Laparoscopic Liver Resection

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With the advent of minimally invasive techniques and other medical devices, laparoscopic liver resection (LLR) has been a common procedure since 1992. Once experts in liver surgery established the “Louisville Statement”, a set of guidelines for the rapidly growing area of minimally invasive liver resection, the number of reported LLRs has increased consistently. Although minor LLRs have been performed routinely in clinical practice, reports of major and anatomic LLRs have increased sharply. Some specialized centers have reported favorable and competitive outcomes of LLR compared to those of open liver resection. Recently, several reports about single-port LLR, robotic-assisted liver resection, and LLR via video-assisted transthoracic liver resection (VTLR) have been published.

Keywords: laparoscopic liver resection ; hepatocellular carcinoma ; minimally invasive liver surgery

1. Introduction

In LLR, precise localization of the tumor has been a critical issue based on the need to secure the surgical resection margin and preserve the hepatic parenchyma. In conventional liver resection (CLR), the region of the liver to be resected is determined by using preoperative computed tomography and magnetic resonance imaging. Hepatic segmental resection is carried out after ligation of the Glissonean pedicle; this approach was established to localize liver tumors and uses both the surgeon’s tactile sensations and ultrasound equipment [1][2][3][4]. Although a Glissonean pedicle approach or the tattooing method historically has been carried out to confirm the hepatic resection area in LLR, a Glissonean approach for subdivided branches can be limited by the complicated anatomy of the liver, and laparoscopic indigo carmine tattooing is a technically demanding procedure [5][6]. Recently, several researchers have introduced a near infra-red (NIR) fluorescence imaging technique to create a distinction between liver tumors and their boundaries using indocyanine green (ICG) as a fluorescent tracer during LLR [5][7]. Anatomical resection of the hepatic segment is also achieved with the use of a “negative staining technique,” in which portal branches are closed after the targeted segment is determined [8][9].

However, the tumor-fluorescence technique is limited in identifying superficially located tumors. If a tumor occurs in an area that is not visualized easily in the laparoscopic view, tumor-fluorescence does not help to localize the liver tumor. In such cases, although negative staining technique can be applied in defining the resection range for LLR, it is challenging and time-consuming to expose the portal branches of the targeted hepatic segment. Furthermore, it is more difficult and dangerous to inject any tracer through the arterial or portal branches of the targeted segments than negative staining technique. For these reasons, Ueno et al. proposed an angiographic perfusion method in which ICG is perfused directly through the arterial branch of the targeted segment as a tracer for angiography and visualized with an NIR fluorescence imaging system [6].

We modified this angiographic infusion method to use a different fluorophore in conjunction with preoperative angiography. We were inspired by studies that detailed a blue light fluorescence technique in diverse fields [10][11][12] and therefore adopted sodium fluorescein as a fluorescent tracer to be infused directly into the arterial branches of the targeted segment before LLR or VTLR. In the present study, we report the clinical outcomes of LLR or VTLR in which the tumor-embedding segment was enhanced using an intervention-guided fluorescence imaging technique (IFIT).

2. Analysis on Results

This study included 24 HCC patients who underwent LLR or VTLR from February 2017 to March 2020. Their mean age was 55.3 (49–63) years. The underlying liver disease was hepatitis B in 21 (87.5%) patients, hepatitis C in 1 (4.2%) patient, and alcoholic hepatitis in 2 (8.3%) patients. The mean indocyanine green retention rate at 15 min (ICG 15) of the patient group was 12.4 (8.9–15.2), and the AFP (ng/mL) level was 166 (3.2–200). Preoperative serum INR, total bilirubin, and albumin results were 1.05 (0.89–1.38), 1.03 (0.8–1.3) mg/dL, and 3.88 (3.7–4.2) g/dL, respectively. According to Child–Pugh classification, 20 (83.3%) patients belonged to class A, and 4 (16.7%) were placed in class B. Laparoscopic partial hepatectomy was performed mainly in the right lobe and in liver segment 4. VTLL was carried out in segment 7 in two cases and in segment 8 in two cases (**Table 1**).

Table 1. Clinicopathologic data of the patients enrolled in the current study.

Patients Who Underwent Intervention-Guided Fluorescence Imaging Technique (*n* = 24)	
Age	**55.3 (49–63)**
Sex ratio (Male: Female)	**2:1**
Liver disease	
Hepatitis B	**21 (87.5%)**
Hepatitis C	**1 (4.2%)**
Alcoholic hepatitis	**2 (8.3%)**
ICG 15 (%)	**12.4 (8.9–15.2)**
AFP (ng/mL)	**166 (3.2–200)**
Platelets, $\times 10^3$/mm^3	**143 (121–182)**
INR	**1.05 (0.89–1.38)**
Total bilirubin (mg/dl)	**1.03 (0.8–1.3)**
Albumin (g/dL)	**3.88 (3.7–4.2)**
CTP score	
A	**20 (83.3%)**
B	**4 (16.7%)**
Tumor location	
IV	**6 (6 LLR)**
V	**5 (5 LLR)**
VI	**4 (4 LLR)**
VII	**5 (3 LLR, 2 VTLR)**
VIII	**4 (2 LLR, 2 VTLR)**

ICG 15 indicates indocyanine green retention rate at 15 min; AFP, α-fetoprotein; INR, International Normalized Ratio; CTP score, Child–Turcotte–Pugh score for severity of liver cirrhosis; LLR, laparoscopic liver resection; VTLR, Video-assisted transthoracic liver resection.

Compared to the internal group, the study group had a significantly reduced average operation time of 221 (143–275) min. The mean time for intervention was 28 (24–31) min. Three (13%) patients required intraoperative blood transfusion. The average amount of blood loss was 200 (10–1100) mL. The mean tumor size was 2.73 (0.70–3.40) cm, and the average distance from the surgical section to the tumor was 1.03 (0.3–2.0) cm; no tumor remained in the cut section in either group. On average, patients were able to consume a normal diet after 2.4 (1–4) days, and were discharged after 10.2(6–14) days of hospitalization (**Table 2**).

Table 2. Comparison of the clinicopathologic outcomes between the study group and internal controls.

	IFIT (*n* = 24)	**Internal Controls (*n* = 29)**	***p***
Operation time (min)	**221 (143–275)**	**265 (200–300)**	**<0.001**
Time to the first semi-fluid diet (days)	**2.4 (1–4)**	**2.8 (1–5)**	**0.222**
Transfusion [a]	**3 (13%)**	**4 (13.8%)**	**0.758**
Blood loss (cc)	**200 (10–1100)**	**215 (5–1300)**	**0.438**
Hospital stay (days)	**10.2 (6–14)**	**10.0 (6–15)**	**0.556**

	IFIT (n = 24)	Internal Controls (n = 29)	p
Resection margin (cm)	**1.03 (0.3–2.0)**	**1.01(0.2–3.0)**	**0.587**
Tumor size	**2.73 (0.70–3.40)**	**2.51 (0.5–3.5)**	**0.412**

[a] Number of patients who underwent perioperative transfusion. IFIT, the patients who underwent intervention-guided fluorescence imaging technique.

3. Current Insights

In this study, we applied IFIT using blue light fluorescence during LLR or VTLR. In conventional laparoscopic partial hepatectomy, it takes a lot of time to find small areas of HCC located in the dome or round ligament of the liver using intraoperative ultrasound. Moreover, even when resecting the liver, the need to assess continually the boundary using repeated intraoperative ultrasound is burdensome and causes a delay in the operation. However, IFIT using blue light fluorescence brightly illuminates the region to be resected, reducing the time required to find a tumor. Even surgeons who experience difficulty using laparoscopic ultrasound intraoperatively can secure a margin of safety and identify surrounding boundaries if the ultrasound is performed after tumor localization using the IFIT method. Although a distorted liver surface can occur after liver mobilization, the marker generated by IFIT remains in place and can help to determine the tumor location.

IFIT was useful in VTLR to find tumors located in the superior posterior segment. Tumors in this segment are difficult to access laparoscopically; even if LLR is performed, excess parenchyma might be removed. If patients with marginal liver function have lesions in the superior posterior segment, VTLR can be considered. However, the surgical view provided by thoracoscopic access to the liver is not familiar to both thoracic surgeons and hepatobiliary surgeons [13][14][3][15]. In addition, another problem with VTLR is that, unlike LLR, the movement of the diaphragm creates an unstable surgical view. Therefore, it is important to determine the exact location of the liver tumor and to perform minimal liver resection. In such case, if the IFIT method is used, hepatic resection can be performed through a small diaphragmatic incision after the exact location of the liver tumor is determined [16]. In this study, it was possible to locate rapidly the hepatic tumor that fluoresces under the diaphragm, reducing operation time. Even after a tumor is located, it is important to determine the boundary because it is difficult to grasp the structure of the liver as seen through the incised diaphragm. In this case, intraoperative laparoscopic ultrasound can help determine the location and boundaries of a liver tumor.

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