Ultrasound-guided liver resection: Early experience in a district general hospital

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KEYWORDS

Intraoperative ultrasonography;
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Abstract *Introduction:* Intraoperative ultrasonography (IOUS) is the gold standard for tumor staging and operative decision making in liver surgery. Providing dynamic information on tumor–vessel relationships and distribution of intrahepatic veins, IOUS is also an important support for guiding the resection. Few authors report an extensive use of IOUS-guidance as a safe and effective approach. The aim of this study is to investigate the short-term results of an early experience of ultrasound (US) guided liver resection.

Methods: From December 2005 to December 2007 an extensive use of IOUS-guided resection was applied in 11 consecutive patients (8 males and 3 females; median age 74 years). Perioperative data were collected prospectively to assess the influence of this approach on mortality, morbidity and early recurrence.

Results: Four patients had hepatocellular carcinoma, 4 liver metastases, 1 peripheral cholangiocarcinoma, 1 hemangioma and 1 inflammatory pseudotumor. A median of 1 (range: 1–4) nodule per patient was resected. Median lesion size was 44 mm. Liver procedures included: 3 wedge resections, 3 subsegmentectomies, 4 segmentectomies and 3 bisegmentectomies. Median blood loss was 235 ml. Median surgical margin in cancer patients was 5 mm (range: 1–12). An average of 1 unit of blood transfusion was administered in 5 patients. Median post-operative hospital stay was 9 days. There was no mortality. Major complications occurred in 1 patient and minor complications in 5 patients. During a median follow-up of 14 months no recurrences were observed.

Conclusions: In this study, use of IOUS-guided liver resection performed in a district general hospital proved to be a safe and effective approach in terms of short-term outcome.

Sommario *Premessa:* Nell'ambito della chirurgia epatica l'ecografia intraoperatoria svolge un ruolo ben codificato nella stadiazione e nella pianificazione della strategia operatoria. L'importanza dell'ampio utilizzo di questa metodica anche durante la resezione è stata riportata solo da alcuni autori. Questo studio ha come scopo di verificare quali siano i risultati a breve termine di un ampio utilizzo dell'ecografia durante la resezione stessa in un ospedale periferico. *Metodi:* Nell'arco di 24 mesi 11 pazienti consecutivi sono stati sottoposti a resezione epatica ecoguidata. I dati perioperatori sono stati raccolti in modo prospettico per valutare l'influenza di questa metodica sulla mortalità, morbidità e recidive locali.

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Risultati: Otto pazienti erano maschi. Età mediana 74 anni. Quattro HCC, 4 metastasi, 1 colangiocarcinoma periferico, 1 emangioma, 1 pseudotumore infiammatorio. Sono state eseguite 3 resezioni a cuneo, 3 subsegmentectomie, 4 segmentectomie e 3 bisegmentectomie. La perdita ematica mediana è stata 235 ml. In caso di tumore il margine di exeresi mediano è stato 5 mm (range 1–12 mm). Cinque pazienti sono stati trasfusi con emazie concentrate con una mediana di 1 Unità. La degenza mediana è stata 9 giorni, la mortalità zero. Complicanze maggiori e minori sono insorte rispettivamente in 1 e 5 pazienti. Durante un periodo di osservazione mediano di 14 mesi non si sono verificate recidive.

Conclusioni: Nell'esperienza iniziale di un ospedale periferico, l'utilizzo della guida ecografica durante la resezione epatica si è rivelata sicura ed efficace a breve termine.

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Introduction

Intraoperative ultrasonography (IOUS) is the gold standard for staging in primary and secondary metastatic liver tumors [1]. In hepatocellular carcinoma (HCC) IOUS allows detection of new lesions in 7% of cases at the primary hepatectomy and in 7.3% at the secondary hepatectomy [2]. In an analysis related to patients with colorectal liver metastases (CLM), sensitivity of computed tomography (CT) was 69.2%, of helical CT 82.5%, of magnetic resonance imaging (MRI) 84.9%, and of IOUS 95.2% [3]. CT and MRI cannot substitute the real time information provided by IOUS. Due to this specific feature of ultrasonography, IOUS is also essential for guiding the resection as it allows modification of the trajectory whenever needed [4,5]. For these reasons IOUS with color Doppler has been used to guide hepatic surgery in liver cancer since the late 1970s [6]. The feasibility and effectiveness of this surgical approach have reduced resection-related mortality to values below 4% [7,8] and in some cases even to zero [9,10] as shown by numerous cases reported by high-volume liver centers over the last 5 years.

A prospective study on consecutive patients who underwent hepatic resections was undertaken in order to determine whether the systematic use of IOUS-guided resection in a district general hospital is a safe and effective approach in terms of short-term outcome. Primary endpoints were postoperative mortality and morbidity. Secondary endpoint was early cut-end recurrence.

Materials and methods

All patients with potentially resectable liver lesions referred to our institution from December 2005 to December 2007 were considered for inclusion in this study. Forty-six were enrolled but 32 were excluded for various reasons: multiple bilobar CLM ($n = 13$), HCC with ascites and/or total bilirubin level higher than 2.0 mg/dl ($n = 15$) and patients' refusal ($n = 4$) and 3 patients scheduled for liver resection were referred to high-volume liver centers due to the complexity of the planned surgical strategy.

Eleven consecutive patients thus underwent curative liver resection at our institution and were the subjects of the present study. There were 8 males and 3 females; median age was 74 years (62–82 years). American Society of Anesthesiologist classification was 3 (1–3) and Body Mass Index was 23.8 kg/m² (19.8–33.8). Ethical approval was

granted by the Medical Research Ethics Committee of our hospital, and informed consent was obtained from all patients.

Perioperative data were collected and analyzed prospectively. Regardless of whether the patients were presumed to have underlying liver disease, indications for operation were established on the basis of liver function reserve, tumor stage and volume of the remnant liver [11]. In patients with bilirubin concentration below 2.0 mg/dl the surgical strategy was planned according to the flow-chart published by Makuuchi and Kokudo [12]. Indocyanine green retention rate at 15 min (ICGR15) was not evaluated, and in patients with total bilirubin below 1.0 mg/dl, portal vein embolization was indicated if remnant liver volume determined by CT was expected to be less than 50% of the total liver volume.

Fresh frozen plasma (FFP) was administered at a rate exceeding blood loss by 20% and to maintain the serum total protein level at 5.0 g/dl. Packed red blood cells were administered if intraoperative blood loss exceeded 1000 ml or the hemoglobin level fell to 10 mg/dl during surgery or to 8 mg/dl on postoperative days (PODs). The association of International Normalized Ratio (INR) above 1.6 and serum total bilirubin level above 3 mg/dl on POD5 was considered as an indication for multiple bacteriologic examinations and for chest and abdominal CT to rule out pneumonia, abscess or portal vein thrombosis [13]. Total bilirubin in drain discharge was sampled on POD3, POD5, and POD7. Drains were removed on POD7 or when the total bilirubin level in the discharge fluid was lower than the one recorded on the previous POD. Chest and abdominal US examination were performed in the presence of clinical indications and were also routinely performed on POD2, POD4 and POD6.

The terminology for liver anatomy and resection is based on the Couinaud classification [14]. Resection of at least 3 adjacent segments was considered a major resection. Complications were graded on a 1–5-scale according to a grading system published by Dindo et al. [15]. Grade I is any deviation from the normal postoperative course treated with drugs such as antiemetics, antipyretics, analgesics, diuretics and electrolytes. This grade also includes wound infections opened at the bedside. Grade II complications are those requiring blood transfusions or pharmacological treatment with drugs other than those allowed for Grade I. Grade III complications require invasive procedures. Grade IV is life-threatening complications requiring intensive care unit management. Grade V complications result in death. Grades I and II are grouped as "minor" and

Grades III–V are considered as “major” complications. Bile leakage was defined as continuous drainage fluid with a bilirubin concentration greater than 5 mg/dl for more than 7 days or when intra-abdominal collection bilirubin level was greater than 5.0 mg/dl after puncture [10]. Hepatic failure was defined as a serum bilirubin concentration greater than 5.0 mg/dl, a prothrombin time rate below 50% for 3 or more consecutive days, or both [10]. Postoperative mortality was defined as death within 1 month of operation or during the hospital stay. In cancer patients, abdominal US, blood samples for liver function tests and serum tumor markers were performed every 3 months, and contrast-enhanced CT imaging every 6 months. Cut-end recurrence was defined as recurrence in the bed of resection. Operation-related complications identified during hospitalization and follow-up were reported.

Operative procedures

J-shaped incision was performed for lesions located in right segments and/or in segment 4. For lesions in segment 2 and/or 3, an inverted T-shaped incision was performed. After laparotomy, the liver was mobilized by dividing the round and falciform ligaments. In cases of tumors located in the right lobe, the right hemiliver was moved up to access the right edge of the retrohepatic inferior vena cava (IVC), and IIOUS was performed to locate the right hepatic vein (RHV) caval confluence following the trajectory of a diaphragmatic vein [16]. When the tumors were not close to the RHV caval confluence, vascular control of RHV was possible by US-guided blunt finger clamping with no need for taping [17]. The entire liver was studied by following the portal and hepatic vein branches using an Esaote MyLab25 (Esaote, Genoa, Italy) equipped with a high-frequency intraoperative echoprobe (7.5–10 MHz). After detection of known and possible new lesions, surgical

strategy was established on the basis of the type of lesion and its relationship with the intrahepatic vascular structures (Fig. 1) as reported by Torzilli [9]. Portal vein branches and hepatic veins were used as landmarks to define the resection line. In cases of tumors located in either segment 2 or segment 3, the portal branch feeding the subsegmental area, including the lesion, was identified and compressed using the left hand fingertips under IIOUS-guidance [18]. The elective compression of the vein discolored the liver portion fed by the occluded portal branch and the area was then marked on the liver surface.

Parenchyma dissection trajectory was then planned, and the tip of the electrocautery device was positioned between the IIOUS probe and the liver surface. Where the shadow on the IIOUS image below the electrocautery device confirmed that the planned trajectory plane was correct, the liver surface was marked (Fig. 2). Liver resection was performed under warm intermittent ischemia clamping for 15 min alternated with 5 min of reperfusion [19]. Hydrocortisone sodium phosphate (100 mg) was injected intravenously before starting Pringle maneuver [20]. Parenchyma dissection was performed using the crushing clamping technique and a bipolar electrocautery. During resection the operating surgeon checked the dissection trajectory by IIOUS, holding the probe with the right hand while the left hand fingertips, positioned behind the liver, were used as landmarks. The dissection plane appears on the IIOUS image as an echoic line owing to the entrapment of air bubbles and clots between the 2 parenchymal portions defined by the section plane [21] (Fig. 3).

The cut surface of the liver was secured by 2/3–0 absorbable sutures. Fibrin glue (Tissucol; Baxter) was applied to decrease bile leakage [22]. A careful examination was performed for about 45 min after completed resection. A closed suction drain was left close to each cut surface of the liver. All the specimens were examined using

Fig. 1 Surgical strategy based on tumor type and its relationship with the intrahepatic vascular structures. Dashed line shows dissection plane. HCCc = encapsulated hepatocellular carcinoma; HV = hepatic vein; PB = portal branch; HCCi = infiltrative hepatocellular carcinoma; and CLM = colorectal cancer metastases.

Fig. 2 The shadow on the IOUS image below the electrocautery device confirmed correctly? Planned trajectory plane in relation to the lesion. The surgeon's fingertip (F) positioned behind of the liver is used as landmark.

the “water-bath” technique to ensure that target nodules were completely resected [23] (Fig. 4). Liver transaction area was calculated using a white paper spread out over the surface, cut out and measured with tape measure. Values of data collected are expressed as median (range).

Results

Four patients had HCC and histological examination proved that all 4 were affected by cirrhosis; 3 patients had CLM; 2 had synchronous metastases, treated by subsegmentectomy synchronous with colectomy (2 right hemicolectomy and 1 anterior resection), and 1 had a metachronous lesion after a left hemicolectomy performed 36 months earlier. One patient had a metachronous breast liver metastasis. One patient with a history of breast cancer had an inflammatory pseudotumor with preoperative histological examination indicating metastasis. Another patient had a peripheral colangiocarcinoma and 1 had a 13-cm symptomatic hemangioma. One (1–4) lesion per patient was resected. Size was 44 mm (4–130). Five were located in right posterior segments, 3 in right anterior segments, 1 in segment four and 5 in left lateral segments; 21% (3 of 14) of overall nodules were discovered by IOUS. In all cases where IOUS discovered new lesions, preoperative surgical strategy was modified. None of the patients underwent preoperative portal vein embolization (PVE). Intraoperative data are indicated in Table 1. Bilirubin levels in drain discharge on POD3 was 1.8 (1.3–2.8), on POD5: 2.9 (2.0–3.4) and on POD7: 2.2 (2.1–3.2). Drains were removed on POD7 in all cases. No bile leakage was identified. There was no hospital mortality. Morbidity rate was 45% (5 of 11 patients). No re-operation was required. Three major complications occurred in 1 patient (9%) and 6 minor complications in 5 (45%) patients. Hepatic failure (Grade IV), pleural effusion (Grade IIIa), ascites (Grade IIIa) and central venous catheter infection (Grade II) occurred in

a patient with an HCC 4 cm in diameter located 4 mm above the origin of P8. In one patient, intraoperative blood loss was 1800 ml due to severe cirrhosis and a difficult dissection of the origin of P8, and 3 units of packed red blood cells were transfused. Blood transfusions (Grade II) were also administered in 4 patients. Median number of units transfused was 1 (1–3). All packed red blood cells were administered intraoperatively but only in the patient with HCC previously described, transfusion criteria were applied. Postoperative hospital stay was 9 days (7–21). During a median follow-up of 14 months (2–28), no recurrence was observed.

Discussion

IOUS is an essential support in the various intraoperative stages of liver surgery [1]. In our study, 21% of hepatic lesions were identified intraoperatively and in all such cases preoperative surgical strategy was modified. US-guidance was also useful to outline the resection area in case of lesions located in the left lateral sector. Particularly

Fig. 3 (a, b) Dissection trajectory (arrows) was checked (a) and modified (b) by IOUS using lesion and surgeon's fingertip (F) as landmarks.

Fig. 4 Specimen examined in a kidney basin using the "water-bath" technique.

in a patient who had an HCC nodule with undefined margins in contact with the portal branch for segment 3 (P3), US-guided compression of P3 [18] made it possible to visualize the real extension of the afferent segment. IOUS was useful for right lobe mobilization in the 4 cases of lesions located in the right posterior sector. In all 4 cases, color Doppler US control of correct RHV compression by finger pressure [17] eliminated the need for a large resection, while allowing for correct control of the back-flow during resection (Fig. 5).

Because of the extreme accuracy ensured by this method in defining the anatomical relationship between

the lesion and the intra-parenchymal liver structures, IOUS is an essential support also during the resection. US control during the execution of the resection cut permits confirmation or modification of the trajectory in real time, thus making it possible to resort to resection strategies which would otherwise be too difficult or too risky [4,21]. Some authors report an elevated number of cases in which the advanced application of US-guided liver resection decisively contributes to achieving zero postoperative mortality and a major complications rate below 9% [9,10]. In our study mortality rate was zero despite the limited number of patients, and major complications occurred in one patient only. Although numerous studies report a transfusion rate of packed red blood cells below 10% [9,10] or 30% [7,24], in our study 45% of the patients were transfused with packed red blood cells. However, all transfusions were carried out intraoperatively, but study criteria were followed only in one case. No bile fistulas or intra-abdominal collections occurred. We believe this result mainly depends on the accurate intraoperative assessment of the resection cut and on the management of abdominal drains, rather than on the use of IOUS.

The accuracy ensured by US-guidance during resection also permits application of resection strategies resulting in better preservation of liver tissue not involved by the lesion. US-guided resection therefore enhances safe and effective segmental [25,26] or subsegmental [18] resection, consequently reducing the number of major liver resections while keeping oncologic radicality unchanged [9,21]. Such a conservative and yet radical policy is vital in case of reduced liver functionality or in the presence of multiple lesions. Moreover, both in the case of primary and secondary liver tumors, maximizing the preservation of liver tissue not directly involved by the lesion increases the possibility of subsequent resections [2,27].

In our study the use of IOUS did not prevent the execution of major liver resections (>3 segments), because the cases where it would have prevented it were referred to high-volume liver centers. Nonetheless, US support was essential to reduce resection size in 2 cirrhotic patients

Table 1 Intraoperative data.

Type of incision	
J-shape	8
Inverted T-shape	3
Liver procedures	
Wedge resection	3
Subsegmentectomy of segment 4	1
Subsegmentectomy of segment 7	2
Segmentectomy of segment 3	2
Segmentectomy of segment 8	2
Right posterior sectoriectomy	2
Left lateral sectoriectomy	1
Total portal triad clamping (min)	35 (18–85)
Hepatic cut surface area (cm ²)	30 (11–94)
Intraoperative blood loss (ml)	235 (10–1800)
Surgical margin (mm)	
In HCC	3 (1–6)
In MTS or cholangiocarcinoma	6 (4–12)
Operative time (min)	320 (120–450)

Values are median (range); HCC: hepatocellular carcinoma, MTS: metastasis.

Fig. 5 Vascular control of right hepatic vein (RHV) by US-guided blunt finger clamping (F).

affected by HCC located less than 8 mm from the origin of P8. The accurate US identification of P8 and P5 permitted a segmentectomy, using the hooking technique [25], while preventing right anterior sectoriectomy.

When this conservative approach was applied in the 9 patients who had cancer, the resection margins showed a median 3 mm (1–6) value in patients affected by HCC and a median 6 mm (4–12) value in those who had cholangiocarcinoma or secondary lesions. During a 14-month follow-up (2–28) no patient showed any signs of disease recurrence.

Conclusions

This article highlights that the in-depth study of the US anatomy of the liver may represent an essential support for the surgeon in the performance of liver resection surgery, thus contributing to making this type of surgery – although in selected cases – a safe and effective type of surgery even in a district general hospital.

Conflict of interest

The authors have no conflict of interest.

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