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Robot-assisted fenestration of giant hepatic cysts in posterosuperior segments

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Summary
Background The diffusion of the use of robotic surgical platforms, such as the da Vinci Xi Surgical System® (Intuitive Surgical, Sunnyvale, CA, USA), has been advocated by several authors to overcome the limitations of laparoscopy in hepatobiliary surgery.
Methods We reported our experience of robot-assisted fenestration of giant hepatic cysts in posterosuperior segments with the use of indocyanine green fluorescence imaging. We described step by step our surgical technique including the operative room set-up, port placement and robotic instruments.
Results We enrolled 11 patients: nine females and two males with a mean age of 65 years (range 52–80 yrs). All procedures were undertaken successfully without intraoperative or postoperative complications. The mean surgical operating time was 125 min. The mean blood loss was 30 ml. The median postoperative stay was two days (range, 1 to 3 days).
Conclusions The most significant advantage of the robotic approach was the ability to access hepatic cysts close to the diaphragm.

Keywords Robot-assisted fenestration · Indocyanine green fluorescence (ICG) · Giant hepatic cysts · Posterosuperior segments

Video online The online version of this article contains one video. The article and the video are online available (https://doi.org/10.1007/s10353-024-00834-1). The video can be found in the article back matter as "Electronic Supplementary Material".

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Introduction

Simple, non-parasitic cysts represent the most common benign hepatic lesions, affecting up to 5% of the general population [1]. Several treatments have been proposed for symptomatic hepatic cysts. Laparoscopic fenestration is currently the gold standard due to its minimally invasive nature, short-term benefits and fast recovery times [2, 3]. However, long-term recurrence rates range from 14.9 to 25%, affecting most frequently the right posterior segments (S7, S8), due to their proximity to the diaphragm, which in some cases hinders adequate deroofing of the cystic wall [4].

Robotic surgical platforms, such as the da Vinci Xi Surgical System® (Intuitive Surgical, Sunnyvale, CA, USA), may overcome the limitations of laparoscopy by providing advances such as 3D vision, wristed instruments with seven degrees of freedom, and improved ergonomics. Despite the potential benefits of this technique, only few cases of robotic-assisted fenestration of hepatic cysts have been reported in the literature [5, 6]. We hereby report our surgical experience.

Materials and methods

We described step by step our surgical technique including the operative room set-up, port placement and robotic instruments. We also reported our experience of robot-assisted fenestration of giant hepatic cysts with the use of indocyanine green fluorescence (ICG) imaging.

Preoperative study

Indications for surgery included the presence of symptoms correlated with radiological findings by

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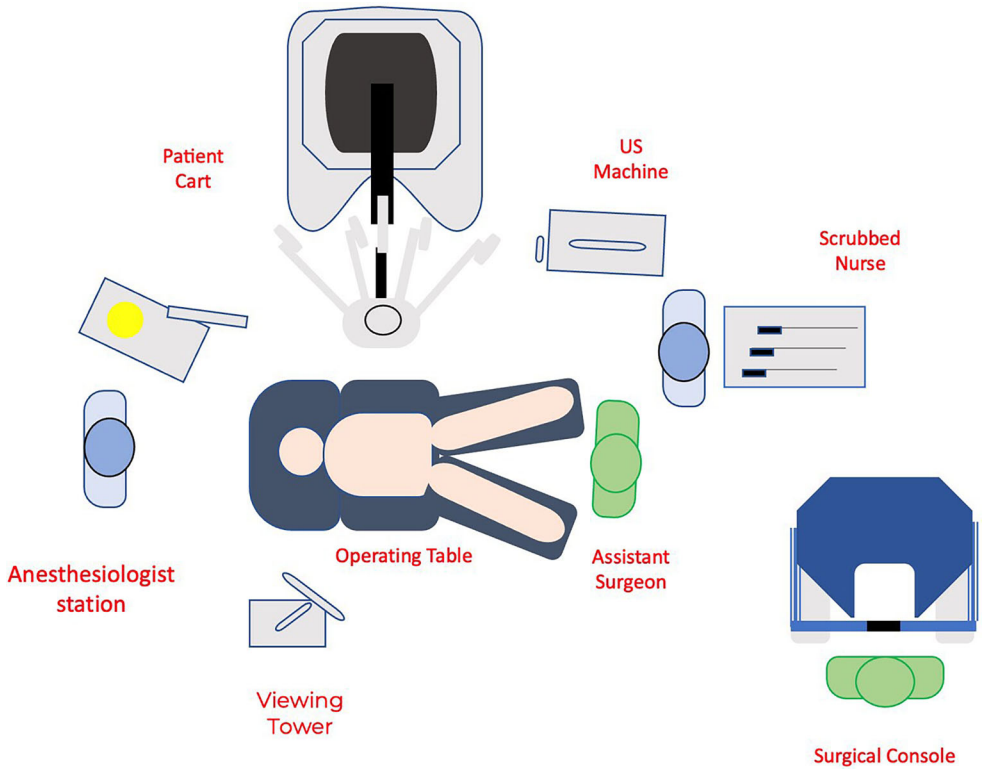

Fig. 1 Operative room set-up

means of computed tomography (CT) or contrast-enhanced magnetic resonance imaging (MRI) to exclude the presence of neoplastic nodules inside the cysts. All patients underwent serology tests for *Echinococcus* and *Entamoeba*. ICG was administered one hour before surgery at a dose of 0.2 mg/kg of body weight.

Operative room set-up

The patients were placed in supine position with legs apart and both arms adducted. The operating table was placed in reverse Trendelenburg position with a right tilt (20°). The robotic cart was located at the patient's left side and the docking set-up was in the upper abdomen. The viewing tower was positioned at the patient's right shoulder, while the ultrasound machine was located at the patient's feet. A laparoscopic assistant surgeon was standing between the legs. The scrub nurse was at the right side of the assistant (Fig. 1).

Port placement

We routinely induced pneumoperitoneum at 12 mm Hg through a Veress needle inserted at the Palmer's point. Trocars were placed as follows: the optical port (8 mm) was placed on the right mid-clavicular line along the transverse umbilical line; the other three operative trocars (8 mm) were placed in a straight line, two on the right and one on the left side. The trocars on the right were used for the surgeon's right hand (monopolar curved scissor or Vessel Sealer®) and for the surgeon's third hand (Cadier forceps). The left unit was used for the surgeon's left hand (fenestrated bipolar forceps). One additional assistant trocar (12 mm or 5 mm) was generally placed in the lower abdomen between two robotic trocars (Fig. 2). The assistant port was frequently used for retraction, aspiration and extraction.

Surgical technique

Surgical technique was standardized for all cases. Cystic margins were delineated using a robotic ultrasound probe (Hitachi Aloka Medical Ltd) and ICG fluorescence. EndoWrist technology (Vessel Sealer®) was used for cystic wall fenestration; the cystic dome was excised as close as possible to the hepatic parenchyma to reduce the risk of bleeding (Fig. 3). ICG was used to identify intramural compressed bile ducts (Fig. 4a, b c). A drainage was routinely placed at the end of the procedure and removed on postoperative day 3 in all cases.

Postoperative follow-up

Patients underwent follow-up by means of a surgical visit and an abdominal ultrasound at one, six and twelve months after surgery.

Results

Between January 2022 and February 2023 we enrolled 11 consecutive patients undergoing robotic fenestra-

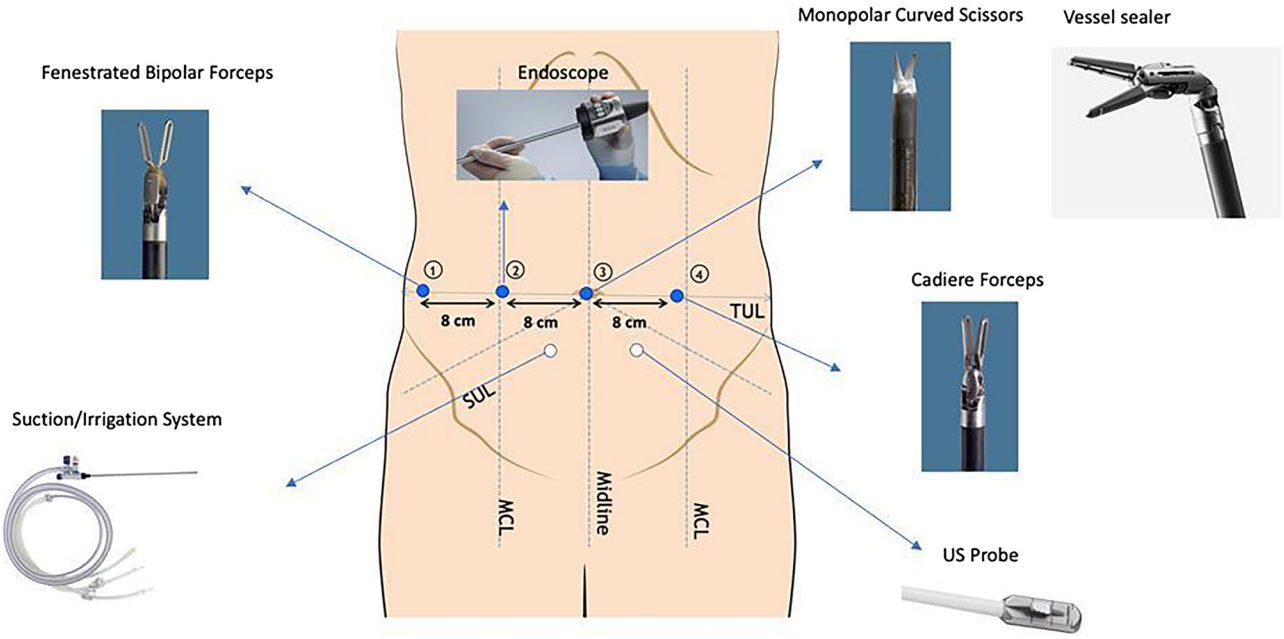

Fig. 2 Operative trocar's position. Four robotic trocars (blue dots) were placed along the transverse umbilical line: n. 1: in the right flank for the fenestrated bipolar forceps (surgeon left hand). n. 2: in the right middle clavicular line (MCL) for the endoscope (optic trocar). n. 3: in the midline for the monopolar curved scissors and vessel sealer (surgeon right hand). n. 4: in the left flank for the Cadiere forceps (surgeon third hand). Two laparoscopic assistant 10 mm trocars (white dots) were placed in the hypogastrium and used to introduce the US probe and the suction/irrigation system

tions of giant hepatic cysts of posterosuperior segments (S7, S8, S4a). Our study includes nine females and two males, with a mean age of 65 years (range 52–80 yrs). Patient's demographic and clinical characteristics are shown in Table 1. ICG was adopted in all cases and allowed identification of cystic margins and avoidance of bile duct injury. All procedures were conducted successfully, without intraoperative or postoperative complications. Mean operating time was 125 min, median blood loss was 30 ml and median post-operative stay was two days (range 1–3 days) (Table 2). Pathologic examination revealed a benign liver cyst in all the resected specimens. No patients developed symptoms or radiological signs of recurrence at six months.

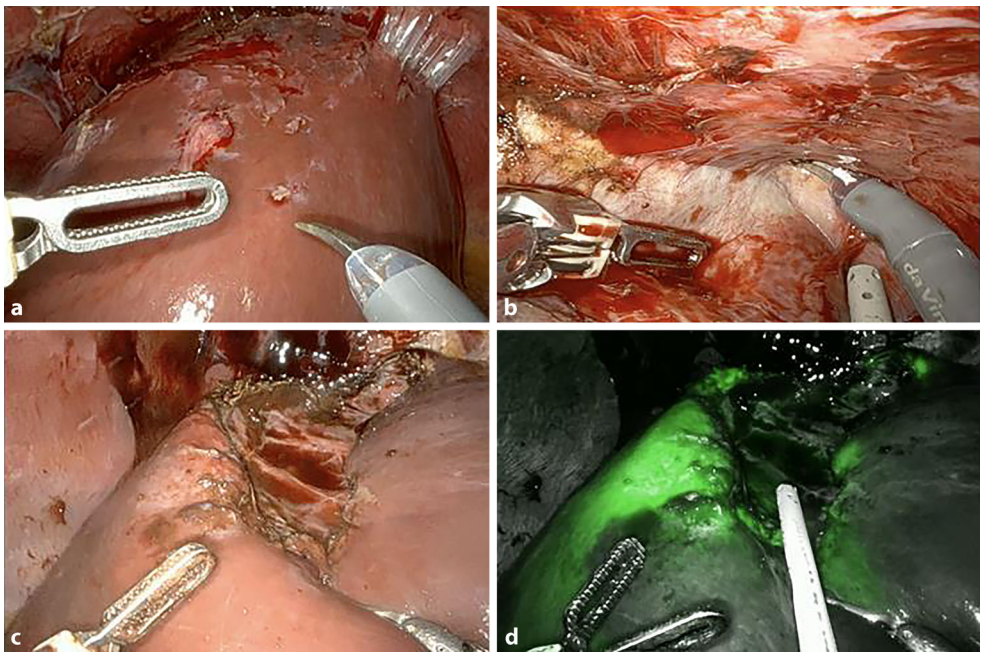

Fig. 3 Robot-assisted fenestration of a giant hepatic cysts in poster superior segments. **a**, **b** Hepatic cyst of the right posterior-superior segment tightly linked to the diaphragmatic muscle. **c** Complete deroofing of the superior cystic wall. **d** ICG staining of hepatic parenchyma which results completely exposed after the removal of cystic wall

Table 1 Patient's clinical characteristics

N	Age (years)	Sex	Symptom	Cyst location (segment)	Size (cm)
1	72 yrs	Female	Bleeding/Pain	S7/S8	16 cm
2	80 yrs	Male	Pain/Shortness of breath	S7	20 cm
3	75 yrs	Female	Fever/Pain	S7/S6	20 cm
4	52 yrs	Female	Bleeding/Pain	S8/S4a	15 cm
5	67 yrs	Female	Pain	S8/S7	24 cm
6	62 yrs	Female	Bleeding/Pain	S2/S4a	10 cm
7	65 yrs	Female	Bleeding/Pain	S8	14 cm
8	58 yrs	Female	Pain/Fever	S7/S8	21 cm
9	60 yrs	Female	Bleeding	S8/S5	15 cm
10	64 yrs	Female	Pain	S4a	11 cm
11	56 yrs	Male	Pain	S8	15 cm

LUS laparoscopic ultrasound, *ICG* indocyanine green fluorescence, *CT* computed tomography, *MRI* contrast-enhanced magnetic resonance imaging

Table 2 Surgical outcomes

N	Timing of ICG injection	Duration of operation (min)	Characteristics of fluid aspirated (ml)	Cholecystectomy	Blood loss (ml)	Complication	Hospital stay (day)
1	1 h before surgery	150 min	1500 ml of cloudy liquid	No	30	No	3
2	1 h before surgery	90 min	2000 ml of clear fluid	No	50	No	2
3	1 h before surgery	160 min	1800 ml of cloudy fluid	Yes	30	No	2
4	1 h before surgery	180 min	1500 ml of cloudy fluid	Yes	50	No	2
5	1 h before surgery	180 min	2100 ml of clear fluid	Yes	50	No	3
6	1 h before surgery	120 min	1000 ml of cloudy liquid	No	30	No	2
7	1 h before surgery	120 min	900 ml of cloudy liquid	No	25	No	2
8	1 h before surgery	120 min	2000 ml of cloudy liquid	No	30	No	1
9	1 h before surgery	90 min	1200 ml of cloudy liquid	No	20	No	2
10	1 h before surgery	90 min	1000 ml of cloudy liquid	No	25	No	2
11	1 h before surgery	90 min	1200 ml of cloudy liquid	No	20	No	1

LUS laparoscopic ultrasound, *ICG* indocyanine green fluorescence, *CT* computed tomography, *MRI* contrast-enhanced magnetic resonance imaging

Discussion

Many authors have reported on the routine use of indocyanine green fluorescence (ICG) in hepatobiliary surgery [7]. Near infrared fluorescent cholangiography (NIRF-C) represents a powerful real-time diagnostic tool for the detection of biliary anatomy during laparoscopic cholecystectomy (LC). Substantial evidence has proved the importance of routine use in elective LC to decrease bile duct injury and conversion to open surgery. NIRF-C could also be used for the detection of bile leakage after hepatic resection [8–10].

Recently, several authors have advocated the use of ICG fluorescence to avoid bile duct injury during laparoscopic liver cyst fenestration [11–13].

In our experience, ICG was injected intravenously one hour before surgery, because the maximum concentration of ICG dye in bile has been observed within two hours from administration. ICG fluorescence was retained in the liver parenchyma and in the biliary tract, but not in the cystic wall, allowing a real-time assessment of surgical margins between the liver parenchyma and the cystic wall. Therefore, ICG proved to be useful to delineate the cystic margins and to reveal intramural compressed bile ducts within the cystic wall, aiding in the avoidance of accidental bile duct injury, which represents the main complication of hepatic cyst fenestration.

In literature, there are only a few cases of robot-assisted fenestration of hepatic cysts [14–16]. Reported advantages of the robotic approach are the three-dimensional view and the possibility to use an instrument with a sealing capability of vessels up to 7 mm in diameter (Vessel Sealer®) [14–16]. Tsirlis T et al. [15] reported the largest case series, enrolling seventeen patients in a single center prospective study. In this case series, the majority of the cysts (5/6) were located in the posterosuperior or central segments (VII, VIII, and IVa). In our small case series, there were no cases of conversion and intraoperative blood loss was minimal. None of the eleven patients developed any complications. During the follow-up period of 12 months, all patients presented without any type (symptomatic or radiological) of recurrence. Despite the absence of complications and recurrence in our case series, there is no actual evidence in the literature that robotic fenestration provides a lower recurrence rate compared to the laparoscopic approach. The robotic approach can decrease the learning curve and increase the application of minimally invasive surgery. In all cases, surgery was performed by a young hepa-

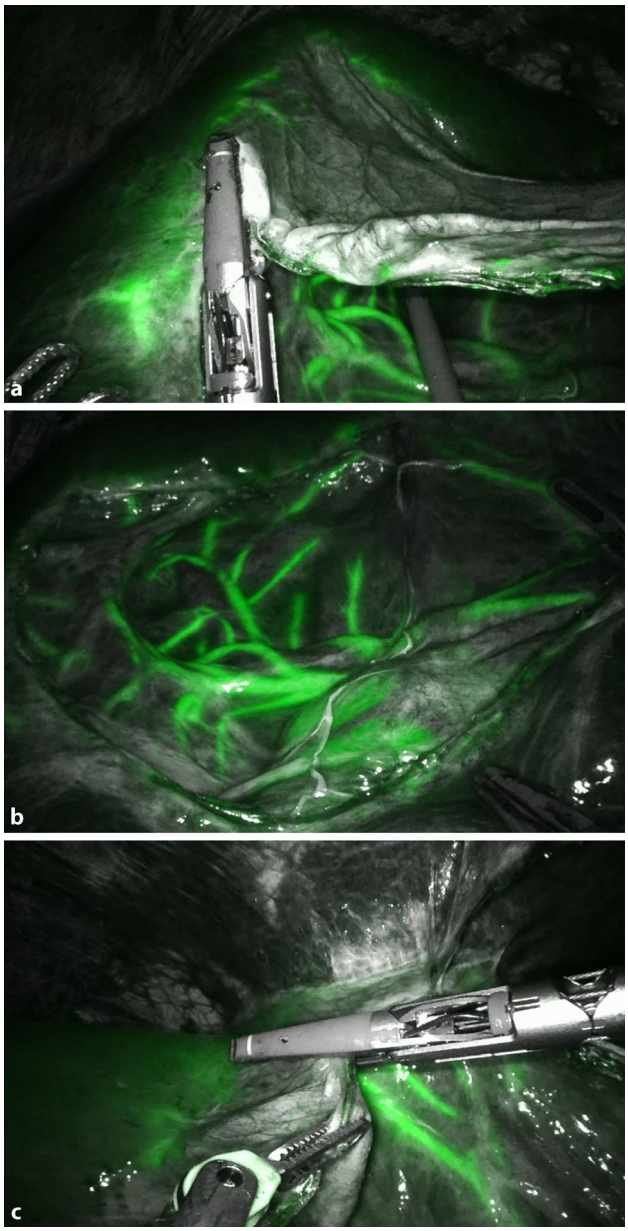

Fig. 4 Robot-assisted fenestration of a giant hepatic cysts with intramural compressed bile ducts

tobiliary (HPB) surgeon; we believe that robotic fenestration of hepatic cysts may constitute an ideal tool in the training of young HPB surgeons.

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Conflict of interest G. Piccolo, M. Barabino, F. Lecchi, R. Masserano and P.P. Bianchi declare that they have no competing interests.

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