus for bleeding oesophageal varices. Br J Surg. 1973; 60: 646-649.
3. Yau T, Tang VY, Yao TJ, Fan ST, Lo CM, et al. Development of Hong Kong Liver Cancer staging system with treatment stratification for patients with hepatocellular carcinoma. Gastroenterology. 2014; 146: 1691-1700 e3.
4. Llovet JM, Bru C, Bruix J. Prognosis of hepatocellular carcinoma: the BCLC staging classification. Semin Liver Dis. 1999; 19: 329-338.
5. Bruix J, Llovet JM. Prognostic prediction and treatment strategy in hepatocellular carcinoma. Hepatology. 2002; 35: 519-524.

6. Llovet JM, Burroughs A, Bruix J. Hepatocellular carcinoma. Lancet. 2003; 362: 1907-1917.

7. Llovet JM, Di Bisceglie AM, Bruix J, ramer BS, Lencioni R, et al. Design and endpoints of clinical trials in hepatocellular carcinoma. J Natl Cancer Inst. 2008; 100: 698-711.

8. Forner A, Reig ME, de Lope CR, Bruix J. Current strategy for staging and treatment: the BCLC update and future prospects. Semin Liver Dis. 2010; 30: 61-74.

9. Poon RT, Fan ST, Lo CM, Liu CL, Lam CM, et al. Improving perioperative outcome expands the role of hepatectomy in management of benign and malignant hepatobiliary diseases: analysis of 1222 consecutive patients from a prospective database. Ann Surg. 2004; 240: 698-708.

10. Caesar J, Shaldon S, Chiandussi L, Guevara L, Sherlock S. The use of indocyanine green in the measurement of hepatic blood flow and as a test of hepatic function. Clin Sci. 1961; 21: 43-57.

11. Morris-Stiff G, Gomez D, Prasad R. Quantitative assessment of hepatic function and its relevance to the liver surgeon. J Gastrointest Surg. 2009; 13: 374-385.

12. Lam CM, Fan ST, Lo CM, Wong J. Major hepatectomy for hepatocellular carcinoma in patients with an unsatisfactory indocyanine green clearance test. Br J Surg. 1999; 86: 1012-1017.

13. Makuuchi M HH, Yamazaki S. Indication for hepatectomy in patients with hepatocellular carcinoma and cirrhosis (in Japanese). Shindan Chiryo. 1986: 1225-1230.

14. Imamura H, Sano K, Sugawara Y, Kokudo N, Makuuchi M. Assessment of hepatic reserve for indication of hepatic resection: decision tree incorporating indocyanine green test. J Hepatobiliary Pancreat Surg. 2005; 12: 16-22.

15. Glover C, Douse P, Kane P, Karani J, Meire H, et al. Accuracy of investigations for asymptomatic colorectal liver metastases. Dis Colon Rectum. 2002; 45: 476-484.

16. Trinchet JC, Chaffaut C, Bourcier V, Degos F, Henrion J, et al. Ultrasonographic surveillance of hepatocellular carcinoma in cirrhosis: a randomized trial comparing 3- and 6-month periodicities. Hepatology. 2011; 54: 1987-1997.

17. O'Neill EK, Cogley JR, Miller FH. The ins and outs of liver imaging. Clin Liver Dis. 2015; 19: 99-121.

18. Yu NC, Chaudhari V, Raman SS, Lassman C, Tong MJ, et al. CT and MRI improve detection of hepatocellular carcinoma, compared with ultrasound alone, in patients with cirrhosis. Clin Gastroenterol Hepatol. 2011; 9:161-167.

19. Marrero JA, Ahn J, Rajender Reddy K, Americal College of Gastroenterology. ACG clinical guideline: the diagnosis and management of focal liver lesions. Am J Gastroenterol. 2014; 109: 1328-1347.

20. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2015. CA Cancer J Clin. 2015; 65: 5-29.

21. Fong ZV, Tanabe KK. The clinical management of hepatocellular carcinoma in the United States, Europe, and Asia: a comprehensive and evidence-based comparison and review. Cancer. 2014; 120: 2824-2838.

22. Schmidt J, Strotzer M, Fraunhofer S, H Boedeker, H Zirngibl. Intraoperative ultrasonography versus helical computed tomography and computed tomography with arterioportography in diagnosing colorectal liver metastases: lesion-by-lesion analysis. World J Surg. 2000; 24: 43-47.

23. Catheline JM, Turner R, Champault G. Laparoscopic ultrasound of the liver. Eur J Ultrasound. 2000; 12: 169-177.

24. Piscaglia F, Lencioni R, Sagrini E, Pina CD, Cioni D, et al. Characterization of focal liver lesions with contrast-enhanced ultrasound. Ultrasound Med Biol. 2010; 36: 531-550.

25. Prokop M. Multislice CT: technical principles and future trends. Eur Radiol. 2003; 13: M3-13.

26. Klingenbeck-Regn K, Schaller S, Flohr T, Ohnesorge B, Kopp AF, et al. Subsecond multi-slice computed tomography: basics and applications. Eur J Radiol. 1999; 31: 110-124.

27. Hu H, He HD, Foley WD, Fox SH. Four multidetector-row helical CT: image quality and volume coverage speed. Radiology. 2000; 215: 55-62.

28. Bruix J, Sherman M, American Association for the Study of Liver D. Management of hepatocellular carcinoma: an update. Hepatology. 2011; 53: 1020-1022.

29. Omata M, Lesmana LA, Tateishi R, Chen PJ, Lin SM, et al. Asian Pacific Association for the Study of the Liver consensus recommendations on hepatocellular carcinoma. Hepatol Int. 2010; 4: 439-474.

30. Mitchell DG, Bruix J, Sherman M, Sirlin CB. LI-RADS (Liver Imaging Reporting and Data System): summary, discussion, and consensus of the LI-RADS Management Working Group and future directions. Hepatology. 2015; 61: 1056-1065.

31. European Association For The Study Of The Liver,, European Organisation For Research And Treatment Of Cancer.. EASL-EORTC clinical practice guidelines: management of hepatocellular carcinoma. J Hepatol 2012; 56: 908-943.

32. Omata M, Cheng AL, Kokudo N, Kudo M, Lee JM, et al. Asia-Pacific clinical practice guidelines on the management of hepatocellular carcinoma: a 2017 update. Hepatol Int. 2017; 11: 317-370.

33. Heymsfield SB, Fulenwider T, Nordlinger B, Barlow R, Sones P, et al. Accurate measurement of liver, kidney, and spleen volume and mass by computerized axial tomography. Ann Intern Med. 1979; 90: 185-187.

34. Nakayama Y, Li Q, Katsuragawa S, Ikeda R, Hiai Y, et al. Automated hepatic volumetry for living related liver transplantation at multisection CT. Radiology. 2006; 240: 743-748.

35. Campadelli P, Casiraghi E, Esposito A. Liver segmentation from computed tomography scans: a survey and a new algorithm. Artif Intell Med. 2009; 45: 185-196.

36. Masutani Y, Uozumi K, Akahane M, Ohtomo K. Liver CT image processing: a short introduction of the technical elements. Eur J Radiol. 2006; 58: 246-251.

37. Lee JM, Yoon JH, Kim KW. Diagnosis of hepatocellular carcinoma: newer radiological tools. Semin Oncol. 2012; 39: 399-409.

38. Fulcher AS, Szucs RA, Bassignani MJ, Marcos A. Right lobe living donor liver transplantation: pre-

operative evaluation of the donor with MR imaging. AJR Am J Roentgenol. 2001; 176: 1483-1491.

39. Hanna RF, Aguirre DA, Kased N, Shawn CE, MR Peterson, et al. Cirrhosis-associated hepatocellular nodules: correlation of histopathologic and MR imaging features. Radiographics. 2008; 28: 747-769.

40. Zech CJ, Reiser MF, Herrmann KA. Imaging of hepatocellular carcinoma by computed tomography and magnetic resonance imaging: state of the art. Dig Dis. 2009; 27: 114-124.

41. Taouli B, Koh DM. Diffusion-weighted MR imaging of the liver. Radiology. 2010; 254: 47-66.

42. Kornberg A, Freesmeyer M, Barthel E, Jandt K, Katenkamp K, et al. 18F-FDG-uptake of hepatocellular carcinoma on PET predicts microvascular tumor invasion in liver transplant patients. Am J Transplant. 2009; 9: 592-600.

43. Sugiyama M, Sakahara H, Torizuka T, Kanno T, Nakamura F, et al. 18F-FDG PET in the detection of extrahepatic metastases from hepatocellular carcinoma. J Gastroenterol. 2004; 39: 961-968.

44. Wolfort RM, Papillion PW, Turnage RH, Lillien DL, Ramaswamy MR, et al. Role of FDG-PET in the evaluation and staging of hepatocellular carcinoma with comparison of tumor size, AFP level, and histologic grade. Int Surg. 2010; 95: 67-75.

45. Huo L, Wu Z, Zhuang H, Fu Z, Dang Y. Dual time point C-11 acetate PET imaging can potentially distinguish focal nodular hyperplasia from primary hepatocellular carcinoma. Clin Nucl Med. 2009; 34: 874-877.

46. Ho CL, Chen S, Yeung DW, Cheng TK. Dual-tracer PET/CT imaging in evaluation of metastatic hepatocellular carcinoma. J Nucl Med. 2007; 48: 902-909.

47. Yang SH, Suh KS, Lee HW, Cho EH, Cho JY, et al. The role of (18)F-FDG-PET imaging for the selection of liver transplantation candidates among hepatocellular carcinoma patients. Liver Transpl. 2006; 12:1655-1660.

48. Cheung TT, Chan SC, Ho CL, Chok KS, Chan AC, et al. Can positron emission tomography with the dual tracers [11 C] acetate and [18 F]fludeoxyglucose predict microvascular invasion in hepatocellular carcinoma? Liver Transpl. 2011; 17: 1218-1225.

49. Kinoshita H, Sakai K, Hirohashi K, Sumito Igawa, Osamu Yamasaki, et al. Preoperative portal vein embolization for hepatocellular carcinoma. World J Surg. 1986; 10: 803-808.

50. Abulkhir A, Limongelli P, Healey AJ, Damrah O, Tait P, et al. Preoperative portal vein embolization

for major liver resection: a meta-analysis. Ann Surg. 2008; 247: 49-57.

51. Lau H, Man K, Fan ST, Yu WC, Lo CM, et al. Evaluation of preoperative hepatic function in patients with hepatocellular carcinoma undergoing hepatectomy. Br J Surg. 1997; 84: 1255-1259.

52. Kubota K, Makuuchi M, Kusaka K, Kobayashi T, Miki K, et al. Measurement of liver volume and hepatic functional reserve as a guide to decision-making in resectional surgery for hepatic tumors. Hepatology. 1997; 26: 1176-1181.

53. Shirabe K, Shimada M, Gion T, Hasegawa H, Takenaka K, et al. Postoperative liver failure after major hepatic resection for hepatocellular carcinoma in the modern era with special reference to remnant liver volume. J Am Coll Surg. 1999; 188: 304-309.

54. Zorzi D, Laurent A, Pawlik TM, Lauwers GY, Vauthey JN, et al. Chemotherapy-associated hepatotoxicity and surgery for colorectal liver metastases. Br J Surg. 2007; 94: 274-286.

55. Palavecino M, Chun YS, Madoff DC, Zorzi D, Kishi Y, et al. Major hepatic resection for hepatocellular carcinoma with or without portal vein embolization: Perioperative outcome and survival. Surgery. 2009; 145: 399-405.

56. Ribero D, Curley SA, Imamura H, Madoff DC, Nagorney DM, et al. Selection for resection of hepatocellular carcinoma and surgical strategy: indications for resection, evaluation of liver function, portal vein embolization, and resection. Ann Surg Oncol. 2008; 15: 986-992.

57. Mullin EJ, Metcalfe MS, Maddern GJ. How much liver resection is too much? Am J Surg. 2005; 190: 87-97.

58. Yanaga K, Honda H, Ikeda Y, Nishizaki AT, Yamamoto K, et al. Significance of liver size in hepatic surgery. HPB Surg. 1997; 10:195-199.

59. Abdalla EK, Denys A, Chevalier P, Nemr RA, Vauthey JN. Total and segmental liver volume variations: implications for liver surgery. Surgery. 2004; 135: 404-410.

60. Nagino M, Nimura Y, Kamiya J, Kondo S, Uesaka K, et al. Right or left trisegment portal vein embolization before hepatic trisegmentectomy for hilar bile duct carcinoma. Surgery. 1995; 117: 677-681.

61. Correa D, Schwartz L, Jarnagin WR, Tuorto S, DeMatteo R, et al. Kinetics of liver volume changes in the first year after portal vein embolization. Arch Surg. 2010; 145: 351-354.

62. Ribero D, Abdalla EK, Madoff DC, Donadon M, Loyer EM, et al. Portal vein embolization before

major hepatectomy and its effects on regeneration, resectability and outcome. Br J Surg. 2007; 94: 1386-1394.

63. Abdalla EK, Barnett CC, Doherty D, Curley SA, Vauthey JN. Extended hepatectomy in patients with hepatobiliary malignancies with and without preoperative portal vein embolization. Arch Surg. 2002; 137: 675-680.

64. Nagino M, Nimura Y, Kamiya J, Kondo S, Uesaka K, et al. Changes in hepatic lobe volume in biliary tract cancer patients after right portal vein embolization. Hepatology. 1995; 21: 434-439.

65. Imamura H, Shimada R, Kubota M, Matsuyama Y, Nakayama A, et al. Preoperative portal vein embolization: an audit of 84 patients. Hepatology. 1999; 29: 1099-1105.

66. Farges O, Belghiti J, Kianmanesh R, Regimbeau JM, Santoro R, et al. Portal vein embolization before right hepatectomy: prospective clinical trial. Ann Surg. 2003; 237: 208-217.

67. Aoki T, Imamura H, Hasegawa K, Matsukura A, Sano K, et al. Sequential preoperative arterial and portal venous embolizations in patients with hepatocellular carcinoma. Arch Surg. 2004; 139: 766-774.

68. Ogata S, Belghiti J, Farges O, Varma D, Sibert A, et al. Sequential arterial and portal vein embolizations before right hepatectomy in patients with cirrhosis and hepatocellular carcinoma. Br J Surg. 2006; 93: 1091-1098.

69. Seo DD, Lee HC, Jang MK, Min HJ, Kim KM, et al. Preoperative portal vein embolization and surgical resection in patients with hepatocellular carcinoma and small future liver remnant volume: comparison with transarterial chemoembolization. Ann Surg Oncol. 2007; 14: 3501-3509.

70. Azoulay D, Castaing D, Krissat J, Alloua S, Guillermo MH, et al. Percutaneous portal vein embolization increases the feasibility and safety of major liver resection for hepatocellular carcinoma in injured liver. Ann Surg. 2000; 232: 665-672.

71. Tanaka H, Hirohashi K, Kubo S, Shuto T, Higaki I, et al. Preoperative portal vein embolization improves prognosis after right hepatectomy for hepatocellular carcinoma in patients with impaired hepatic function. Br J Surg. 2000; 87: 879-882.

72. Wakabayashi H, Ishimura K, Okano K, K Izuishi, Y Kara, et al. Is preoperative portal vein embolization effective in improving prognosis after major hepatic resection in patients with advanced-stage hepatocellular carcinoma? Cancer. 2001; 92: 2384-2390.

73. Hayashi S, Baba Y, Ueno K, Nakajo M, Kubo F, et al. Acceleration of primary liver tumor growth rate in embolized hepatic lobe after portal vein embolization. Acta Radiol. 2007; 48: 721-727.

74. Nagino M, Nimura Y, Kamiya J, Kondo S, Kanai M. Selective percutaneous transhepatic embolization of the portal vein in preparation for extensive liver resection: the ipsilateral approach. Radiology. 1996; 200: 559-563.

75. Gibo M, Unten S, Yogi A, Tadashi N, Y Ayukawa, et al. Percutaneous ipsilateral portal vein embolization using a modified four-lumen balloon catheter with fibrin glue: initial clinical experience. Radiat Med. 2007; 25: 164-172.

76. Shaw CM, Madoff DC. Acute Thrombosis of Left Portal Vein during Right Portal Vein Embolization Extended to Segment 4. Semin Intervent Radiol. 2011; 28:156-161.

77. Nagasue N, Yukaya H, Ogawa Y, H Kohno, T Nakamura. Human liver regeneration after major hepatic resection. A study of normal liver and livers with chronic hepatitis and cirrhosis. Ann Surg. 1987; 206: 30-39.

78. Chen MF, Hwang TL, Hung CF. Human liver regeneration after major hepatectomy. A study of liver volume by computed tomography. Ann Surg. 1991; 213: 227-229.

79. Yamanaka N, Okamoto E, Kawamura E, Kato T, Oriyama T, et al. Dynamics of normal and injured human liver regeneration after hepatectomy as assessed on the basis of computed tomography and liver function. Hepatology. 1993; 18: 79-85.

80. Nagino M, Nimura Y, Kamiya J, Kanai M, Hayakawa N, et al. Immediate increase in arterial blood flow in embolized hepatic segments after portal vein embolization: CT demonstration. AJR Am J Roentgenol. 1998; 171: 1037-1039.

81. Elias D, De Baere T, Roche A, Mducreux, Leclere J, et al. During liver regeneration following right portal embolization the growth rate of liver metastases is more rapid than that of the liver parenchyma. Br J Surg. 1999; 86: 784-788.

82. Kokudo N, Tada K, Seki M, Ohta H, Azekura K, et al. Proliferative activity of intrahepatic colorectal metastases after preoperative hemihepatic portal vein embolization. Hepatology. 2001; 34: 267-272.

83. de Graaf W, van Lienden KP, van den Esschert JW, Bennink RJ, van Gulik TM. Increase in future remnant liver function after preoperative portal vein embolization. Br J Surg. 2011; 98: 825-834.

84. Okabe H, Beppu T, Ishiko T, Masuda T, Hayashi H, et al. Preoperative portal vein embolization (PVE) for patients with hepatocellular carcinoma

can improve resectability and may improve disease-free survival. J Surg Oncol. 2011; 104: 641-646.

85. Xu C, Lv PH, Huang XE, Wang SX, Sun L, et al. Safety and efficacy of sequential transcatheter arterial chemoembolization and portal vein embolization prior to major hepatectomy for patients with HCC. Asian Pac J Cancer Prev. 2014; 15: 703-706.

86. Heinrich S, Jochum W, Graf R, Clavien PA. Portal vein ligation and partial hepatectomy differentially influence growth of intrahepatic metastasis and liver regeneration in mice. J Hepatol. 2006; 45: 35-42.

87. Baumgart J LS, Lang H. A new method for induction of liver hypertrophy prior to right trisectionectomy: a report of three cases. HPB (Oxford). 2011: 71-72.

88. de Santibanes E, Clavien PA. Playing Play-Doh to prevent postoperative liver failure: the "ALPPS" approach. Ann Surg. 2012; 255: 415-417.

89. Schadde E, Ardiles V, Robles-Campos R, Malago M, Machado M, et al. Early Survival and Safety of ALPPS: First Report of the International ALPPS Registry. Ann Surg. 2014; 260: 829-838.

90. Cavaness KM, Doyle MB, Lin Y, Maynard E, Chapman WC. Using ALPPS to induce rapid liver hypertrophy in a patient with hepatic fibrosis and portal vein thrombosis. J Gastrointest Surg. 2013; 17: 207-212.

91. Vennarecci G, Laurenzi A, Santoro R, Colasanti M, Lepiane P, et al. The ALPPS procedure: a surgical option for hepatocellular carcinoma with major vascular invasion. World J Surg. 2014; 38:1498-1503.

92. Vennarecci G, Laurenzi A, Levi Sandri GB, Busi Rizzi E, Cristofaro M, et al. The ALPPS procedure for hepatocellular carcinoma. Eur J Surg Oncol. 2014; 40: 982-988.

93. Levi Sandri GB, Lai Q, Rayar M, Laurent S. ALPPS procedure for hepatocellular carcinoma with macrovascular thrombosis: A new opportunity? J Hepatol. 2014; 62: 241–242.

94. Schnitzbauer AA, Lang SA, Goessmann H, Nadalin S, Baumgart J, 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: 405-414.

95. Schadde E, Ardiles V, Slankamenac K, Tschuor C, Sergeant G, et al. ALPPS offers a better chance

of complete resection in patients with primarily unresectable liver tumors compared with conventional-staged hepatectomies: results of a multicenter analysis. World J Surg. 2014; 38: 1510-1519.

96. Ielpo B, Quijano Y, Vicente E. Pearls and pitfalls on ALPPS procedure: new complications in a new technique. Updates Surg. 2014; 66: 159-161.

97. Chan AC, Pang R, Poon RT. Simplifying the ALPPS Procedure by the Anterior Approach. Ann Surg. 2014; 260: e3.

98. Nadalin S, Capobianco I, Li J, Girotti P, Königsrainer I, et al. Indications and limits for associating liver partition and portal vein ligation for staged hepatectomy (ALPPS). Lessons Learned from 15 cases at a single centre. Z Gastroenterol. 2014; 52: 35-42.

99. Knoefel WT, Gabor I, Rehders A, Alexander A, Krausch M, et al. In situ liver transection with portal vein ligation for rapid growth of the future liver remnant in two-stage liver resection. Br J Surg. 2013; 100: 388-394.

100. Schadde E, Schnitzbauer AA, Tschuor C, Raptis DA, Bechstein WO, et al. Systematic Review and Meta-Analysis of Feasibility, Safety, and Efficacy of a Novel Procedure: Associating Liver Partition and Portal Vein Ligation for Staged He-

patectomy. Ann Surg Oncol. 2015; 22: 3109-3120.

101. Litynski GS. Profiles in laparoscopy: Mouret, Dubois, and Perissat: the laparoscopic breakthrough in Europe (1987-1988). JSLS. 1999; 3: 163-167.

102. National Institutes of Health Consensus Development Conference Statement on Gallstones and Laparoscopic Cholecystectomy. Am J Surg. 1993; 165: 390-398.

103. Begos DG, Modlin IM. Laparoscopic cholecystectomy: from gimmick to gold standard. J Clin Gastroenterol. 1994; 19: 325-330.

104. Azagra JS, Goergen M, Gilbart E, Jacobs D. Laparoscopic anatomical (hepatic) left lateral segmentectomy-technical aspects. Surg Endosc. 1996; 10: 758-761.

105. Soubrane O, Goumard C, Laurent A, Tranchart H, Truant S, et al. Laparoscopic resection of hepatocellular carcinoma: a French survey in 351 patients. HPB (Oxford). 2014; 16: 357-365.

106. Topal B, Fieuws S, Aerts R, H Vandeweyer, F Penninckx. Laparoscopic versus open liver resection of hepatic neoplasms: comparative analysis of short-term results. Surg Endosc. 2008; 22: 2208-2213.

107. Soubrane O, Schwarz L, Cauchy F, Perotto LO, Brustia R, et al. A Conceptual Technique for

Laparoscopic Right Hepatectomy Based on Facts and Oncologic Principles: The Caudal Approach. Ann Surg. 2015; 261:1226-1231.

108. Xiong JJ, Altaf K, Javed MA, W Huang, Rajarshi M, et al. Meta-analysis of laparoscopic vs open liver resection for hepatocellular carcinoma. World J Gastroenterol. 2012; 18: 6657-6668.

109. Lopez-Ben S, Palacios O, Codina-Barreras A, M Teresa Albiol, Laia Falgueras. Pure laparoscopic liver resection reduces surgical site infections and hospital stay. Results of a case-matched control study in 50 patients. Langenbecks Arch Surg. 2014; 399: 307-314.

110. Tranchart H, Di Giuro G, Lainas P, Roudie J, Agostini H, et al. Laparoscopic resection for hepatocellular carcinoma: a matched-pair comparative study. Surg Endosc. 2010; 24: 1170-1176.

111. Truant S, Bouras AF, Hebbar M, Boleslawski E, Fromont G, et al. Laparoscopic resection vs. open liver resection for peripheral hepatocellular carcinoma in patients with chronic liver disease: a case-matched study. Surg Endosc. 2011; 25: 3668-3677.

112. Fong Y, Jarnagin W, Conlon KC, DeMatteo R, Dougherty E, et al. Hand-assisted laparoscopic liver resection: lessons from an initial experience. Arch Surg. 2000; 135: 854-859.

113. Huang MT, Lee WJ, Wang W, Wei PL, Chen RJ. Hand-assisted laparoscopic hepatectomy for solid tumor in the posterior portion of the right lobe: initial experience. Ann Surg. 2003; 238: 674-679.

114. Koffron AJ, Kung RD, Auffenberg GB, Abecassis MM. Laparoscopic liver surgery for everyone: the hybrid method. Surgery. 2007; 142: 463-468.

115. Nitta H, Sasaki A, Fujita T, Itabashi H, Hoshikawa K, et al. Laparoscopy-assisted major liver resections employing a hanging technique: the original procedure. Ann Surg. 2010; 251: 450-453.

116. Ho KM, Han HS, Yoon YS, Cho JY, Choi YR, et al. Laparoscopic Anatomical Segment 2 Segmentectomy by the Glissonian Approach. J Laparoendosc Adv Surg Tech A. 2017; 27: 818-822.

117. Lee W, Han HS, Yoon YS, Cho JY, Choi Y, et al. Comparison of laparoscopic liver resection for hepatocellular carcinoma located in the posterosuperior segments or anterolateral segments: A case-matched analysis. Surgery. 2016; 160:1219-1226.

118. Han HS, Shehta A, Ahn S, Yoon YS, Cho JY, et al. Laparoscopic versus open liver resection for hepatocellular carcinoma: Case-matched

study with propensity score matching. J Hepatol. 2015; 63: 643-650.

119. Cho JY, Han HS, Yoon YS, Choi Y, Lee W. Outcomes of laparoscopic right posterior sectionectomy in patients with hepatocellular carcinoma in the era of laparoscopic surgery. Surgery. 2015; 158:135-141.

120. Choi Y, Han HS, Sultan AM, YS Yoon, JY Cho. Glissonean pedicle approach in laparoscopic anatomical liver resection. Hepatogastroenterology. 2014; 61: 2317-2320.

121. Yoon YS, Han HS, Cho JY, JH Kim, Yujin K. Laparoscopic liver resection for centrally located tumors close to the hilum, major hepatic veins, or inferior vena cava. Surgery. 2013; 153: 502-509.

122. Hwang DW, Han HS, Yoon YS, Cho JY, Kim JH, et al. Totally anatomic laparoscopic right anterior sectionectomy. J Laparoendosc Adv Surg Tech A. 2012; 22: 913-916.

123. Ahn KS, Han HS, Yoon YS, Cho JY. Laparoscopic anatomic S4 segmentectomy for hepatocellular carcinoma. Surg Laparosc Endosc Percutan Tech. 2011; 21: e183-186.

124. Ahn KS, Han HS, Yoon YS, Cho JY, Kim JH. Laparoscopic anatomical S5 segmentectomy

by the Glissonian approach. J Laparoendosc Adv Surg Tech A. 2011; 21: 345-348.

125. Yoon YS, Han HS, Cho JY, Ahn KS. Total laparoscopic liver resection for hepatocellular carcinoma located in all segments of the liver. Surg Endosc. 2010; 24:1630-1637.

126. Cho JY, Han HS, Yoon YS, Shin SH. Experiences of laparoscopic liver resection including lesions in the posterosuperior segments of the liver. Surg Endosc. 2008; 22: 2344-2349.

127. Buell JF, Cherqui D, Geller DA, O'Rourke N, Iannitti D, et al. The international position on laparoscopic liver surgery: The Louisville Statement, 2008. Ann Surg. 2009; 250: 825-830.

128. Wakabayashi G, Cherqui D, Geller DA, Buell JF, Kaneko H, et al. Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. Ann Surg. 2015; 261: 619-629.

129. Ban D, Tanabe M, Ito H, Otsuka Y, Nitta H, et al. A novel difficulty scoring system for laparoscopic liver resection. J Hepatobiliary Pancreat Sci. 2014; 21: 745-753.

130. Wakabayashi G, Cherqui D, Geller DA, Han HS, Kaneko H, et al. Laparoscopic hepatecto-

my is theoretically better than open hepatectomy: preparing for the 2nd International Consensus Conference on Laparoscopic Liver Resection. J Hepatobiliary Pancreat Sci. 2014; 21: 723-731.

131. Cheung TT, Dai WC, Tsang SH, Chan AC, Chok KS, et al. Pure Laparoscopic Hepatectomy Versus Open Hepatectomy for Hepatocellular Carcinoma in 110 Patients With Liver Cirrhosis: A Propensity Analysis at a Single Center. Ann Surg. 2016; 264: 612-620.

132. Chiappa A, Bertani E, Biffi R, Zbar AP, Viale G, et al. Effectiveness of LigaSure diathermy coagulation in liver surgery. Surg Technol Int. 2008; 17: 33-38.

133. Kaneko H, Otsuka Y, Tsuchiya M, A Tamura, T Katagiri, et al. Application of devices for safe laparoscopic hepatectomy. HPB (Oxford). 2008; 10: 219-224.

134. Scatton O, Brustia R, Belli G, Pekolj J, Wakabayashi G, et al. What kind of energy devices should be used for laparoscopic liver resection? Recommendations from a systematic review. J Hepatobiliary Pancreat Sci. 2015; 22: 327-334.

135. Gayet B, Cavaliere D, Vibert E, Perniceni T, Levard H, et al. Totally laparoscopic right hepatectomy. Am J Surg. 2007; 194: 685-689.

136. Gumbs AA, Gayet B. Totally laparoscopic

left hepatectomy. Surg Endosc. 2007; 21:1221.

137. Gumbs AA, Gayet B, Gagner M. Laparoscopic liver resection: when to use the laparoscopic stapler device. HPB (Oxford). 2008; 10: 296-303.

138. Slakey DP. Laparoscopic liver resection using a bipolar vessel-sealing device: LigaSure. HPB (Oxford). 2008; 10: 253-255.

139. Gallagher AG, Ritter EM, Lederman AB, McClusky DA, Smith CD. Video-assisted surgery represents more than a loss of three-dimensional vision. Am J Surg. 2005; 189: 76-80.

140. Hubber JW, Taffinder N, Russell RC, Darzi A. The effects of different viewing conditions on performance in simulated minimal access surgery. Ergonomics. 2003; 46: 999-1016.

141. Wagner OJ, Hagen M, Kurmann A, Horgan S, Candinas D, et al. Three-dimensional vision enhances task performance independently of the surgical method. Surg Endosc. 2012; 26: 2961-2968.

142. van der Vorst JR, Schaafsma BE, Hutteman M, Verbeek FP, Liefers GJ, et al. Near-infrared fluorescence-guided resection of colorectal liver metastases. Cancer. 2013; 119: 3411-3418.

143. Ishizawa T, Masuda K, Urano Y, Kawagu-

chi Y, Satou S, et al. Mechanistic background and clinical applications of indocyanine green fluorescence imaging of hepatocellular carcinoma. Ann Surg Oncol. 2014; 21: 440-448.

144. Ishizawa T, Gumbs AA, Kokudo N, Gayet B. Laparoscopic segmentectomy of the liver: from segment I to VIII. Ann Surg. 2012; 256: 959-964.

145. Terasawa M, Ishizawa T, Mise Y, Inoue Y, Ito H, et al. Applications of fusion-fluorescence imaging using indocyanine green in laparoscopic hepatectomy. Surg Endosc. 2017.

146. Arita J, Takahashi M, Hata S, Shindoh J, Beck Y, et al. Usefulness of contrast-enhanced intraoperative ultrasound using Sonazoid in patients with hepatocellular carcinoma. Ann Surg. 2011; 254: 992-999.

147. Takahashi M, Hasegawa K, Arita J, Hata S, Aoki T, et al. Contrast-enhanced intraoperative ultrasonography using perfluorobutane microbubbles for the enumeration of colorectal liver metastases. Br J Surg. 2012; 99: 1271-1277.

148. Kawaguchi Y, Velayutham V, Fuks D, Christidis C, Kokudo N, et al. Usefulness of Indocyanine Green-Fluorescence Imaging for Visualization of the Bile Duct During Laparoscopic Liver Resection. J Am Coll Surg. 2015; 221: e113-117.

149. Kaibori M, Ishizaki M, Matsui K, Kwon

AH. Intraoperative indocyanine green fluorescent imaging for prevention of bile leakage after hepatic resection. Surgery. 2011; 150: 91-98.

150. Fan ST, Cheung ST, Lo CM. Indications for liver transplantation in patients with chronic hepatitis B and C virus infection and hepatocellular carcinoma. J Gastroenterol Hepatol. 2000; 15: E181-186.

151. Lo CM, Fan ST, Liu CL, Wei WI, Chan JK, et al. Applicability of living donor liver transplantation to high-urgency patients. Transplantation. 1999; 67: 73-77.

152. Liu CL, Fan ST, Lo CM, Yong BH, Fung AS, et al. Right-lobe live donor liver transplantation improves survival of patients with acute liver failure. Br J Surg. 2002; 89: 317-322.

153. Mazzaferro V, Regalia E, Doci R, Salvatore A, A Pulvirenti, et al. Liver transplantation for the treatment of small hepatocellular carcinomas in patients with cirrhosis. N Engl J Med. 1996; 334: 693-699.

154. Yao FY, Ferrell L, Bass NM, Watson JJ, Bacchetti P, et al. Liver transplantation for hepatocellular carcinoma: expansion of the tumor size limits does not adversely impact survival. Hepatology. 2001; 33: 1394-1403.

155. Lo CM, Fan ST. Liver transplantation for hepatocellular carcinoma. Br J Surg. 2004; 91: 131-133.

156. Darwish Murad S, Kim WR, Harnois DM, Douglas DD, Burton J, et al. Efficacy of neoadjuvant chemoradiation, followed by liver transplantation, for perihilar cholangiocarcinoma at 12 US centers. Gastroenterology. 2012; 143: 88-98.

157. Heimbach JK. Successful liver transplantation for hilar cholangiocarcinoma. Curr Opin Gastroenterol. 2008; 24: 384-388.

158. Heimbach JK, Gores GJ, Haddock MG, Alberts SR, Nyberg SL, et al. Liver transplantation for unresectable perihilar cholangiocarcinoma. Semin Liver Dis. 2004; 24: 201-207.

159. Heimbach JK, Gores GJ, Nagorney DM, CB Rosen. Liver transplantation for perihilar cholangiocarcinoma after aggressive neoadjuvant therapy: a new paradigm for liver and biliary malignancies? Surgery 2006; 140: 331-334.

160. Rosen CB, Heimbach JK, Gores GJ. Liver transplantation for cholangiocarcinoma. Transpl Int 2010; 23: 692-697.

161. Hagness M, Foss A, Line PD, Scholz T, Jørgensen PF, et al. Liver transplantation for nonre-

sectable liver metastases from colorectal cancer. Ann Surg. 2013; 257: 800-806.

162. Dueland S, Guren TK, Hagness M, Glimelius B, Line PD, et al. Chemotherapy or liver transplantation for nonresectable liver metastases from colorectal cancer? Ann Surg. 2015; 261: 956-960.

163. Dueland S, Hagness M, Line PD, Guren TK, Tveit KM, et al. Is Liver Transplantation an Option in Colorectal Cancer Patients with Nonresectable Liver Metastases and Progression on All Lines of Standard Chemotherapy? Ann Surg Oncol. 2015; 22: 2195-2200.

164. Cherqui D, Soubrane O, Husson E, Barshasz E, Vignaux O, et al. Laparoscopic living donor hepatectomy for liver transplantation in children. Lancet. 2002; 359: 392-396.

165. Samstein B, Cherqui D, Rotellar F, Griesemer A, Halazun KJ, et al. Totally laparoscopic full left hepatectomy for living donor liver transplantation in adolescents and adults. Am J Transplant 2013; 13: 2462-2466.

166. Samstein B, Griesemer A, Cherqui D, Mansour T, Pisa J, et al. Fully laparoscopic left-sided donor hepatectomy is safe and associated with shorter hospital stay and earlier return to work: A comparative study. Liver Transpl. 2015; 21: 768-773.

167. Troisi RI, Wojcicki M, Tomassini F, Houtmeyers P, Vanlander A, et al. Pure laparoscopic full-left living donor hepatectomy for calculated small-for-size LDLT in adults: proof of concept. Am J Transplant. 2013; 13: 2472-2478.

168. Han HS, Cho JY, Yoon YS, Hwang DW, Kim YK, et al. Total laparoscopic living donor right hepatectomy. Surg Endosc. 2015; 29: 184.

169. Soubrane O, Perdigao Cotta F, Scatton O. Pure laparoscopic right hepatectomy in a living donor. Am J Transplant. 2013; 13: 2467-2471.

170. Takahara T, Wakabayashi G, Hasegawa Y, Nitta H. Minimally invasive donor hepatectomy: evolution from hybrid to pure laparoscopic techniques. Ann Surg. 2015; 261: e3-4.