7

# Laparoscopic Liver Surgery

Steven A. White, Rajesh Y. Satchidanand and Derek M. Manas
*Department of Hepatobiliary and Transplant Surgery,*
*The Freeman Hospital, Newcastle upon Tyne, Tyne and Wear,*
*England*

## 1. Introduction

Recent improvements in cross sectional imaging, chemotherapy and advances in the techniques of liver resection have resulted in rates of 5 year survival approaching 60% for patients with colorectal liver metastasis. Historically liver resection was perceived as a formidable operation but now liver resection is safe and specialist centres should expect low mortality rates in the region of 1-2%[1,2]. Consequently, many more patients are now referred for liver resection and its indications are continually being revised and expanded.

At the same time there have been many advances in minimally invasive laparoscopic surgical techniques so much so that laparoscopic liver resection (LLR) is becoming an increasingly popular option amongst laparoscopic enthusiasts. Indeed the first laparoscopic liver resection was described nearly 20 years ago for focal nodular hyperplasia[3]. In a recent review by Nguyen and colleagues [4,5] over 3,000 laparoscopic liver resections have now been reported in various series and meta-analyses [6 7 8]. Despite this enthusiasm doubts still remain over its more widespread application because of the risks of complications and whether there is any patient benefit [9-11]. The latter is still very difficult to demonstrate in the absence of any well designed randomized controlled trials. Like laparoscopic cholecystectomy that came before, it is now very unlikely that any well designed Randomised controlled trials (RCT) will ever be performed. Perhaps the most important RCT that should have been done is outcome after laparoscopic left lateral resection versus open resection. Yet for laparoscopic enthusiasts the advantages are so obvious they would now be very reluctant to offer open resection in a trial setting. The situation is very different for major resections e.g. right hepatectomy where any advantage is still very difficult to demonstrate. In this situation a RCT would be difficult to design as few centres regularly perform this operation and large numbers would be needed because of high rates of conversion and recruiting patients with tumours distributed in such away that they can be resected laparoscopically.

## 2. Indications and contra-indications

### 2.1 International consensus - The Louisville statement

In 2008 a consensus meeting was convened in Louisville to discuss the position of LLR amongst some of the worlds leading hepatobiliary surgeons. This was a very important development and the following guidelines were suggested as follows[11]:

1. LLR can be performed safely in specialized centres with results comparable to those achieved after open resection

2. The main indications are for both symptomatic benign and malignant tumours the latter being predominantly Hepatocellular carcinoma (HCC) and liver metastasis (colorectal-CRLM) and in determinant liver lesions.
3. It is important that the indications for resection of benign liver tumours are not expanded (e.g. asymptomatic tumours where there is no diagnostic doubt)
4. Harvested grafts for living donation should only be performed in very specialised centres and should be scrutinized in a world registry [12 13-15].

Other areas of discussion focused on patient safety and contraindications with the following guidelines being suggested

1. The contraindications for LLR should be the same as those for open resection.
2. Other contraindications include;
3. The presence of dense adhesions and failing to progress after prolonged dissection
4. Tumour adjacent to a major vascular structure
5. Tumour too large to manipulate
6. The need for a portal lymphadenectomy.

### 2.2 Benign liver tumours

Paired comparisons between laparoscopic and open resection for benign tumours have not been frequently reported [16 17 18]. A few series are dedicated to LLR for benign tumours only but these can be subdivided into solid or cystic [19 20]. Most studies report outcomes in series mixed for both benign and malignant tumours [21]. The largest series of LLR for benign tumours have been reported by Koffron et al. (n=177) [22]. Forty seven were hepatic adenomas the others being made up of haemangiomas (n=37), FNH (n=23) and liver cysts (n=70). It is not clear in this article what the indications for resection were. Most centres report predominantly resection of malignant tumours. From the Newcastle series of 69 patients; 28% constitute benign lesions and 72% malignant. The most common benign lesions include hepatic adenoma **(Figure 1),** symptomatic FNH (or where there was diagnostic doubt), biliary cysts, angiomyolipoma, haemangioma, biliary haematoma and polycystic liver disease. In our experience most of these lesions were resected in patients with a known diagnosis of colorectal carcinoma where there was diagnostic doubt regarding a liver lesion despite cross sectional imaging by CT and MRI and in some cases contrast enhanced ultrasound. It is important not to expand the indications for resection just because it can be done laparoscopically. In general for benign tumours most report less morbidity (including incisional hernias), shorter hospital stay and faster time to oral intake [19].

### 2.3 Malignant liver tumours

Although there have been many reports of LLR for malignant tumours being resected including hilar cholangiocarcinoma [23] and neuroendocrine/carcinoid tumours, for the purposes of this chapter discussion will concentrate on the most commonly resected malignant tumours e.g. CRLM and HCC.

### 2.4 Colorectal

One of the disadvantages of LLR for CRLM is that all patients have had previous surgery and initial dissection can be tedious because of adhesions. Especially when patients have had a previous right hemicolectomy or cholecystectomy. Indeed in one patient in the authors series LLR was abandoned after 3 hours of dissection and failure to progress.

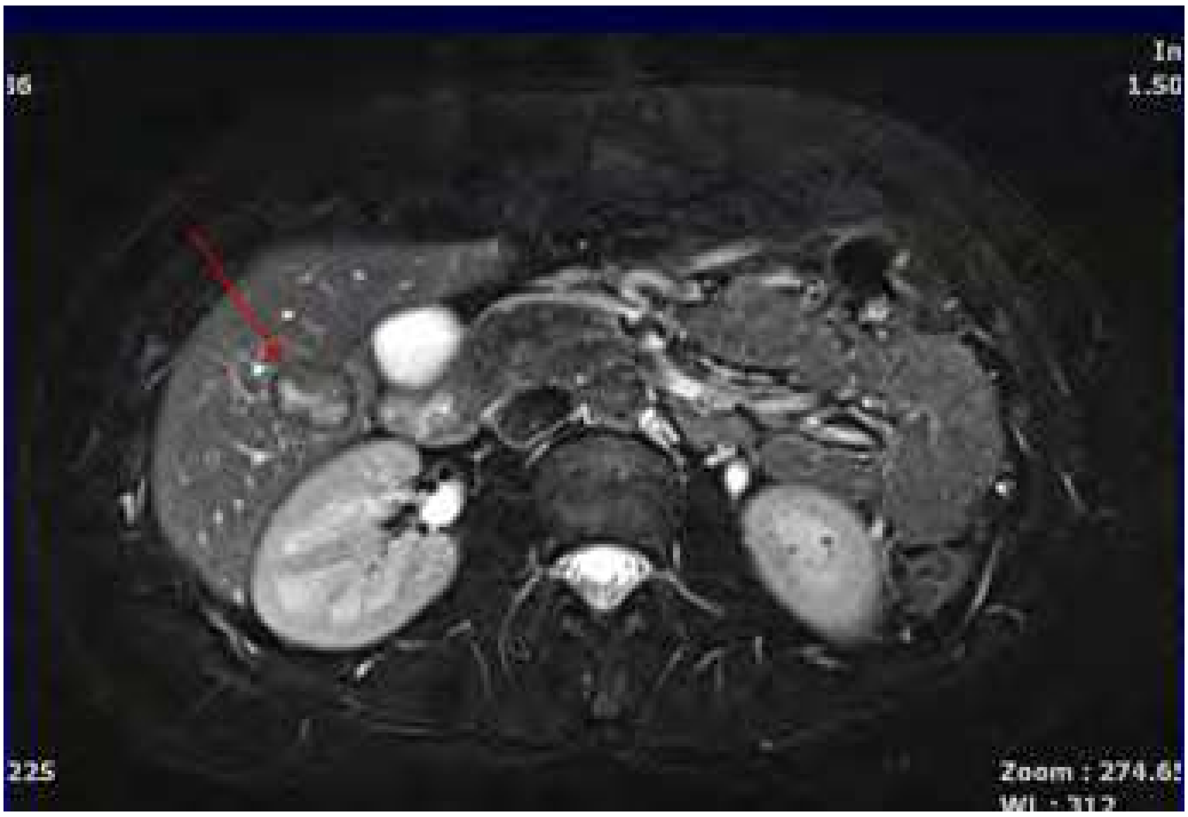



Fig. 1. Hepatic Adenoma ideally placed for Laparoscopic resection

Surgery for LLR should be divided in two broad categories, a) Those patients with metastasis confined to liver and b) those patients with concomitant extra-hepatic disease. Essentially all patients with CRLM who have had radical treatment for their primary CRC should be considered resectable and falls into one of the following groups;

A. Those patients with metastasis confined to liver

i. Unilobar or bilobar disease
ii. Single or multiple metastases
iii. Remnant liver is approximately 20-30%. Total liver volume (TLV) dependent on remnant function or equivalent to at least two liver segments

B. Those patients with concomitant extra-hepatic disease

i. CRLM in the presence of resectable or ablatable pulmonary disease
ii. CRLM in the presence of resectable isolated extra-hepatic disease e.g. spleen, adrenal or resectable local recurrence
iii. CRLM in the presence of resectable invasion of adjacent structures (e.g. diaphragm, adrenal).

With respect to extra-hepatic disease. Elias et al. have reported overall 5-year crude survival rates of 28% when hepatic and extra-hepatic disease are both resected in a curative manner, however in this situation it must be accepted that an R0 resection will not be possible in 50% of patients [24]. More importantly, the presence of extra hepatic disease does not appear to influence outcome when resection is complete along with the liver metastases [25]. Nevertheless it cannot be denied that there are few long term survivors in the presence of peritoneal disease [26]. Certainly these types of patients should be carefully evaluated by open surgery and not by LLR. The easiest patients to consider for LLR are those with disease confined to a single segment who ideally have a solitary metastasis in the anterior segments (IVb, V and in some cases VI) (**Figure 2.)** or in the left lateral segment (group Ai or Aii). Laparoscopic posterior sectionectomy has been described but they are significantly more challenging [27-29].

Fig. 2. Colorectal metastasis in segment VI for laparoscopic resection

Patients with extra-hepatic disease (group B) fall into a very difficult group as resection of extra-heptic disease may require more advanced laparoscopic skills which could be more easily dealt with by open surgery. The temptation to laparoscopically resect a single lesion and then perhaps laparoscopically ablate a more difficult lesion should be avoided and open surgery performed.

With respect to nodal disease, regional metastasis to peri-hepatic lymph nodes deposits should not be regarded as a contraindication to open resection but does reduce long-term outcome. Recent studies suggest up to 20% of patients will have hepatic nodal involvement at the time of resection [30]. It is very difficult to evaluate this laparoscopically. Resection of nodes involving second tier nodes (i.e.celiac nodes) is far more controversial and offers no survival benefit. Another problem highlighted by the MSKCC group is the ability to identify which lymph nodes are involved during open surgery. Routine sampling of lymph node stations and lymphadenectomy is unnecessary and time consuming, without any evidence of benefit. The best approach is selective sampling based on intra-operative assessment and pre-operative imaging [31]. Again performing this laparoscopically would not be advisable.

One of the main advantages of LLR, in our experience, has been its use with synchronous tumours **(Figure 3).** LLR can be performed at the same time with a laparoscopic colorectal specialist who removes the primary in one sitting. Up to 25% of patients may present in this way [32]. Nonetheless there are no significant publications with any reasonable numbers to draw on any useful conclusions as to whether there is any benefit with combined laparoscopic procedures [33 34]. Minimally invasive techniques have obvious advantages over two major laparotomies in a short space of time. With advances in chemotherapy more patients are now becoming operable with their primary still in situ as there liver disease can be controlled. This cohort is becoming increasingly more common and challenging [35 36]. Generally these patients have either laparoscopic right hemicoloectomy or laparoscopic anterior resection with excision of either a solitary or unilobar metastasis. A further group includes those patients who have major colonic resection with clearing of a single lobe and then further downstaging chemotherapy prior to definitive resection by a second open liver resection. Recent reports have suggested no significant differences in post-operative morbidity or mortality or 5 year survival rates in those patients with synchronous disease who need a minor hepatectomy with colonic resection [37 38] . In patients who require a major hepatectomy, a test of time, to enable an assessment of the biological behaviour of the disease and to provide adjuvant treatment, is still sensible. Although simultaneous laparoscopic major liver resection e.g. right hepatectomy along with major colonic resection e.g. anterior resection have been successfully described [39 40] the authors would not recommend this without a careful assessment of the patients fitness because of the need for prolonged anaesthesia beyond 5 hours.

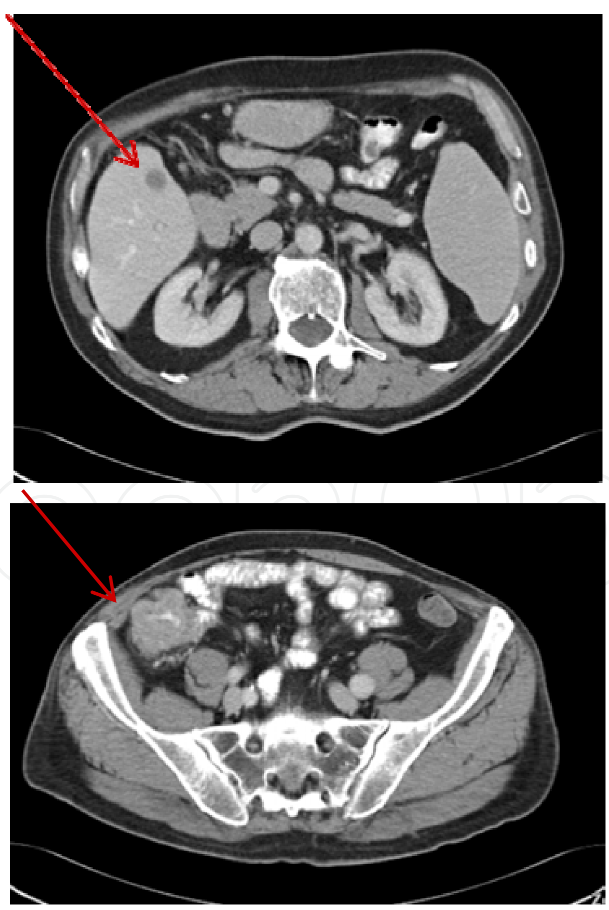


Fig. 3. Colorectal metastasis with the primary colonic tumour still in situ ideal for simultaneous laparoscopic

Two-thirds of patients undergoing liver resection for CRLM will develop recurrence of their disease within 2 years [32]. One third will manifest with liver only disease and a small proportion of them will be suitable for repeat liver resection [41]. Technically repeat liver resections are demanding. However long-term survival is similar to those following initial liver resections for open resections [42] [43] . In a series of 60 third hepatectomies [43] complication rates were similar to those having first and second hepatectomies with no obvious survival disadvantage. Five year survival rates of 32% have been reported after open resection. Multivariate analysis suggests a curative resection (R0) as the most important predictor of improved survival after open resection. There are no studies reporting repeat LLR but these are likely to be technically more challenging. Further studies are needed to evaluate repeat LLR in terms of survival rates and complications.

### 2.5 Hepatocellular carcinoma

The treatment of HCC covers a broad spectrum including surgical (Resection, Ablation or Liver Transplant-LT) and non-surgical treatments (Sphere therapy, TACE, Sorafenib). Mortality after liver resection in large series of non cirrhotics are now around 3%. Yet in large volume centres in the east, mortality after resection for HCC in cirrhotics is now approaching zero. Substantial refinements in the surgical techniques have played an important role including the development of liver "hardware" such as ultrasonic dissectors, low CVP anaesthesia, hepatoduodenal compression (Pringle's manoeuvre) and vascular staplers have all contributed to reducing blood loss, post-op morbidity and mortality [44].

There is no doubt that the results of LT for primary HCC have improved dramatically in the last decade following the publication of the Milan criteria by Mazzaferro et al. in 1996 [45]. Consequently more patients with HCC are being referred for consideration of LT and the management of these patients on the ever expanding waiting list present an interesting cohort of patients to discuss. With this in mind bridging treatments such as resection, chemo-embolisation or ablation by RFA are becoming increasingly important The clinical characteristics after such treatments are also important in terms of predicting overall prognosis.

One of the disadvantages of resection is tumour recurrence as some suggest that this can hinder subsequent LT [46] yet this has not been substantiated by others and in terms of technical difficulty is no different to re-transplantation for other indications [47]. To avoid this problem there is a niche for the development of LLR which can reduce morbidity and have an impact on curative intent as a potential bridging treatment. Resection can be useful as a bridging treatment if patients are Childs A with a low MELD score, have a small tumour <3cm without any obvious macroscopic tumour thrombus [44]. Overall 3 year survival rates in patients with Child's A cirrhosis can be as high as 93% [48] for segmental resections. Segmental resections are best performed given the risks of recurrence with non segmental resections due to microscopic satellite nodules that are not easily visualised by intra-operative ultrasound. Comparisons of LLR with open resection for HCC in cirrhotic patients are favourable [49] [50] [51] [52] but the main advantage of LLR is a shorter hospital stay and less blood loss. LLR is also less likely to lead to problematic adhesions if LT is required at a later date. Numerous single centre [49] [50] [53] [54] and multi-centre series [55] have published their series of LLR in patients with HCC and cirrhosis confirming it is safe and reproducible without oncological compromise or survival.

## 3. Imaging

### 3.1 Computed tomography

This modality is the work-horse of all imaging techniques in the pre-operative planning phase for LLR. Present generation triple phase multi-detector CT scanning technology enables image acquisition during a single-breath hold, of the entire chest and abdomen and pelvis. The improved resolution results in excellent detection of lesions in solid organs and enables better local, regional and distant staging. The other advantage of CT scanning is the high incidence of detection of lesions in the lung, liver and pelvis, when intravenous contrast is used with arterial or venous phase scanning. Slice thickness or maximum collimation should be 3- 5mm. The sensitivity for detecting a metastatic lesion approaches 80%, which increases to 90% when CT angiography is used, however lesions less than 1 cm in size are liable to be missed [56]. Contrast enhanced helical CT is the investigation of choice in the initial evaluation of liver tumours assessing response to chemotherapeutic agents and for post-operative surveillance for tumour recurrence.

### 3.2 Magnetic resonance imaging

Magnetic resonance imaging has an extremely high sensitivity in identifying and characterizing small lesions within the liver. In addition patients are not exposed to radiation but the procedure is far more expensive and labour intensive. One of its limitations is the identification of extra hepatic disease. The technique is very sensitive to respiratory artefact and this can limit its resolution in certain patients who are unable to hold their breath for a sufficient length of time. Contrast agents such as gadolinium and the liver specific super magnetic iron oxide result in very high sensitivities in diagnosing small (less than 1 cm) liver metastases [57] and differentiating between potentially malignant and benign liver lesions (e.g. FNH, adenoma etc). Usually MR imaging is utilised just prior to resection, in order to identify small lesions not visualised by conventional CT scanning but this is not universally routine.

### 3.3 Intra-operative ultrasound

Intra-operative ultrasound (IOUS) is an essential pre-requisite for assessment of the liver prior to commencement of liver resection. IOUS allows for mapping of the major vascular and ductal structures in relation to the metastasis and aids in planning the final approach to resection. It also serves as a guide in confirming the accuracy of the plane of dissection. However following chemotherapy, when fatty change supervenes and in the presence of cirrhosis, identification of small iso-echoic masses becomes poor, decreasing the sensitivity of IOUS. IOUS must be used before, during and at the end of resection in order to keep R1 resection rates as low as possible. It is also important to leave an adequate margin around the tumour and to mark the margins prior to commencing parenchymal transaction. This is also useful to avoid coning as it is very difficult to estimate the depth of a tumour without measuring the dimensions.

## 4. Anaesthesia

One of the overlooked contra-indications for LLR is the patients inability to withstand a prolonged pneumoperitoneum especially with major resections e.g. right hepatectomy. Results of left lateral liver resection suggest that resection time can be comparable to open.

The median duration in the literature is around 2-3 hours [58] . In the authors experience laparoscopic left lateral resection can be performed as quick laparoscopically as open once the learning curve has been overcome. Transection time can be less than 1 hour as reported in a recent meta-analysis [59]. For major hepatectomy operative times are prolonged and the duration of anaesthesia can be in excess of 5 hours compared to 3 hours for open surgery [60 61]. This can be reduced by performing a hybrid resection or, using a hand-port as it is generally the parenchymal transection and dealing with the right hepatic vein that causes the prolonged pneumoperitoneum. In the UK most centres use epidural anaesthesia for post-operative pain relief but for LLR the duration of anaesthesia can be significantly reduced as an epidural and central venous pressure line are no longer required.

Few studies have reported the consequences of the prolonged peritoneum. There is no doubt that increased intra-abdominal pressure reduces liver, renal lower limb and mesenteric blood flow. It also increases cardiac output and arterial pressures . The presence of obesity exacerbates these problems further. Careful consideration therefore needs to be given to those patients with significant renal and cardiac disease. There is also experimental evidence that prolonged peritoneum can impair post-operative liver regeneration, oxidative stress and hepatocellular damage[62]. Sometimes the pneumoperitoneum can have advantages in that during bleeding a careful increase in intra-abdominal pressure can reduce bleeding and allow parenchymal transection without portal clamping. However prolonged pneumoperitoneum with portal clamping can cause a significant reduction in hepatic oxygen tensions, tissue hypoxia, with higher transaminase and increased tissue necrosis [63]. Gas embolism is also thought to be of concern in that it can cause haemodynamic disturbance in 50% of episodes but usually has no clinical consequences as the solubility of carbon dioxide is greater than nitrogen. It is important to avoid high intra-abdominal pressures when dissecting the major venous structures in an effort to avoid this problem [64]. By controlling the differential pressures between the pneumoperitoneum and central venous pressure the risk of air embolism can be reduced significantly.

## 5. Techniques of laparoscopic liver resection

Definitions of laparoscopic liver surgery have been standardised. There are 3 techniques, totally laparoscopic, hand assisted and hybrid [11]. Hand assisted can be used either at the start of the operation or introduced at any time to aid dissection. This is most often performed during right hepatectomy or major resection and to control bleeding. Hybrid procedures comprise either totally laparoscopic converted to hand assisted and then the operation is completed through a small incision usually this is for parenchymal transection or to aid mobilisation of the right or left lobe after hilar dissection.

### 5.1 Patient positioning

During resection of the left lateral segment, and tumours within the anterior segments e.g. IVb, V, VI the patient is positioned in the supine position with split legs with the surgeon standing in between them and the assistants on each side **(Figure 4).** For tumours placed in the posterior segments (VI and VII), patients are positioned in the left lateral decubitus position. For those patients positioned supine with split legs, five ports (ENDO PATH Xcel ™, Ethicon Endosurgery, LLC, USA) are positioned; three 12 mm ports: the first at the umbilicus (sometimes higher if distance between the xiphoid and umbilicus is greater than 15 cm), the second and third working ports in the right and left mid clavicular line; and two

5 mm ports in the right and left anterior axilliary line **(Figure 5).** For tumours positioned in segments IVa and VIII, high up towards the dome of the right diaphragm a further 10mm port is placed at the xiphisternum to allow for CUSA parenchymal division (Integra, Saint Priest, France, USA)

Fig. 4. The surgeons preferred position for lap resection

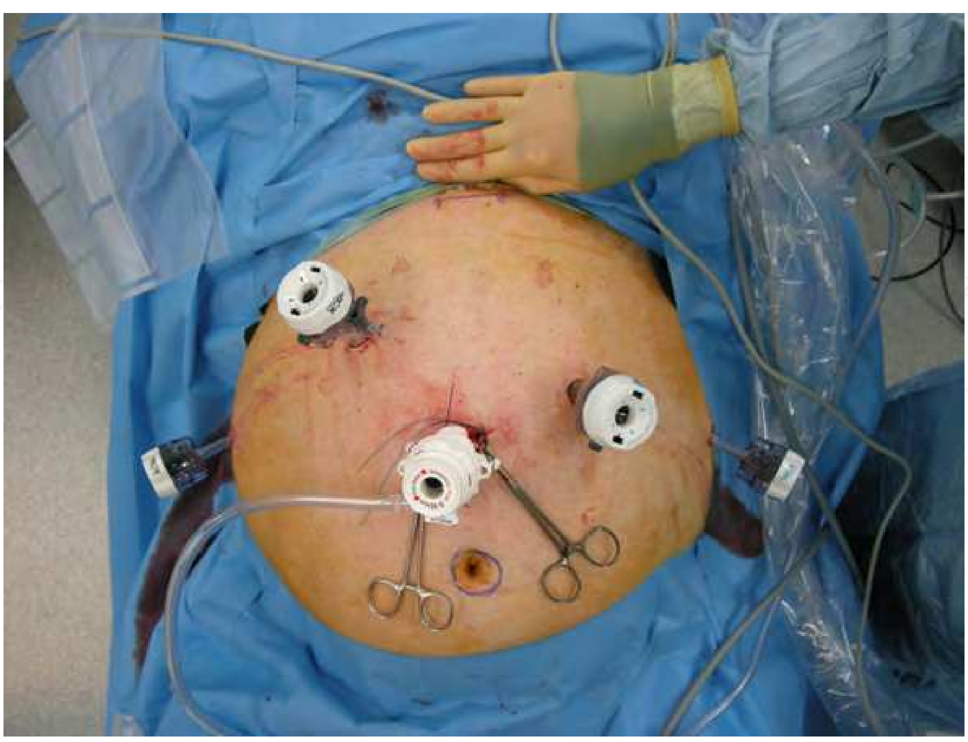


Fig. 5. Port position for lap left lateral resection

Left hepatectomy can usually be performed using similar port positions to left lateral resection. For right hepatectomy the surgeon stands between the patients legs with two assistants on either side. The right side and right shoulder are slightly elevated. Ports are shifted to the right and are placed as far across as the mid axillary line **(Figures 7a and 7b).** A hand port, if required, is usually placed in the right iliac fossa **(Figure 8).** If it is placed too high the hand will be over the liver, if it placed too low the surgeon has to stoop for prolonged periods which can become uncomfortable. A laparoscopic port can also be placed through the hand port to assist with totally laparoscopic dissection. Right hepatectomy hepatectomy should only be performed if the tumour is located away from the hilum or the RHV or IVC so as to give an oncologically sound resection.

### 5.2 Pringle's manoeuvre

A staging laparoscopy is performed first to rule out the presence of significant extra-hepatic disease although this is often limited due to dense pelvic adhesions. Laparoscopic ultrasound (7.5 MHz, Aloka Co. Ltd, Tokyo, Japan) of the liver is then performed to define the vascular anatomy and to confirm the location of metastases. The liver can be lifted by two methods; early in our series a Nathanson hook was placed at the xiphisternum as described for Nissen's Fundiplication. This elevates the left lateral segment and the hepato-duodenal ligament off the inferior vena cava thus ensuring good access through the foramen of Winslow and giving fixed retraction for all hilar dissection. Now either a hand retractor (fan), diamond flex or goldfinger retractor can be placed through a 5mm port to elevate the LLS. The xiphisternal Nathanson Hook can then be replaced with a 5mm port after hilar dissection to assist with tumours high on the dome of VIII.

An alternative method is to retract the falciform ligament towards the shoulder but this uses an instrument through a 5 mm port. A better approach is to divide the falciform ligament and then place an Endoloop ™ (Autosuture, Tyco Healthcare UK Ltd) around the free edge of the ligamentum teres. This can be retracted superiorly by bringing this through the anterior abdominal wall using an 'Endo Close™' (Autosuture, Tyco Healthcare UK Ltd) device. The suture is then held in a haemostat thus holding the ligament against the anterior abdominal wall. The gallbladder can also be used for retraction but some patients may have already had this removed. Calot's triangle should be dissected first and the cystic duct and cystic artery divided.. Sometimes it is necessary to partially dissect the infundibulum of the gallbladder prior to retraction over the liver. This elevates the liver and also assists with access to the posterior surface of V and VI.

Once the liver has been retracted and the hepato-duodenal ligament has been lifted a tape can then be placed. The pars lucida is opened, care being taken to look for an accessory left hepatic artery. To place a tourniquet around the hepato-duodenal ligament a 'Gold finger' (Gold finger ™, Blunt Dissector and Suture Retrieval System, Ethicon Endo Surgery, Johnson & Johnson, USA) is used. This is an endoscopic dissector previously developed for laparoscopic bariatric surgery. The Gold finger is a long instrument with a versatile tip which is used to help position laparoscopic gastric bands and creation of a retro-gastric tunnel. The tip is blunt and includes a slot to snare and pull a pre-tied suture, and a keyhole for multiple gastric bands. The tip can be set at varying degrees between the neutral position and 90 degrees. It has multi-positional flexibility, is malleable and provides precise articulation. The Gold finger has a one-handed, ergonomic operation which enables precise dissection and controlled grasping and snaring. It is also disposable and ensures sterility and consistent performance.

A nylon tape is passed through the snare in the tip of a Gold finger ™ (Ethicon Endo Surgery, Johnson & Johnson, USA). As the tip of the Gold finger is blunt and atraumatic, it can safely be introduced through a 10 mm working port in the right upper quadrant. It is best to do this through the right sided port as the natural curvature of the liver from this side avoids placing the tip into the caudate lobe and porta-hepatis if done from the left side. The hepato-duodenal ligament is then cradled by the 'Gold finger ™' (Ethicon Endo Surgery, Johnson & Johnson, USA). The Gold finger is then advanced beyond the porta-hepatis until the tip with the nylon tape can be visualised on the left side of the hepato-duodenal ligament. As the tip of the Gold finger is atraumatic, it can be safely deployed the tip is then flexed and articulated to 90 degrees. The tape can then be grasped through the port placed in the left upper quadrant in the mid-clavicular line **(Figure 6).** The two ends are positioned through the port onto the anterior abdominal wall and placed through a 'snugger' using tubing (Suction tubing 10 cm, 7 mm, Pennine Healthcare Ltd, UK). The port is removed and replaced with the tape lying adjacent to the side of the port.

Portal triad clamping (Pringle's manoeuvre) is one of the methods used to reduce bleeding from the hepatic transection plane. This manoeuvre of encircling the hepato-duodenal ligament with a nylon tape is widely used and is easily performed during conventional open surgery. However, this step can be difficult and technically challenging during laparoscopic liver surgery and not all surgeons place a tape laparoscopically for fear of injury to the IVC and structures within the porta hepatitis. For major laparoscopic resection it is a vital adjunct to reduce haemorrhage. This is as a result of the two dimensional view during laparoscopy and the ergonomics of most laparoscopic instruments make this manipulation blind with the potential of injury to vital structures. Most of the literature on totally laparoscopic liver resection mentions the placement of a tape or vascular sling around the portal triad in the hepato-duodenal ligament in case a Pringle's manoeuvre is necessary during parenchymal division [21] although opinions differ [65] [14] [66] and once experience has been gained for minor resections is often not necessary at all, even in some cirrhotic patients [67] Nonetheless it is our policy to always place a tape around the hepatoduodenal ligament for training purposes.

Some surgeons use a tape around the hepato-duodenal ligament with intra-peritoneal clamping. However, this uses up an extra port as an instrument clamps it on the inside. Moreover laparoscopic instruments are not robust enough to give a satisfactory clamp. The technique of using the Gold finger to facilitate placement of a tape around the hepato-duodenal ligament for the Pringle manoeuvre is an easy, safe and efficient technique. This manoeuvre is performed easily in a few minutes. Although this technique has evolved in a small series we believe this to be a simplified technique that is much easier and safer for laparoscopic liver resection.

## 6. Parenchymal transection and haemostasis

### 6.1 Hilar dissection

There are many preferences for hilar dissection for major resection e.g. right trisectionetomy, right hepatectomy or left hepatectomy. Intra-hepatic [68] or extra-hepatic [69] (conventional or anterior approach) division of major structures have both been described**.** It is the authors practice to divide all major structures extra-hepatically with the exception of the hepatic bile duct. This is divided last of all, within the liver parenchyma, using a suitable stapling device. Fortunately the use of vascular staplers with roticulators has overcome most of the problems relating to the management of major pedicles and vessels, these can be either 45 or 60mm varieties. When the bile duct is divided within the liver there is less risk of damaging the remnant hepatic duct.

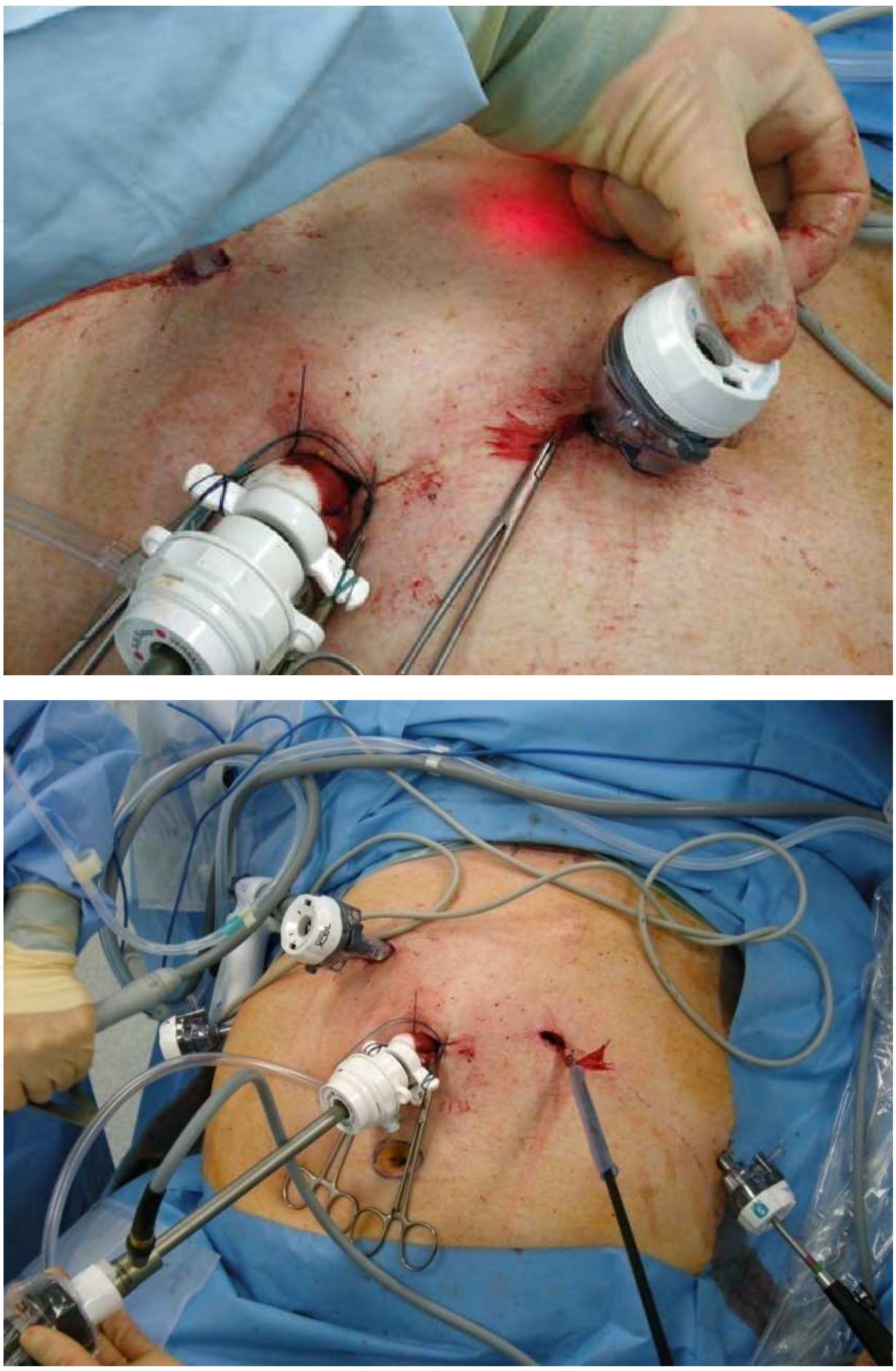


Fig. 6. Hepatoduodenal tape positioned lateral to the port for a Pringle manoeuvre

Fig. 7a. Port position for laporoscopic right hepatectomy with RIF incision

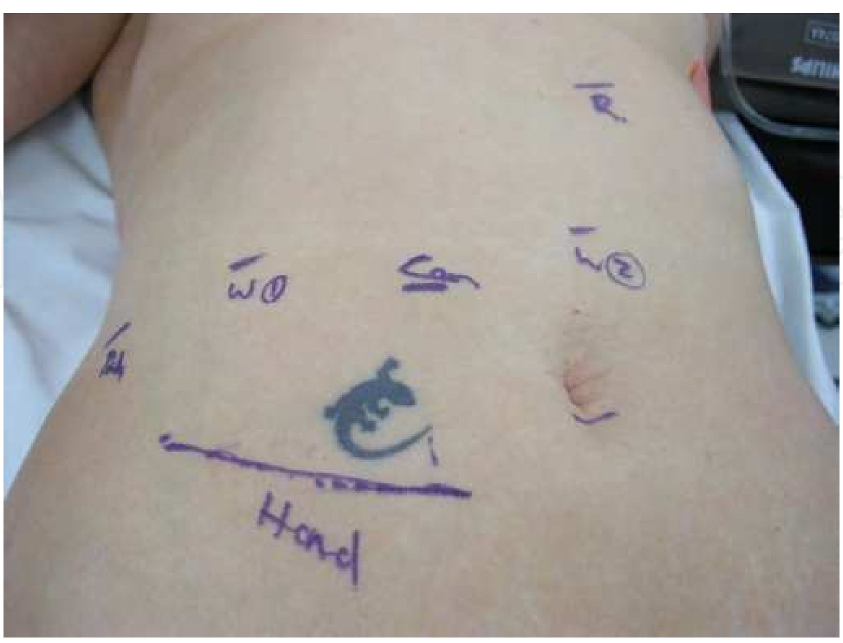



Fig. 7b. Pre-operative marking for hand assisted right hepatectomy

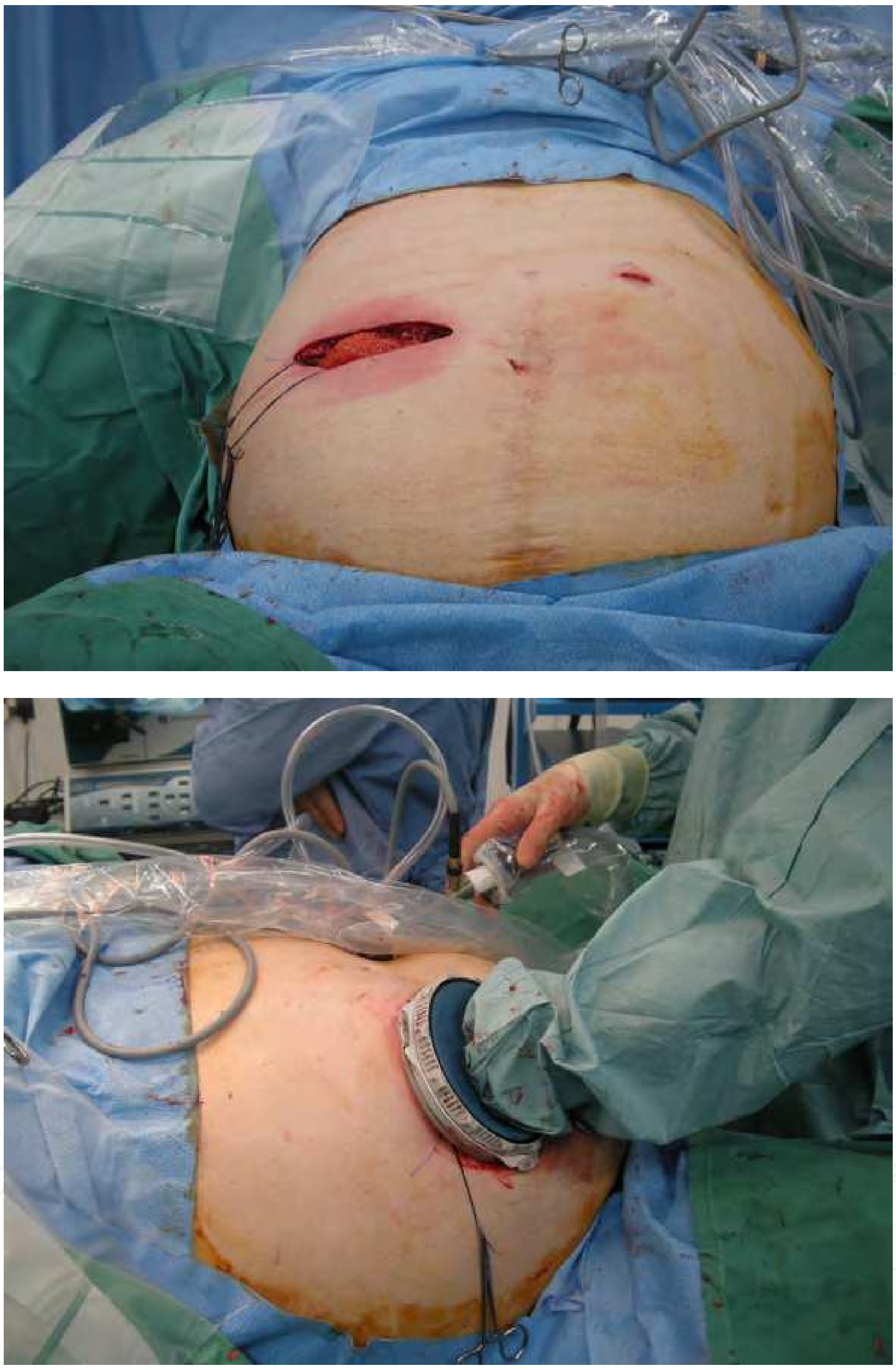


Fig. 8. Hand assisted liver resection

Hilar dissection can be tedious and difficult especially when there are extensive adhesions. Major structures can be inadvertently injured and troublesome bleeding can be difficult to deal with for the inexperienced surgeon. Extensive dissection in the hepatoduodenal ligament is never necessary and can lead to devascularisation of the common hepatic duct or remnant hepatic duct. For a right hepatectomy identification of major structures such as the right hepatic artery (RHA), and right portal vein (RPV) can be approached either anteriorly or laterally, posterior to the hepatic duct.. The author's preference is to use locking clips such as Weck Clips**.** The portal vein can be approached differently. This can be divided using either a vascular stapler or Weck clips. However, care needs to be taken when achieving vascular control as bleeding at the portal confluence can be difficult to stop. Dividing the caudate process prior to this assists this manoeuvre by allowing more room. Tiny venous tributaries supplying the true caudate lobe and caudate process may also be encountered.

The posterior or Glissonian approach described by Launois and Jamieson [70] avoids hilar dissection within the hepatoduodenal ligament. The basic concept is that the major right sided structures such as RHA, RPV and RHD are enveloped in a tough fibrous Glissonian sheath. This is more common for hand assisted procedures [71]. Keeping very close, posterior to the sheath a finger is used to encircle the right pedicle. If inflow to the remnant is confirmed the whole pedicle is ligated using a vascular stapling device. There is certainly no doubt that the posterior approach is the quickest way for inflow division [72,73].

Another technique for right hepatectomy is the anterior approach [68]. This avoids the potential hazard of major injury to the RHV with injudicious mobilization of liver and the potential for hepatic ischaemia. Another problem that is avoided is IVC obstruction when the liver is continually rotated to the left. It also has a theoretical advantage of less propagation of tumour cells during the mobilisation phase as the liver is only mobilised once the RHV has been disconnected. The anterior approach involves hilar dissection and inflow control, complete parenchymal transection and division of the RHV only then is liver mobilised. Survival appears to be better for the anterior approach 'open procedures', when compared to the conventional mobilisation technique for patients with HCC[74].

### 6.2 Parenchymal transection

Haemorrhage can be exsanguinating and unpredictable particularly after sustained use of chemotherapy. However it is the constant steady bleeding sustained in the phase of parenchymal transection that contributes most to the overall blood loss. A variety of techniques and surgical adjuncts can be used to aid parenchymal transection. Most experience is with the Cavitational ultrasonic aspirator (CUSA ™), bipolar sealing device Tissue Link, The Habib x4 ™ radiofrequency device or the Harmonic Scalpel ultrasonically activated shears (now Harmonic ACE ™). The Harmonic Scalpel ® cuts and coagulates by using ultrasound. Vessels are coapted (tamponaded) and sealed by a protein coagulum. Coagulation occurs by means of protein denaturation when the blade, vibrating at 55,000 Hz, couples with protein, denaturing it to form a coagulum that seals small coapted vessels. The newer Harmonic ACE version appears to be more effective in that it is faster and seals vessels up to 5mm in diameter and seals up to twice systolic pressure. However after a 15 second application heat can be 140 °C 1cm away from the tip causing significant lateral thermal damage away from the tissues being sealed [75]. Their powerful compression forces are directed at the tip of the device as well [76].

Newer generation devices include the LOTUS Torsion ™, which uses torsional ultrasound, transfers less energy to adjacent structures. The torsional waveform is thought to be safer as there are only weak frictional forces at the tip of the active blade and reduces' distal drilling' and tissue charring. The Ligasure ™ device which utilises low voltage bi-polar radiofrequency energy seals vessels up to 7mm in diameter up to 3 times systolic pressure and monitors changes in tissue impedance and adjusts the energy output accordingly causing less collateral tissue damage to within 1.5mm of the grasping jaws [77]. Tissuelink (Aquamantys ™) works using transcollation (transforming collagen) technology sealing small biliary radicals, no charringand gives a bloodless operating field. This device delivers radiofrequency energy and saline simultaneously to achieve temperatures of 100°C [78]. The major disadvantage is that is can be slower and is more expensive. A cheap and effective time honoured method is bipolar diathermy giving good haemostasis on the liver parenchyma using a power of up to 80 watts. There have been concerns regarding Argon Beam Coagulation (ABC) and gas embolism[79] because of the stream of argon gas when the instrument is activated particularly on the liver bed when there are large open vessels. It is strongly advisable not to use ABC in this situation.

There are no well designed controlled studies comparing different haemostatic techniques during LLR but these have been reviewed in detail elsewhere [80] [81]. Attention to detail regarding securing the bile ducts, identifying and ligating the medium and larger vascular structures are important in ensuring minimal blood loss, bile leaks and achieving an oncologically sound surgical procedure. To realize this, various techniques might be needed at different stages of the operation and therefore a working knowledge of all available techniques is useful.

## 7. Laparoscopic versus open liver resection - The evidence

### 7.1 The learning curve/patient benefit

Most studies reporting laparoscopic liver resection report a learning curve. How long that learning curve is depends on the type of resection. Small resections less than 2cm require little additional skill to that needed for a complex laparoscopic cholecystectomy when positioned in the anterior segments V, IVb or left lateral segment on the proviso the surgeon has completed a recognised training program in HPB surgery. For more major resections e.g. right heptectomy, left hepatectomy the bar is significantly raised and should only be attempted by surgeons who regularly perform complex laparoscopic procedures. The main limiting factor is technical difficulty and access. Some would suggest that increasing size of tumour is not a limiting factor [60] but this is not what has been recommended in the Louisville guidelines [11].

It cannot be denied that not everyone is suitable for a laparoscopic liver resection. Most centres suggest that up to 30% [68] [29] are suitable although those centres performing more major resections regularly report higher rates up to 80% but also report higher rates with hand assisted techniques [82] [4]. One study suggests a learning curve of 60 cases is adequate to demonstrate quicker operating times and a lower conversion rate [83]. Indeed during our 4 year experience the conversion rate has decreased from 14% to 3%. The commonest reason for conversion is usually technical or due to bleeding.

Most studies doing detailed analysis report reduced operating time when different era's are evaluated[68]. For example, laparoscopic left lateral resection can become significantly quicker[84] [58] as in our experience, yet for major resection (e.g. right hepatectomy) there is still some progress to be made to reduce operating times compared to open (5 hours versus 3 hours) [61,68] even procedures up to 10 hours have been reported [60]. Also anatomical resections are generally quicker than non anatomical wedge resections [68]. Nonetheless the learning curve is difficult to assess as it depends on the definition of success which to most would be disease free survival which is rarely discussed. One study has addressed this in detail in a non randomized study comparing 120 patients. There does not appear to be any difference in overall 5 year survival in those having either LLR or open resection in terms of disease free survival [85]. Most studies report no difference in rates of R0 resection and no increased risk of positive margins after LLR as reviewed elsewhere [10]. Although a recent meta-analysis suggests the risk of an R0 resection (<1cm) is twice as high after LLR than for open resection[86]. Indeed R1 resection rates of up to 43% have been reported [18] and non segmental resections may have the highest risk [87].

For left lateral resections and segmental resections blood loss and transfusion requirements have improved significantly through eras and now most involved in the field would suggest that with more minor resections blood loss is less when compared to open surgery [22,86,4]. However this is perhaps not the case for major resection and bleeding can be catastrophic and problematic when it is from a major tributary such as the RHV or venous confluence [19] and this is why some prefer the safety of a hand port when they approach the RHV during right hepatectomy.

The main advantage of LLR are the reported benefits which apply to all minimally invasive procedures. These include reduced post-operative pain relief, reduced hospital stay, less morbidity and mortality. Certainly a recent meta-analysis suggests patients have less blood loss, shorter post-operative stay and a quicker return to activities of daily living for left lateral resection or metastectomy[7 6,86,4,10]. Without randomized studies this will be difficult to confirm as laparoscopic enthusiasts may have a tendency to send patients home earlier than usual practise and may vary between centres. Generally the disadvantage of higher costs is offset by the shorter stay [88,7,89,90].

## 8. Training in laparosopic liver surgery

An important consideration certainly in Europe is the recent introduction of the European Working Time Directive (EWTD) which has threatened surgical training by a reduction in working hours and doctor/patient contact. Surgical trainees are therefore not exposed to as many opportunities to learn new or advanced techniques in laparoscopic surgery. There is no doubt that laparoscopic training programs need to be developed to keep pace with the introduction of new techniques and to allow surgical trainees adequate exposure and applies to all surgical specialities.

A growth area in this field has been the introduction of various structured programs, virtual reality systems and laparoscopic simulators which have been reviewed in detail elsewhere. [91] [92]. Alternative approaches to facilitate training has been the use of porcine or canine simulators [93] . Nevertheless these can be expensive to implement and can be problematic for licensing. An alternative approach which has not been widely reported is the use of a Cadaver Lab Training Facility [94].

The Newcastle Surgical Training Centre (NSTC) based at the Freeman Hospital opened in September 2007 **(Figure 9).** The laparoscopic training facility provides a specialist forum for the development of advanced laparoscopic skills and is part of the national drive to improve the delivery of near-patient technology. It is a unique, state of the art facility providing advanced cadaveric education which enables surgeons to gain cadaveric training in a unique and extremely high specification “wet lab” environment on fresh frozen cadavers. This centre is one of the very first anatomical examination units of its kind in the UK to carry a formal license from the Human Tissue Authority (HTA). The Human Tissue Act 2004 received Royal Assent in November 2004 and the act sets out standards and provides guidance to clinicians carrying out education and training in using human cadaveric materials.

Fig. 9. Laparoscopic cadaver training lab

A course has been designed by a faculty of experienced, advanced laparoscopic surgeons providing an intensive 2 day course of lectures, debate, exchange and practical hands on with a live link to clinical laparoscopic liver resection operations. All participants are given an opportunity to perform 8 key tasks in order to develop their laparoscopic liver surgery skills. These include the following;

1. Port Positioning for left lateral liver resection
2. Tape placement around the hepatoduodenal ligament for a safe Pringle's manoeuvre
3. Dissection of hilar structures, portal vein, hepatic artery, and confluence of the hepatic ducts and common bile duct.
4. Left lateral liver mobilisation.
5. Left lateral sectionectomy with an ultrasonic aspirator and stapling of the left hepatic vein.
6. Right lobe mobilisation
7. Right hepatectomy with dissection of RHA, RPV, RHD and IVC dissection with stapling of the RHV.
8. Use of hand ports for facilitating right hepatectomy.

Although safety, efficacy and reproducibility of LLS has been established, the same cannot be said of the training and accreditation of junior surgeons. The specialist surgical societies both at National and International levels are yet to establish guidelines for training and mentoring.

With rapid progress in the field of electronics, computers and robotics, training of residents/junior surgeons through surgical simulation is slowly gaining popularity as it provides an opportunity for the trainee to develop the necessary skills for the clinical situation. Furthermore with advanced software technologies, visual fidelity , manual dexterity, hand eye co-ordination, real time response to emergency situations can now be assessed. The down side of the virtual reality simulators is their computing power and the initial set up costs. Oversimplification of complex reality isolates the trainee from the clinical situation. As far as the authors are aware there are no virtual reality simulators for LLR available for training.

Though basic psychomotor skills can be learnt on a surgical simulator or virtual reality simulator, learning to use high energy devices like diathermy or dissectors, tissue handling need a more realistic model like an animal or human cadaver. A synthetic model though attractive in terms of cost benefit falls short in recreating training outcomes. Rodents have been used extensively in both open and laparoscopic training models as they are well suited for laboratory based research activities, are expensive to buy, breed and house in a laboratory. Krahenbuhl et al. [95] have reported a safe technique of LLR in rats for liver physiology research. Canine models have also been advocated but their major drawback are anatomical constraints having multiple liver lobes but also stringent laws in the United Kingdom which prevent their routine use in the laboratory for training [96 97]. Porcine models have been used extensively in Europe because of size and more favourable anatomy. Unfortunately their overall cost and safety regulations prohibit their use in the UK. Sheep have also been used for LLR because they are anatomically similar to human [98].

The use of a cadaver in a dissection laboratory for imparting anatomical knowledge is well established [99]. Cadaver training has also been used successfully in a workshop to train residents in internal medicine to perform bedside procedures like thoracocentesis, paracentesis, lumbar puncture and bone marrow biopsy [100]. Fresh cadavers have also been used for vascular surgery training [101].

Using cadavers for learning laparoscopic procedures holds immense potential. Katz et al. [102] described a cadaver model to be superior to porcine models for urological laparoscopic training. Cadaver laparoscopic dissection has been used to enhance resident comprehension of pelvic anatomy [103]. In the UK with the introduction of the Human Tissue Act 2004, it is possible to store and use cadavers for laparoscopic training. The advantages of using cadavers are perfect for reproducing anatomical landmarks, tissue consistency and flexibility, tactile feedback and tissue handling, use of gravity and retraction to make it more realistic and almost near perfect reproduction of critical steps. Furthermore, the use of proper instruments, patient positioning and an operation room setup helps the surgeon to train in a more conducive atmosphere.

We have been conducting cadaver laparoscopic liver surgery courses for both practising and training surgeons at NSTC since 2007. We have shown that the overall rating of the course by the trainees attending has been very good.

## 9. References

[1] Jarnagin WR, Gonen M, Fong Y, Dematteo RP, Ben-Porat L, Little S et al. Improvement in perioperative outcome after hepatic resection: analysis of 1,803 consecutive cases over the past decade. *Ann Surg* 2002; 236(4):397-406.

[2] Rees M, Tekkis PP, Welsh FK, O'Rourke T, John TG. Evaluation of long-term survival after hepatic resection for metastatic colorectal cancer: a multifactorial model of 929 patients. *Ann Surg* 2008; 247(1):125-135.

[3] Laparoscopic partial hepatectomy for liver tumour. Surg.Endosc. 6, 99. 1-9-1992. Gagner, M., Rheault, M., and Dubuc, J. Ref Type: Generic

[4] Nguyen KT, Geller DA. Laparoscopic liver resection--current update. *Surg Clin North Am* 2010; 90(4):749-760.

[5] Nguyen KT, Gamblin TC, Geller DA. World review of laparoscopic liver resection-2,804 patients. *Ann Surg* 2009; 250(5):831-841.

[6] Simillis C, Constantinides VA, Tekkis PP, Darzi A, Lovegrove R, Jiao L et al. Laparoscopic versus open hepatic resections for benign and malignant neoplasms--a meta-analysis. *Surgery* 2007; 141(2):203-211.

[7] Rao A, Rao G, Ahmed I. Laparoscopic left lateral liver resection should be a standard operation. *Surg Endosc* 2011; 25(5):1603-1610.

[8] Croome KP, Yamashita MH. Laparoscopic vs open hepatic resection for benign and malignant tumors: An updated meta-analysis. *Arch Surg* 2010; 145(11):1109-1118.

[9] Vigano L, Tayar C, Laurent A, Cherqui D. Laparoscopic liver resection: a systematic review. *J Hepatobiliary Pancreat Surg* 2009; 16(4):410-421.

[10] Nguyen KT, Marsh JW, Tsung A, Steel JJ, Gamblin TC, Geller DA. Comparative Benefits of Laparoscopic vs Open Hepatic Resection: A Critical Appraisal. *Arch Surg* 2011; 146(3):348-356.

[11] Buell JF, Cherqui D, Geller DA, O'Rourke N, Iannitti D, Dagher I et al. The international position on laparoscopic liver surgery: The Louisville Statement, 2008. *Ann Surg* 2009; 250(5):825-830.

[12] Soubrane O, Cherqui D, Scatton O, Stenard F, Bernard D, Branchereau S et al. Laparoscopic left lateral sectionectomy in living donors: safety and reproducibility of the technique in a single center. *Ann Surg* 2006; 244(5):815-820.

[13] Suh KS, Yi NJ, Kim T, Kim J, Shin WY, Lee HW et al. Laparoscopy-assisted donor right hepatectomy using a hand port system preserving the middle hepatic vein branches. *World J Surg* 2009; 33(3):526-533.

[14] Troisi RI, Van HJ, Berrevoet F, Vandenbossche B, Sainz-Barriga M, Vinci A et al. Evolution of laparoscopic left lateral sectionectomy without the Pringle maneuver: through resection of benign and malignant tumors to living liver donation. *Surg Endosc* 2011; 25(1):79-87.

[15] Koffron AJ, Kung R, Baker T, Fryer J, Clark L, Abecassis M. Laparoscopic-assisted right lobe donor hepatectomy. *Am J Transplant* 2006; 6(10):2522-2525.

[16] Farges O, Jagot P, Kirstetter P, Marty J, Belghiti J. Prospective assessment of the safety and benefit of laparoscopic liver resections. *J Hepatobiliary Pancreat Surg* 2002; 9(2):242-248.

[17] Ardito F, Tayar C, Laurent A, Karoui M, Loriau J, Cherqui D. Laparoscopic liver resection for benign disease. *Arch Surg* 2007; 142(12):1188-1193.

[18] Morino M, Morra I, Rosso E, Miglietta C, Garrone C. Laparoscopic vs open hepatic resection: a comparative study. *Surg Endosc* 2003; 17(12):1914-1918.

[19] Troisi R, Montalti R, Smeets P, Van HJ, Van VH, Colle I et al. The value of laparoscopic liver surgery for solid benign hepatic tumors. *Surg Endosc* 2008; 22(1):38-44.

[20] Katkhouda N, Hurwitz M, Gugenheim J, Mavor E, Mason RJ, Waldrep DJ et al. Laparoscopic management of benign solid and cystic lesions of the liver. *Ann Surg* 1999; 229(4):460-466.

[21] Vibert E, Perniceni T, Levard H, Denet C, Shahri NK, Gayet B. Laparoscopic liver resection. *Br J Surg* 2006; 93(1):67-72.

[22] Koffron AJ, Auffenberg G, Kung R, Abecassis M. Evaluation of 300 minimally invasive liver resections at a single institution: less is more. *Ann Surg* 2007; 246(3):385-392.

[23] Giulianotti PC, Sbrana F, Bianco FM, Addeo P. Robot-assisted laparoscopic extended right hepatectomy with biliary reconstruction. *J Laparoendosc Adv Surg Tech A* 2010; 20(2):159-163.

[24] Elias D, Sideris L, Pocard M, Ouellet JF, Boige V, Lasser P et al. Results of R0 resection for colorectal liver metastases associated with extrahepatic disease. *Ann Surg Oncol* 2004; 11(3):274-280.

[25] Elias D, Liberale G, Vernerey D, Pocard M, Ducreux M, Boige V et al. Hepatic and extrahepatic colorectal metastases: when resectable, their localization does not matter, but their total number has a prognostic effect. *Ann Surg Oncol* 2005; 12(11):900-909.

[26] Elias D, Delperro JR, Sideris L, Benhamou E, Pocard M, Baton O et al. Treatment of peritoneal carcinomatosis from colorectal cancer: impact of complete cytoreductive surgery and difficulties in conducting randomized trials. *Ann Surg Oncol* 2004; 11(5):518-521.

[27] Gumbs AA, Gayet B. Video: the lateral laparoscopic approach to lesions in the posterior segments. *J Gastrointest Surg* 2008; 12(7):1154.

[28] Costi R, Capelluto E, Sperduto N, Bruyns J, Himpens J, Cadiere GB. Laparoscopic right posterior hepatic bisegmentectomy (Segments VII-VIII). *Surg Endosc* 2003; 17(1):162.

[29] 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(11):2344-2349.

[30] Jaeck D. The significance of hepatic pedicle lymph nodes metastases in surgical management of colorectal liver metastases and of other liver malignancies. *Ann Surg Oncol* 2003; 10(9):1007-1011.

[31] Grobmyer SR, Wang L, Gonen M, Fong Y, Klimstra D, D'Angelica M et al. Perihepatic lymph node assessment in patients undergoing partial hepatectomy for malignancy. *Ann Surg* 2006; 244(2):260-264.

[32] Lochan R, White SA, Manas DM. Liver resection for colorectal liver metastasis. *Surg Oncol* 2007; 16(1):33-45.

[33] Kim SH, Lim SB, Ha YH, Han SS, Park SJ, Choi HS et al. Laparoscopic-assisted combined colon and liver resection for primary colorectal cancer with synchronous liver metastases: initial experience. *World J Surg* 2008; 32(12):2701-2706.

[34] Lee JS, Hong HT, Kim JH, Lee IK, Lee KH, Park IY et al. Simultaneous laparoscopic resection of primary colorectal cancer and metastatic liver tumor: initial experience of single institute. *J Laparoendosc Adv Surg Tech A* 2010; 20(8):683-687.

[35] Pathak S, Sarno G, Nunes QM, Poston GJ. Synchronous resection for colorectal liver metastases: the future. *Eur J Surg Oncol* 2010; 36(11):1044-1046.

[36] Reddy SK, Pawlik TM, Zorzi D, Gleisner AL, Ribero D, Assumpcao L et al. Simultaneous resections of colorectal cancer and synchronous liver metastases: a multi-institutional analysis. *Ann Surg Oncol* 2007; 14(12):3481-3491.

[37] Tanaka K, Shimada H, Matsuo K, Nagano Y, Endo I, Sekido H et al. Outcome after simultaneous colorectal and hepatic resection for colorectal cancer with synchronous metastases. *Surgery* 2004; 136(3):650-659.

[38] de SE, Fernandez D, Vaccaro C, Quintana GO, Bonadeo F, Pekolj J et al. Short-term and long-term outcomes after simultaneous resection of colorectal malignancies and synchronous liver metastases. *World J Surg* 2010; 34(9):2133-2140.

[39] Tranchart H, Diop PS, Lainas P, Pourcher G, Catherine L, Franco D et al. Laparoscopic major hepatectomy can be safely performed with colorectal surgery for synchronous colorectal liver metastasis. *HPB (Oxford)* 2011; 13(1):46-50.

[40] Casaccia M, Famiglietti F, Andorno E, Di DS, Ferrari C, Valente U. Simultaneous laparoscopic anterior resection and left hepatic lobectomy for stage IV rectal cancer. *JSLS* 2010; 14(3):414-417.

[41] Khatri VP, Petrelli NJ, Belghiti J. Extending the frontiers of surgical therapy for hepatic colorectal metastases: is there a limit? *J Clin Oncol* 2005; 23(33):8490-8499.

[42] Petrowsky H, Gonen M, Jarnagin W, Lorenz M, DeMatteo R, Heinrich S et al. Second liver resections are safe and effective treatment for recurrent hepatic metastases from colorectal cancer: a bi-institutional analysis. *Ann Surg* 2002; 235(6):863-871.

[43] Adam R, Pascal G, Azoulay D, Tanaka K, Castaing D, Bismuth H. Liver resection for colorectal metastases: the third hepatectomy. *Ann Surg* 2003; 238(6):871-883.

[44] White SA, Manas DM, Farid SG, Prasad KR. Optimal treatment for hepatocellular carcinoma in the cirrhotic liver. *Ann R Coll Surg Engl* 2009; 91(7):545-550.

[45] Mazzaferro V, Regalia E, Doci R, Andreola S, Pulvirenti A, Bozzetti F et al. Liver transplantation for the treatment of small hepatocellular carcinomas in patients with cirrhosis. *N Engl J Med* 1996; 334(11):693-699.

[46] Adam R, Azoulay D, Castaing D, Eshkenazy R, Pascal G, Hashizume K et al. Liver resection as a bridge to transplantation for hepatocellular carcinoma on cirrhosis: a reasonable strategy? *Ann Surg* 2003; 238(4):508-518.

[47] Belghiti J, Cortes A, Abdalla EK, Regimbeau JM, Prakash K, Durand F et al. Resection prior to liver transplantation for hepatocellular carcinoma. *Ann Surg* 2003; 238(6):885-892.

[48] Cherqui D, Laurent A, Tayar C, Chang S, Van Nhieu JT, Loriau J et al. Laparoscopic liver resection for peripheral hepatocellular carcinoma in patients with chronic liver disease: midterm results and perspectives. *Ann Surg* 2006; 243(4):499-506.

[49] Tranchart H, Di GG, Lainas P, Roudie J, Agostini H, Franco D et al. Laparoscopic resection for hepatocellular carcinoma: a matched-pair comparative study. *Surg Endosc* 2010; 24(5):1170-1176.

[50] Sarpel U, Hefti MM, Wisnievsky JP, Roayaie S, Schwartz ME, Labow DM. Outcome for patients treated with laparoscopic versus open resection of hepatocellular carcinoma: case-matched analysis. *Ann Surg Oncol* 2009; 16(6):1572-1577.

[51] Lai EC, Tang CN, Ha JP, Li MK. Laparoscopic liver resection for hepatocellular carcinoma: ten-year experience in a single center. *Arch Surg* 2009; 144(2):143-147.
[52] Belli G, Limongelli P, Fantini C, D'Agostino A, Cioffi L, Belli A et al. Laparoscopic and open treatment of hepatocellular carcinoma in patients with cirrhosis. *Br J Surg* 2009; 96(9):1041-1048.
[53] Zhang L, Chen YJ, Shang CZ, Zhang HW, Huang ZJ. Total laparoscopic liver resection in 78 patients. *World J Gastroenterol* 2009; 15(45):5727-5731.
[54] Belli G, Fantini C, Belli A, Limongelli P. Laparoscopic liver resection for hepatocellular carcinoma in cirrhosis: long-term outcomes. *Dig Surg* 2011; 28(2):134-140.
[55] Dagher I, Belli G, Fantini C, Laurent A, Tayar C, Lainas P et al. Laparoscopic hepatectomy for hepatocellular carcinoma: a European experience. *J Am Coll Surg* 2010; 211(1):16-23.
[56] Sahani DV, Kalva SP. Imaging the liver. *Oncologist* 2004; 9(4):385-397.
[57] Ward J, Robinson PJ, Guthrie JA, Downing S, Wilson D, Lodge JP et al. Liver metastases in candidates for hepatic resection: comparison of helical CT and gadolinium- and SPIO-enhanced MR imaging. *Radiology* 2005; 237(1):170-180.
[58] Abu HM, Pearce NW. Laparoscopic left lateral liver sectionectomy: a safe, efficient, reproducible technique. *Dig Surg* 2008; 25(4):305-308.
[59] Rao A, Rao G, Ahmed I. Laparoscopic left lateral liver resection should be a standard operation. *Surg Endosc* 2011; 25(5):1603-1610.
[60] Dagher I, O'Rourke N, Geller DA, Cherqui D, Belli G, Gamblin TC et al. Laparoscopic major hepatectomy: an evolution in standard of care. *Ann Surg* 2009; 250(5):856-860.
[61] Abu HM, Di FF, Teng MJ, Lykoudis P, Primrose JN, Pearce NW. Single-Centre Comparative Study of Laparoscopic Versus Open Right Hepatectomy. *J Gastrointest Surg* 2011.
[62] Schmidt SC, Schumacher G, Klage N, Chopra S, Neuhaus P, Neumann U. The impact of carbon dioxide pneumoperitoneum on liver regeneration after liver resection in a rat model. *Surg Endosc* 2010; 24(1):1-8.
[63] Nsadi B, Gilson N, Pire E, Cheramy JP, Pincemail J, Scagnol I et al. Consequences of pneumoperitoneum on liver ischemia during laparoscopic portal triad clamping in a swine model. *J Surg Res* 2011; 166(1):e35-e43.
[64] Fors D, Eiriksson K, Arvidsson D, Rubertsson S. Gas embolism during laparoscopic liver resection in a pig model: frequency and severity. *Br J Anaesth* 2010.
[65] Kazaryan AM, Pavlik M, I, Rosseland AR, Rosok BI, Mala T, Villanger O et al. Laparoscopic liver resection for malignant and benign lesions: ten-year Norwegian single-center experience. *Arch Surg* 2010; 145(1):34-40.
[66] Pulitano C, Catena M, Arru M, Guzzetti E, Comotti L, Ferla G et al. Laparoscopic liver resection without portal clamping: a prospective evaluation. *Surg Endosc* 2008; 22(10):2196-2200.
[67] Belli G, Fantini C, D'Agostino A, Belli A, Russolillo N, Cioffi L. [Laparoscopic liver resection without a Pringle maneuver for HCC in cirrhotic patients]. *Chir Ital* 2005; 57(1):15-25.

[68] Bryant R, Laurent A, Tayar C, Cherqui D. Laparoscopic liver resection-understanding its role in current practice: the Henri Mondor Hospital experience. *Ann Surg* 2009; 250(1):103-111.

[69] Belli G, D'Agostino A, Fantini C, Belli A, Cioffi L, Limongelli P et al. Laparoscopic hand-assisted right hemihepatectomy by ultrasound-directed intrahepatic approach. *J Hepatobiliary Pancreat Surg* 2009; 16(6):781-785.

[70] Launois B, Jamieson GG. The posterior intrahepatic approach for hepatectomy or removal of segments of the liver. *Surg Gynecol Obstet* 1992; 174(2):155-158.

[71] Belli G, D'Agostino A, Fantini C, Belli A, Cioffi L, Limongelli P et al. Laparoscopic hand-assisted right hemihepatectomy by ultrasound-directed intrahepatic approach 21. *J Hepatobiliary Pancreat Surg* 2009; 16(6):781-785.

[72] Machado MA, Makdissi FF, Herman P, Surjan RC. Intrahepatic Glissonian approach for pure laparoscopic left hemihepatectomy. *J Laparoendosc Adv Surg Tech A* 2010; 20(2):141-142.

[73] Machado MA, Makdissi FF, Galvao FH, Machado MC. Intrahepatic Glissonian approach for laparoscopic right segmental liver resections. *Am J Surg* 2008; 196(4):e38-e42.

[74] Liu CL, Fan ST, Cheung ST, Lo CM, Ng IO, Wong J. Anterior approach versus conventional approach right hepatic resection for large hepatocellular carcinoma: a prospective randomized controlled study. *Ann Surg* 2006; 244(2):194-203.

[75] Emam TA, Cuschieri A. How safe is high-power ultrasonic dissection? *Ann Surg* 2003; 237(2):186-191.

[76] Sutton PA, Awad S, Perkins AC, Lobo DN. Comparison of lateral thermal spread using monopolar and bipolar diathermy, the Harmonic Scalpel and the Ligasure. *Br J Surg* 2010; 97(3):428-433.

[77] Harold KL, Pollinger H, Matthews BD, Kercher KW, Sing RF, Heniford BT. Comparison of ultrasonic energy, bipolar thermal energy, and vascular clips for the hemostasis of small-, medium-, and large-sized arteries. *Surg Endosc* 2003; 17(8):1228-1230.

[78] Nissen NN, Grewal N, Lee J, Nawabi A, Korman J. Completely laparoscopic nonanatomic hepatic resection using saline-cooled cautery and hydrodissection. *Am Surg* 2007; 73(10):987-990.

[79] Kono M, Yahagi N, Kitahara M, Fujiwara Y, Sha M, Ohmura A. Cardiac arrest associated with use of an argon beam coagulator during laparoscopic cholecystectomy. *Br J Anaesth* 2001; 87(4):644-646.

[80] Abu HM, Underwood T, Taylor MG, Hamdan K, Elberm H, Pearce NW. Bleeding and hemostasis in laparoscopic liver surgery. *Surg Endosc* 2010; 24(3):572-577.

[81] The use of fibrin sealants in laparoscopic liver surgery. Laparoscopic . 2011. saif, r. Ref Type: Generic

[82] Buell JF, Thomas MT, Rudich S, Marvin M, Nagubandi R, Ravindra KV et al. Experience with more than 500 minimally invasive hepatic procedures. *Ann Surg* 2008; 248(3):475-486.

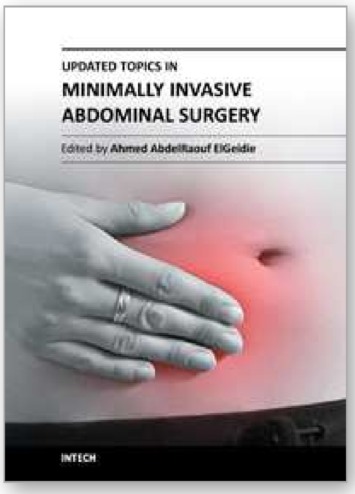
[83] Vigano L, Laurent A, Tayar C, Tomatis M, Ponti A, Cherqui D. The learning curve in laparoscopic liver resection: improved feasibility and reproducibility. *Ann Surg* 2009; 250(5):772-782.

[84] Lesurtel M, Cherqui D, Laurent A, Tayar C, Fagniez PL. Laparoscopic versus open left lateral hepatic lobectomy: a case-control study. *J Am Coll Surg* 2003; 196(2):236-242.
[85] Castaing D, Vibert E, Ricca L, Azoulay D, Adam R, Gayet B. Oncologic results of laparoscopic versus open hepatectomy for colorectal liver metastases in two specialized centers. *Ann Surg* 2009; 250(5):849-855.
[86] Croome KP, Yamashita MH. Laparoscopic vs open hepatic resection for benign and malignant tumors: An updated meta-analysis *Arch Surg* 2010; 145(11):1109-1118.
[87] Kazaryan AM, Marangos IP, Rosok BI, Rosseland AR, Villanger O, Fosse E et al. Laparoscopic resection of colorectal liver metastases: surgical and long-term oncologic outcome *Ann Surg* 2010; 252(6):1005-1012.
[88] Simillis C, Constantinides VA, Tekkis PP, Darzi A, Lovegrove R, Jiao L et al. Laparoscopic versus open hepatic resections for benign and malignant neoplasms--a meta-analysis. *Surgery* 2007; 141(2):203-211.
[89] Polignano FM, Quyn AJ, de Figueiredo RS, Henderson NA, Kulli C, Tait IS. Laparoscopic versus open liver segmentectomy: prospective, case-matched, intention-to-treat analysis of clinical outcomes and cost effectiveness. *Surg Endosc* 2008; 22(12):2564-2570.
[90] Vanounou T, Steel JL, Nguyen KT, Tsung A, Marsh JW, Geller DA et al. Comparing the clinical and economic impact of laparoscopic versus open liver resection. *Ann Surg Oncol* 2010; 17(4):998-1009.
[91] Fairhurst K, Strickland A, Maddern G. The LapSim virtual reality simulator: promising but not yet proven. *Surg Endosc* 2010.
[92] Vassiliou MC, Dunkin BJ, Marks JM, Fried GM. FLS and FES: comprehensive models of training and assessment. *Surg Clin North Am* 2010; 90(3):535-558.
[93] Fransson BA, Ragle CA. Assessment of laparoscopic skills before and after simulation training with a canine abdominal model. *J Am Vet Med Assoc* 2010; 236(10):1079-1084.
[94] Supe A, Dalvi A, Prabhu R, Kantharia C, Bhuiyan P. Cadaver as a model for laparoscopic training. *Indian J Gastroenterol* 2005; 24(3):111-113.
[95] Krahenbuhl L, Feodorovici M, Renzulli P, Schafer M, Abou-Shady M, Baer HU. Laparoscopic partial hepatectomy in the rat: a new resectional technique. *Dig Surg* 1998; 15(2):140-144.
[96] Frezza EE, Wachtel MS. A proposed canine model of laparoscopic nonanatomic liver resection. *J Laparoendosc Adv Surg Tech A* 2006; 16(1):15-20.
[97] Machado MA, Galvao FH, Pompeu E, Ribeiro C, Bacchella T, Machado MC. A canine model of laparoscopic segmental liver resection. *J Laparoendosc Adv Surg Tech A* 2004; 14(5):325-328.
[98] Teh SH, Hunter JG, Sheppard BC. A suitable animal model for laparoscopic hepatic resection training. *Surg Endosc* 2007; 21(10):1738-1744.
[99] Parker LM. Anatomical dissection: why are we cutting it out? Dissection in undergraduate teaching. *ANZ J Surg* 2002; 72(12):910-912.
[100] Oxentenko AS, Ebbert JO, Ward LE, Pankratz VS, Wood KE. A multidimensional workshop using human cadavers to teach bedside procedures. *Teach Learn Med* 2003; 15(2):127-130.

[101] Reed AB, Crafton C, Giglia JS, Hutto JD. Back to basics: use of fresh cadavers in vascular surgery training. *Surgery* 2009; 146(4):757-762.

[102] Katz R, Hoznek A, Antiphon P, Van VR, Delmas V, Abbou CC. Cadaveric versus porcine models in urological laparoscopic training. *Urol Int* 2003; 71(3):310-315.

[103] Cundiff GW, Weidner AC, Visco AG. Effectiveness of laparoscopic cadaveric dissection in enhancing resident comprehension of pelvic anatomy. *J Am Coll Surg* 2001; 192(4):492-497.




**Updated Topics in Minimally Invasive Abdominal Surgery**
Edited by Prof. Ahmed Elgeidie

ISBN 978-953-307-773-4
Hard cover, 246 pages
**Publisher** InTech
**Published online** 14, November, 2011
**Published in print edition** November, 2011