Review Article

Anatomically unfavorable segments: laparoscopic and robotic liver resection in posterosuperior segments and the caudate lobe, a narrative review

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Objective: Laparoscopic liver resection (LLR) for hepatocellular carcinoma (HCC) has grown since the early minimally invasive liver surgery (MILS) reports. The advantages of this approach in the treatment of HCC are well known today. However, the indication for LLR for HCC is not yet well defined.

Background: The resection of tumors located in the posterosuperior segments and the caudate lobe is still debated. Many techniques have been described, focusing on the trocar introduction and the patient's position.

Methods: A literature search was performed using the PubMed database. Thirty-seven publications, including 331 patients, were relevant to laparoscopic or robotic resection for HCC in unfavorable liver segments. All the articles with no clear indications about the histology of the tumor or the precise posterosuperior or caudate localization were excluded. The present review aims to report the experience of laparoscopic and robotic resection for HCC in unfavorable segments. Based on technical approaches, the resections of tumors located in the segments IVa, VII, VIII, and the caudate lobe have been discussed analyzing preoperative and intraoperative features; in a separate section, the resections performed through robotic approach have been discussed.

Conclusions: According to the current literature, LLR for HCC is feasible and safe in unfavorable segments. It is necessary to gradually increase the skills of laparoscopic or robotic surgery according to the experience level before performing technically demanding procedures.

Keywords: Hepatocellular carcinoma (HCC); robotic; minimally invasive liver surgery (MILS); cirrhosis; hepatectomy

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Introduction

Laparoscopic liver resection (LLR) has spread since the First International Consensus Conference on Laparoscopic Liver Surgery held in Louisville in 2008. It is nowadays adopted for the surgical treatment of liver malignancies (1). Hepatocellular carcinoma (HCC) is the most common liver cancer in cirrhotic patients. In selected cases requiring a downstaging, surgical resection can be considered both a curative therapy and a "bridge-to-transplantation". The

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minimally invasive approach techniques potentially bring benefits to patients who need liver resection for HCC (2), bearing in mind that surgery option for HCC, especially in cirrhotic patients, should aim to obtain a radical resection preserving as much liver parenchyma as possible and allowing a lower rate of post-hepatectomy liver failure, less impact on the abdominal wall with the respect of venous shunts, reduced surgical trauma and delicate tissues manipulation.

LLR is worldwide accepted for the treatment of tumors located in the anterior lateral segments, according to Couinaud's classification (segments II, III, V, VI, and IVb) (3). They were considered for years as the classical "laparoscopic liver segments" because of their easy access to a minimally invasive approach, and in the second consensus meeting held in Morioka in 2014, anterolateral segment laparoscopic resections were recognized as a standard treatment; in contrast, it has been stated that posterosuperior segment resections could be applied experimentally by experienced surgeons in advanced centers where innovative procedures are carried out (4).

Different minimally invasive liver surgery (MILS) reports were published in the last years for tumors located in the unfavorable segments (I, IVa, VI, VII, and VIII) (5-7).

This review aims to analyze the role of MILS for HCC located in unfavorable segments, considering laparoscopic and robotic resection. We present the following article in accordance with the Narrative Review reporting checklist (available at https://ls.amegroups.com/article/view/10.21037/ls-21-20/rc).

Materials and methods

Literature review of published robotic and LLR for HCC focused specifically on posterosuperior segments

A literature search was performed using the PubMed database with the search phrases "robotic liver resection", "laparoscopic liver resection", "posterosuperior liver segments", "caudate lobe laparoscopic resection", "caudate lobe robotic resection", "unfavorable liver segments", "laparoscopic liver resection for hepatocellular carcinoma" or "robotic liver resection for hepatocellular carcinoma". All titles, abstracts, and articles were screened for review, carefully examining the data to remove double counting of patients between series. Series focused on biliary reconstruction (choledochal cyst or biliary atresia), colorectal liver metastases, cholangiocarcinoma, and resection for benign pathology of the liver were excluded. Perioperative characteristics (tumor size, operating maneuvers, and technique, patient installation) and outcomes (operation time, blood loss, need for hepatic pedicle clamping and mean clamping time, conversion, and hospital stay) were analyzed.

Results

Search results and baseline characteristics of patients in the included studies

Thirty-eight publications, including 371 patients, were relevant to laparoscopic or robotic resection for HCC in unfavorable liver segments. All the articles with no clear indications about the histology of the tumor or the precise posterosuperior localization were excluded. A check for the doubly counted cases was performed. All the cases concerning resection for other pathologies such as colorectal liver metastases, cholangiocarcinoma, choledochal cyst or biliary atresia, and other benign pathologies of the liver were excluded (*Table 1*).

All the studies concerning robotic surgery used the Da Vinci robot system (Intuitive, Sunnyvale, CA, USA).

Laparoscopic resection of posterosuperior segments

Seventeen articles were selected (8-23,33,45) (*Table 2*). The mean tumor size was 33.1±15.9 mm. The techniques used were heterogeneous, varying from the anterior approach in the supine position to the left lateral decubitus or semi-prone position. The number of trocars placed is strictly dependent on the operator so that in three cases, five ports were placed [Ishizawa *et al.* (8), Chen *et al.* (9), Xiao *et al.* (10)], D'Hondt *et al.* (11) placed five or six ports, Jang *et al.* (12) placed five abdominal ports, and one intercostal port, Tarantino *et al.* five or five ports (13), Magistri *et al.* (14) placed only four ports. In contrast, Ikeda *et al.* (15) and Lee *et al.* (16) placed four abdominal ports, adding 1 or 2 intercostal ports. Teramoto *et al.* (23) described the total transthoracic technique for segment 8 laparoscopic resections, with the patient in left decubitus position and 5 transthoracic trocars. The mean operating time (OT) was 258.9±123.3 minutes (ranging from 66 to 599 minutes), the intraoperative estimated blood loss (EBL) was on average 363.9±293.1 mL (ranging from 0 to 1,200 mL). The hepatic pedicle clamping was not performed according to three authors [Tarantino *et al.* (13), D'Hondt *et al.* (11), Magistri *et al.* (14)]. In contrast, an intermittent

Table 1 All articles considered for review

Authors	Year	Journal	Type of study	Patients	Technique	HCC	Other pathologies
Ishizawa *et al.* (8)	2012	*Annals of Surgery*	Surgical technique	62 (30 with posterosuperior malignancy localization)	Laparoscopic resection	11	19
Chen *et al.* (9)	2017	*Chinese Journal of Cancer*	Article	10	Laparoscopic resection	10	0
Xiao *et al.* (10)	2015	*Journal of Surgical Oncology*	How I do it	10	Laparoscopic resection	10	0
D'Hondt *et al.* (11)	2019	*Langenbeck's Archives of Surgery*	Original article	18	Laparoscopic resection	6	12
Jang *et al.* (12)	2017	*Annals of Surgical Oncology*	Original article	1	Laparoscopic resection	1	0
Tarantino *et al.* (13)	2017	*Journal of Laparoendoscopic & Advanced Surgical Techniques*	Full report	13	Laparoscopic resection	13	0
Magistri *et al.* (14)	2017	*Journal of Surgical Research*	–	46	Laparoscopic and robotic resection	11 (LLR, posterolateral segments); 7 (RLR, posterolateral segments)	0
Ikeda *et al.* (15)	2014	*Surgical Endoscopy*	Video	76	Laparoscopic resection	44	32
Lee *et al.* (16)	2014	*J Hepatobiliary Pancreat Sci*	Case series	5	Laparoscopic resection	1	4
Berardi *et al.* (17)	2019	*Annals of Surgical Oncology*	Original article	1	Laparoscopic resection	1	0
Cheng *et al.* (18)	2011	*Surgical Endoscopy*	Multimedia manuscript	1	Laparoscopic resection	1	0
Cho *et al.* (19)	2008	*Surgery*	Article	82	Laparoscopic resection	52 (20 in posterosuperior segments)	30
Yoon *et al.* (20)	2006	*Journal of Laparoendoscopic & Advanced Surgical Techniques*	Case report	1	Laparoscopic resection	1	0
Kim *et al.* (21)	2019	*Surgical Oncology*	Video	1	Laparoscopic resection	1	0
Lim *et al.* (22)	2021	*Surgical Endoscopy*	Article	93 (6 laparoscopic resection of posterosuperior segments, 5 robotic resection of posterosuperior segments)	Laparoscopic and robotic resection	11	0
Teramoto *et al.* (23)	2003	*World Journal of Surgery*	Original article	11	Laparoscopic resection	11	0
Parikh *et al.* (24)	2021	*Scientific Reports*	Article	21 (12 laparoscopic resection, 9 open resection)	Laparoscopic resection	11	1
Oh *et al.* (25)	2016	–	–	6	Laparoscopic resection	6	
Ho *et al.* (26)	2017	*Journal of Laparoendoscopic & Advanced Surgical Techniques*	Article	1	Laparoscopic resection	1	0
Liu *et al.* (27)	2019	*Annals of Surgical Oncology*	Original article	1	Laparoscopic resection	1	0

Table 1 (*continued*)

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Authors	Year	Journal	Type of study	Patients	Technique	HCC	Other pathologies
Jin *et al.* (28)	2018	*Biomed Research International*	Research article	12	Laparoscopic resection	7	5
Xu *et al.* (29)	2021	*Surgical Endoscopy*	–	131 (19 laparoscopic resection, 112 open surgery resection)	Laparoscopic resection	7	12
Chai *et al.* (30)	2018	*Journal of Laparoscopic and Advanced Surgical Technique*	Article	4	Laparoscopic resection	4	
Patriti *et al.* (31)	2014	*Journal of the Society of Laparoscopic & Robotic Surgeons*	Article	88 (19 robotic resection, 69 open surgery resection)	Robotic resection	1	
Casciola *et al.* (32)	2011	*Surgical Endoscopy*	Article	23	Robotic resection	3	20
Montalti *et al.* (33)	2015	*Surgical Endoscopy*	Article	108 (36 robotic resection, 72 laparoscopic resection)	Laparoscopic resection and robotic resection	9	99
Magistri *et al.* (34)	2020	*Cancer*	Article	24	Robotic resection	24	0
Ong *et al.* (35)	2016	*Journal of Endourology Case Reports*	Case report	1	Robotic resection	1	0
Khan *et al.* (36)	2018	*Annals of Surgical Oncology*	Original article	61	Robotic resection	34 (4 posterolateral segments)	27
Nota *et al.* (37)	2019	*Annals of Surgical Oncology*	Original article	51	Robotic resection	12	39
Boggi *et al.* (38)	2015	*Updates in Surgery*	Original article	12	Robotic resection	7	5
Chen *et al.* (39)	2017	*Annals of Surgical Oncology*	Original article	81 (10 posterosuperior resections)	Robotic resection	10	0
Lai *et al.* (40)	2016	*Surg Laparosc Endosc Percutan Tech*	Original article	100 (29 posterosuperior resection)	Robotic resection	29	0
Zhao *et al.* (41)	2020	*Hepatobiliary and Pancreatic Diseases International*	Original article	32	Robotic resection	17	15
Cañada Trofo Surjan and do Prado Silveira (42)	2020	*The International Journal of Medical Robotics and Computer Assisted Surgery*	Original article	1	Robotic resection	1	0
Marino *et al.* (43)	2018	*Cirugia Espanola*	Original article	10	Robotic resection	5	5
Lai *et al.* (44)	2014	*Surgical Laparoscopy, Endoscopy and Percutaneous Techniques*	Technical reports	2	Robotic resection	2	0
Chen *et al.* (45)	2017	*Medicine (Baltimore)*	Article	526 (225 laparoscopic resection, 291 open surgery resection)	Laparoscopic resection	225 (19 in posterosuperior segments)	0

HCC, hepatocellular carcinoma; LLR, laparoscopic liver resection; RLR, robotic liver resection.

Table 2 Article considered for review about LLR of posterosuperior segments

Authors	Patients	Tumor size	Technique	Trocars	OT	EBL	HPCT	LOS	Conversion rate
Ishizawa *et al.* (8), 2012	22 patients	N/A	Anterior approach (segmentectomy VI) and lateral approach (segmentectomy VII); *anatomical resection (segmentectomy)	5 ports	90–240 min	50–1,200 mL	N/A	N/A	0 (0%)
Chen *et al.* (9), 2017	10 patients	31 mm [23–41]	Jack-knife position; *anatomical resection	5 ports	166±28 min	220±135 mL	N/A	2.5 days [2–3]	0 (0%)
Xiao *et al.* (10), 2015	10 patients	38 mm [20–60]	Supine position + anatomical segmentectomy with the hepatic veins exposed from the head side; *non anatomical and anatomical resection	5 ports	326.20±51.13 min	375.0±166.42 mL	N/A	6.70±0.82 days	0 (0%)
D'Hondt *et al.* (11), 2019	6 patients	N/A	Semiprone position; *anatomical resection	5 or 6 ports	162.5 min [140–190]	325 mL [150–450]	0	6 days [5–8]	1 (5.6%)
Jang *et al.* (12), 2017	1 patient	66 mm	Lithotomy and left semi-decubitus position; *anatomical resection	5 ports + 1 intercostal port	420 min	600 mL	Intermittent 15 + 5 min release period (for 8 times)	6 days	0 (0%)
Tarantino *et al.* (13), 2017	13 patients	26.5±9 mm	45° right hemi-lateral supine position	4 or 5 ports	234±57 min	125±80 mL	0	5.7±3 days	3 (23%)
Magistri *et al.* (14), 2017	11 patients	22.61±11.33 mm	Left decubitus position; *non anatomical and anatomical resection	4 ports	211±78.13 min	328 mL [100–1,100]	0	6.2±2.57 days	4 (16.7%)
Ikeda *et al.* (15), 2014	44 (15 Group-S, 29 Group-SP)	2.9±1.3 (3.0±1.3 Group-S; 2.5±1.0 Group-SP)	Supine position and Semiprone position; *non-anatomical and anatomical resection	Group-SP: 4 ports + additional intercostal port in case of S8 or S7 resection; Group-S: 4 ports	Group-S 344 min [99–685]; Group-SP 296 min [66–599]	Group-S 899 mL [120–3,200]; Group-SP 158 mL [0–1070]	N/A	Group-S 35 days [7–71]; Group-SP 11 days [5–23]	0 (0%)

Table 2 (*continued*)

Table 2 (*continued*)

Authors	Patients	Tumor size	Technique	Trocars	OT	EBL	HPCT	LOS	Conversion rate
Lee *et al.* (16), 2014	1 patient	2.2±1.1	Anterior approach + transthoracic; *non anatomical resection	4 ports + 2 intercostal ports	197±68 min [110–300]	161±138 mL	N/A	7±3.5 days	0 (0%)
Berardi *et al.* (17), 2019	1 patient	30 mm	Glissonian approach + ICG dye; *anatomical resection	–	420 min	261 mL	N/A	8 days	0 (0%)
Cheng *et al.* (18), 2011	1 patient	26 mm	Posterior approach; *anatomical resection	–	510 min	800 mL	N/A	6 days	–
Cho *et al.* (19), 2008	20 patients of Group-PS (20/28)	33±15 mm	Supine or 15° right semilateral position; *anatomical and non-anatomical resection	–	320 min [160–540]	500 mL [200–900]	N/A	10 days [4–19]	3 (11%)
Yoon *et al.* (20), 2006	1 patient	50 mm	*Anatomical resection	–	–	–	N/A	13 days	0 (0%)
Lim *et al.* (22), 2021	6 patients	40±25 mm	Supine position + 15° reverse Trendelenburg; *non anatomical and anatomical resection	5 or 6 ports	269±100 min	N/A	N/A	7±5 days	N/A
Teramoto *et al.* (23), 2003	11 patients (3 tumors in posterosuperior segments)	15–55 mm	Thoracoscopic hepatectomy—left decubitus position and transthoracic ports	5 ports	198–310 min	50–650 mL	N/A	8–15 days	0 (0%)
Montalti *et al.* (33), 2015	6 patients (total of 72 patients who underwent LLR)	49.5±35 mm	Supine position + 30° reverse Trendelenburg, turned two-thirds on the left side; *non anatomical and anatomical resection	4 or 6 ports	295±107 min	437±523 mL	24.6±16.5 min	4.9±2.95 days	7 patients on the total (9.7%)
Chen *et al.* (45), 2017	29 patients	64 mm [14–130]	Left decubitus position; *anatomical resection	5 ports	240 min [75–590]	200 mL [20–2,500]	N/A	6 days [3–21]	N/A

*, when anatomical resection is described. Group-S: group supine; Group-SP: group semiprone; Group-PS: posterosuperior. LLR, laparoscopic liver resection; OT, operating time; EBL, estimated blood loss; HPCT, hepatic pedicle clamping time; LOS, length of stay; ICG, indocyanine green.

Pringle's Maneuver consisting of a 15-minute clamping and 5-minute release was performed by Jang *et al.* (12). All the other authors reported nothing about hepatic pedicle clamping time (HPCT). The length of stay (LOS) was on average 6.8±2.9 days, ranging from 2 to 23 days, and the mean percentage of conversion to open resection was equal to 4.6±7.9 [5.6% reported from D'Hondt *et al.* (11) to 23% reported from Tarantino *et al.* (13)].

Laparoscopic resection of the caudate lobe

Seven articles were selected (24-30) (*Table 3*). The tumor means size was equal to 36.6±20.4 mm (ranging from 9 to 65 mm). Four authors approached the caudate lobe from the left side [Parikh *et al.* (24), Oh *et al.* (25), Ho *et al.* (26)], while Liu *et al.* (27) and Jin *et al.* (28) chose respectively a combined and an anterior approach; Xu *et al.* (29) used a left side or a right side or a combined approach depending on the tumor localization. An innovative approach is reported by Chai *et al.* (30), who proposed the Arantius ligament suspension. The number of ports placed was 5 in all cases, except in the cases reported by Jin *et al.* (28), in which six ports were used. The mean OT in laparoscopic caudate resection was 229.8±86.4 minutes (ranging from 128.5 to 615 minutes), the reported EBL was 164.7±72.8 mL (ranging from 0 to 650 mL), and the hepatic pedicle clamping was performed only by three authors, with a mean time of 25.22±16.7 minutes [Xu *et al.* (29), Liu *et al.* (27), Jin *et al.* (28)]. The conversion rate was equal to 0%; the mean LOS was 5.7±2.2 days.

Robotic resection of posterosuperior segments

Twelve articles about posterosuperior segments robotic resection for HCC were selected (14,22,31-40) (*Table 4*). The tumor means size was 36.91±6.34 mm (ranging from 2 to 160 mm). The technique has undergone slight variations according to the preferences of the authors, but generally, the patient was in the supine position (tilted 20° in reverse Trendelenburg) or in left lateral position; the number of ports ranged from 4 to 5 abdominal ports, which disposition is highly depending on patient conformation and tumor localization. In the case series by Patriti *et al.* (31), Casciola *et al.* (32) and Montalti *et al.* (33) is also reported the placement of an intercostal port between the 10th and the 11th rib along the scapular line. The mean OT was 281.06±63.14 minutes (ranging from 53 to 825 minutes), the reported EBL was 288.22±94.76 mL (ranging from 10 to 3,500 mL), and eight authors performed the hepatic pedicle clamping with a mean clamping time equal to 50.70±23.39 minutes (ranging from 13.3 to 166 minutes). In these series, the mean conversion to open surgery rate was 4.47% (ranging from 0% to 13.9%), and the mean LOS was 6.23±1.92 days.

Robotic resection of the caudate lobe

Only four articles about caudate lobe robotic resection for HCC were selected (41-44) (*Table 5*), with a mean tumor size equal to 28.12±13.16 mm, all performed in supine position with a variable tilted position angle in reverse Trendelenburg and five ports placement. The mean OT was 186.64±54.29 minutes (ranging from 70 to 522 minutes), the EBL 76.71±38.67 mL (ranging from 10 to 1,500 mL), conversion to open surgery rate 0% and a LOS on average equal to 4.95±1.74 days (ranging from 2 to 19 days).

Discussion

Laparoscopic resection of posterosuperior segments (segments VIII-VII-IVa)

Laparoscopic posterior segments resection is considered a challenging procedure. First, because of anatomical reasons: this is an area located in the dome of the liver, in the small sub-phrenic space; it could be technically demanding since it requires the handling of the liver. Moreover, hepatic segments VII and VIII are located deeply and adjacent to the hepatic vein, inferior vena cava (IVC), and hepatic hilum.

Also, patients with lesions located in segment IVa are considered poor candidates for laparoscopic resection; it could be technically challenging mainly for the limited visualization and the difficult bleeding control, taking care not to injure the hepatic vein running between segments III and IV.

The introduction of efficient and useful equipment allows the surgeon to minimize bleeding during liver dissection. The ultrasound (US) liver map technique enables planning and real-time guidance during LLRs (8); moreover, the US can detect safe margins confirming sufficient tumor-free resections and demonstrate the adjacent hepatic vasculature, justifying LLR.

From the technical point of view, handling the right liver may be performed by a hand-assisted approach, robotic liver resection (RLR), or spacers, such as a sterile glove pouch.

Table 3 Article considered for review about laparoscopic resection of the caudate lobe

Authors	Patients	Tumor size	Technique	Trocars	OT	EBL	HPCT	LOS	Conversion rate
Parikh *et al.* (24)	11	20 mm [9–41]	Left to right approach; *anatomical resection	Five-port technique	204.5 min [75–450]	250 mL [0–650]	Not available	4 days [2–10]	0%
Oh *et al.* (25)	6	9–51 mm	Left to right approach; *non-anatomical and anatomical resection	Five-port technique	382 min [168–615]	242.5 mL [120–360]	Not available	7 days [6–13]	0%
Ho *et al.* (26)	1	10 mm	Left to right approach; *anatomical resection	Five-port technique	270 min	200 mL	Not available	4 days	0%
Liu *et al.* (27)	1	25 mm	Combined left/right approach; *anatomical resection	N/A	300 min	N/A	50 min	N/A	0%
Jin *et al.* (28)	7	49–65mm	Anterior approach; *anatomical resection	Six-port technique	140.8±95.34 min	97.92±90.54 mL	15–21 min	9.17±2.88 days	0%
Xu *et al.* (29)	7	38.7 mm	Left side, right side or combined approach; *anatomical resection	Five-port technique	186.5 min [128.5–219]	75 mL [48.75–200]	14.88 min	6 days [4.75–8]	N/A
Chai *et al.* (30)	4	44.5 mm [27–65]	Arantius ligament suspension; *anatomical resection	Five-port technique	235 min [173–320]	187.5 mL [50–280]	Not available	6.75 days [5–9]	0%

*, when anatomical resection is described. OT, operating time; EBL, estimated blood loss; HPCT, hepatic pedicle clamping time; LOS, length of stay.

Table 4 Article considered for review about robotic resection of posterosuperior segments

Authors	Patients	Tumor size	Technique	Trocars	OT	EBL	HPCT	LOS	Conversion rate
Magistri *et al.* (14)	22 patients	34.06±13.50 mm	Da Vinci—supine position + 20° reverse Trendelenburg; *non anatomical and anatomical resection	4 ports (disposition of the trocars highly depending on patients conformation and lesion localization)	318±113.5 min	400 mL [50–1,500]	1 case (13.3 min)	5.1±2.4 days	0 (0%)
Lim *et al.* (22)	44 patients (5 posterior segments)	42±28 mm	Da Vinci—supine + reverse Trendelenburg; *non anatomical and anatomical resection	4 or 5 ports	252±137 min	N/A	9 cases (34±29 min)	9±14 days	2 (5%)
Patriti *et al.* (31)	1 patient	41±26 mm	Da Vinci—left decubitus position; *non anatomical and anatomical resection	4 abdominal trocars and 1 intercostal trocar	303±132.3 min	376.3±410 mL	75.4±43.2 min	6.7 ± 3 days	0 (0%)
Casciola *et al.* (32)	3 patients	34±18 mm [5–60]	Da Vinci—segment VI-VII-VIII left lateral position; *anatomical resection	5 ports—camera port and left robotic trocars placed at the level of right costal margin + right robotic trocar inserted in the intercostal space between the 10th and the 11th rib along the scapular line	280±101 min [150–420]	245 ± 254 mL [0–1,000]	68.9±31.7 min [40–120]	8.9±9.4 days [3–46]	2/23 (8.6%)
Montalti *et al.* (33)	3 patients (36 RLR)	44.4±30.6 mm [2–110]	Da Vinci—left lateral position; *non anatomical and anatomical	5 ports—camera port and left robotic trocars placed at the level of right costal margin + right robotic trocar inserted in the intercostal space between the 10th and the 11th rib along the scapular line	306±182 min [53–790]	415±414 mL [0–1,500]	76.7±41.3 min [24–166]	6±2.9 days [2–91]	5/36 (13.9%)

Table 4 (*continued*)

Table 4 (*continued*)

Authors	Patients	Tumor size	Technique	Trocars	OT	EBL	HPCT	LOS	Conversion rate
Magistri *et al.* (34)	24 patients	<30 mm	Da Vinci—supine position + 20° reverse Trendelenburg; *non anatomical and anatomical resection [16 wedge resections and 8 segmentectomies]	4 ports [disposition of the trocars highly depending on patients conformation and lesion localization]	200 min [70–380]	230 mL [10–800]	3 cases [total clamping time 32/50/72 min]	4 days [1–18]	0 (0%)
Ong *et al.* (35)	1 patient	30 mm	Da Vinci—left decubitus with flank banding; retroperitoneal approach	5 ports	312 min [115–458]	251 mL [10–650]	N/A	6 days [3–10]	0 (0%)
Khan *et al.* (36)	34 patients (4 posterior segments)	41 mm [7–160]	Da Vinci—supine position; *non anatomical and anatomical resection	4 ports	246 min [114–790]	125 mL [10–2,200]	N/A	4 days [2–91]	3 (8.8%)
Nota *et al.* (37)	12 patients	25 mm [16–31]	Da Vinci; *anatomical and non anatomical	–	198 min [141–381]	180 mL [100–400]	N/A	4 days [3–6]	4 (8%)
Boggi *et al.* (38)	7 patients	42.4 mm [12–50]	Da Vinci—segments VIII or IVa supine position + reverse Trendelenburg; segment VII left flank position + reverse Trendelemburg; *anatomical resection	5 ports—segments VIII or IVa optic port placed along midclavicular line; segment VII optic port placed along anterior axillary line	260.4 min [115–430]	252.7 mL [50–600]	–	8.5 days [7–96]	1 (8.3%)
Chen *et al.* (39)	112 patients (21 posterior segments)	N/A	Da Vinci—supine position + 30° reverse Trendelenburg	5 ports	361 min [102–805]	249 mL [50–2,250]	N/A	7.5 days [2–41]	N/A
Lai *et al.* (40)	100 patients (29 posterior segments)	33±19 mm	Da Vinci—supine position + 20° reverse Trendelenburg; *non anatomical and anatomical resection	5 ports	207.4±77.1 min	334.6 mL [5–3,500]	34.0±15.4 min	7.3±5.3 days	4/100 (4%) conversion to open approach; 1/100 (1%) conversion to hand-assisted approach

*, when anatomical resection is described. OT, operating time; EBL, estimated blood loss; HPCT, hepatic pedicle clamping time; LOS, length of stay; RLR, robotic liver resection.

Table 5 Article considered for review about robotic resection of caudate lobe

Authors	Patients	Tumor size	Technique	Trocars	OT	EBL	HPCT	LOS	Conversion rate
Zhao *et al.* (41)	17 patients	49.29±4.95 mm	Da Vinci—supine position; *anatomical resection	5 ports—in Spiegel lobectomy and in total caudate lobectomy the left-side approach was preferred; in caudate process or paracaval portion resection the right-side approach was preferred	Group-S: 114 min [70–165]; Group-P: 210 min [85–230]; Group-C: 197.5 min [120–330]	Group-S: 50 mL [10–100]; Group-P: 100 mL [50–1,000]; Group-C: 100 mL [20–1,500]	N/A	Group-S: 4 days [2–6]; Group-P: 4 days [3–12]; Group-C: 7.5 days [4–19]	0%
Cañada Trofo Surjan and do Prado Silveira (42)	1 patient	30 mm	Da Vinci—supine position + 18° reverse Trendelenburg; *anatomical resection	5 ports—left-side approach	240 min	40 mL	N/A	3 days	0%
Marino *et al.* (43)	5 patients	26.3 mm [9–30]	Da Vinci—supine position + 25° reverse Trendelenburg; *anatomical partial resection	5 ports—left-side approach	258 min [150–522]	137 mL [50–359]	N/A	7.2 days [4–13]	0%
Lai *et al.* (44)	2 patients	P1: 20 mm; P2: 15 mm	Da Vinci—supine position + reverse Trendelenburg; *anatomical partial resection	5 ports—left-side approach	P1: 137 min; P2: 150 min	P1: 80 mL; P2: 30 mL	N/A	P1: 4 days; P2: 5 days	0%

*, when anatomical resection is described. Group-S: group supine; Group-SP: group semiprone; Group-C: caudate group; P1: first port; P2: second port. OT, operating time; EBL, estimated blood loss; HPCT, hepatic pedicle clamping time; LOS, length of stay.

According to Kawaguchi *et al.* (46), LLR can be stratified based on their difficulty in three categories: the first level, including wedge resections and left lateral sectionectomy; an intermediate level with anterolateral segmentectomy and left hepatectomy; a highly advanced level which includes posterosuperior segmentectomy, right posterior sectionectomy, right hepatectomy, extended right hepatectomy, central hepatectomy, and extended left hepatectomy. First-level procedures are classified as less technically demanding. Furthermore, this classification is closely related to the postoperative outcome. First and intermediate-level procedures are less likely to be associated with severe postoperative complications and are less complicated than advanced-level LLRs.

Many techniques have been described, focusing on the trocar introduction and the patient's position.

Their anatomical disposition and technical issues hinder nodules in segments VII and VIII; the insertion of a port through an intercostal space can provide a better operative field, facilitating the direct lateral approach into the target area (9). The additional intercostal ports can be placed at the 7th and 9th intercostal space, paying attention to the trocars' insertion at the center of the intercostal space, to avoid intercostal vessels bleeding or parenchymal lung injury when the lung is unexpanded. According to Ishizawa *et al.* (8), deflation of the right lung is not necessary. After removing the intercostal trocars, the diaphragm's incisions should be sutured, and any remaining gas should be aspired both from the abdominal cavity and the thoracic cavity. The trans-thoracic approach to the posterosuperior segments is not common, and in literature, only a few reports are available. A lateral approach was used in seven of the ten patients who underwent segmentectomy VII or VIII. A prophylactic chest tube was not required in any patients, and lung injury or postoperative pneumothorax did not occur (10).

The intercostal port can be placed in three different ways based on their relation to the diaphragm: between the ribs below the diaphragm; between the ribs, and through the diaphragm with instrument pressure on the diaphragm imposed from below to push it against the chest wall to ensure that the lung is pushed away and not injured, and finally, ports can be optically inserted between the ribs into the thoracic cavity and then through the diaphragm. The latter technique will require an additional laparoscopic stack but offers a better view.

Postural changes during the LLR procedure have also been reported to have a crucial role in facilitating the resection. Ikeda *et al.* (15) in 2014 evaluated the outcomes of patients undergoing LLR in a semi-prone position compared to the classic supine position, showing less blood loss in the semi-prone group and a shorter hospital stay. The semi-prone position has proved to have some advantages over the supine one, such as an immediate visualization of Rouviere's sulcus after the laparoscope's insertion and, consequently, a good exposition of the right liver and hepatic hilum. After the transection of coronary and triangular ligaments, the liver is naturally mobilized by its weight falling to the left and leaving a space under the right side of the diaphragm. According to the position, all the fluids and blood decline in the abdominal cavity's left side without interferences in the operative field. Moreover, blood loss in the semi-prone position seems to be reduced because the right liver position is higher than the IVC.

Chen *et al.* (9) employed the left jackknife position in LLR of segments VII and VIII: patients were placed on their left side. Then, the lumbar region was elevated by adjusting the operating table to adjust a 120° angle. Ten patients underwent LLR using this position for lesions located in segments VI, VII, or VIII. These postural changes seem to be necessary to perform a posterosuperior resection of liver lesions because of a better view of the operative field obtained not only thanks to the position but also through a correct mobilization of the right liver: the section of triangular and coronary ligaments associated to the patient position allowed the gravity to rotate the liver to the left. An adequate liver exposure can reduce blood loss. On the contrary, compared with the supine position, the semi-prone position or the lateral decubitus may cause an insufficient exposure of the hepatic hilum, making hilar dissection difficult when hepatic inflow blocking is required.

Among the technically demanding resections, the caudate lobe one has still considered a challenge for its tricky exposure. It is adjacent to the IVC, portal vein, and hepatic vein, inducing significant blood loss or high complications after open surgery (28). Tumors originating in the caudate lobe have been managed by combining a hemi-liver with the caudate lobe to simplify the procedure. However, the frequent association of HCC with cirrhosis restricts the extent of major hepatic resections (47).

Laparoscopic resection of the caudate lobe

The caudate lobe generally includes three parts, the Spiegel's lobe on the left corresponding to Couinaud's segment I, the paracaval portion on the right (Couinaud's segment IX), and the caudate process. A fibrous ligament

surrounding the IVC to join segment VII usually occurs along the caudate lobe's posterior wall. Sometimes, this ligament could be replaced by hepatic parenchyma embracing the IVC completely and adding further difficulty to the caudate resection (48,49). Generally, the arterial supply to the caudate lobe derives from the left hepatic artery and, portal vascularization derives from the left portal branch. Venous drainage occurs directly into the IVC through multiple small branches of variable size, number, and location. Biliary drainage includes small tributaries to both sides, mainly directed to the left hepatic duct (50). Considering all these intricate anatomical landmarks, intra-operative ultrasound (IOUS) should be used during the procedure to enable a radical laparoscopic resection, providing a precise evaluation of tumor location and the adjacent vascular structures.

Three approaches have been described in the caudate resection: the left-sided approach, the right-sided approach, and the anterior trans-hepatic approach. In the first technique, the left lobe is mobilized, turned to the right, and progressively, all the short hepatic veins (SHVs) from the caudate lobe to the IVC are divided caudate lobe could be lifted off the IVC and become more mobile. Parenchymal dissection separates the caudate lobe from the liver's right lobe. This part of the procedure could be the most difficult since there is no definite distinction between the two parts. A right-sided approach could be appropriate and undertaken in all cases. The mobilization from the left side is difficult, for example, in tumors located in the paracaval portion of the caudate lobe or bulky tumors. In the right-sided approach, the right liver is mobilized from the diaphragm until it reaches the IVC's lateral surface in the right-sided approach. Dissection should be continued in the plane between the IVC's anterior and posterior surface of the caudate lobe, dividing all the retro hepatic veins originating from the caudate lobe from the paracaval portion and extending superiorly until the hepatic vein. Finally, in the anterior trans-hepatic approach, the caudate lobe is reached through the split of liver parenchyma anteriorly along the median fissure. This approach's main advantage is that it allows a good view and the access to perform a complete caudate lobe resection, but it could take a long OT and increase blood loss. One of the critical points in the caudate lobe resection is dividing all the small branches from the caudate lobe to the IVC; a good exposure of the retro-hepatic tunnel is therefore mandatory. Laparoscopy allows the view of the surgical field from the caudal to the cranial side, providing excellent access to the retro-hepatic tunnel along the IVC and improving precise dissection and efficient hemostasis (51).

The left-sided laparoscopic approach is suitable in the case of lesions of the Spiegel lobe or lesions with a diameter of <3 cm; the right-sided laparoscopic approach is mainly suitable for the paracaval lesions and the caudate process; the anterior approach or the combination between the left- and right-sided laparoscopic approaches are suggested in lesions involving the whole caudate lobe (28). Some authors prefer the anterior approach for a lesion with a diameter >4 cm since this technique not providing the hepatic rotation can prevent hepatic veins rupture (52,53).

In addition to the difficulties related to the exposure, hemostasis control is fundamental in caudate lobe resection. This procedure is made harsh by caudate vascularization, which doesn't consist of a single pedicle. Moreover, the venous branches of the caudate lobe are usually conformed into the IVC in the form of the SHV, in number variable from 2 to 4, featured by a thin vascular wall, short trunk, and a deep location (54). This anatomical conformation shows how important it is a good exposure of the operating field to establish a safe passage between all the SHVs, the superior hepatic veins, and the IVC (55,56).

Robotic resection

Robotic surgery was introduced in medicine nearly two decades ago. The main innovation was overpassing the laparoscopic instruments (such as image amplification, two-dimensional view, essential tremor, fulcrum effect, limited freedom of movement and ergonomics) and providing a better view of the surgical field. The popularity of RLR has increased since Giulianotti (57) published the first report of robotic liver surgery in 2003. According to the Italian Group of Minimally Invasive Liver Surgery (IgoMILS), HCC represents 56% of indications to minimally invasive liver resection for liver malignancies (58).

The Da Vinci® station is the most used equipment for this kind of surgery. Its three-dimensional view camera allows a better sense of depth; the most important feature of the robot is that it is capable of more movements than the human hand is naturally capable of (59). Despite all these advantages, robotic-assisted hepatectomy and liver resection have evolved slowly over the years, mainly because of the robot's costs and the learning-curve.

Melstrom *et al.* (60) divided the liver resections into three categories: (I) major hepatectomy, (II) minor hepatectomy for segments 3, 4b, 5, 6, and (III) minor hepatectomy for

segments 1, 2, 4a, 7 and 8. For resections belonging to categories II and III, the minimally invasive approach can hasten and improve postoperative recovery. The robotic approach might benefit from the laparoscopic approach in treating lesions of category III due to higher instrument dexterity. Melstrom mainly focused on selecting patients to be submitted to RLR, analyzing the cost-effectiveness of this approach and the real postoperative benefits. For instance, the robotic instruments and the 3D optics are handy to approach anatomically "remote" areas of the liver (segments VII, VIII, IVa, and I).

Consequently, the robotic minimally invasive surgery (MIS) approach is ideal for tumors in these regions, achieving fewer complication rates and very short hospital stays than open surgery. Moreover, this article highlighted the indication of minimally invasive liver resection: small tumors under challenging locations that would otherwise require a large incision for removal in an open approach. As the surgical trauma is the least, the access trauma rather than liver regeneration's physiology dominates the postoperative recovery (61).

Many authors discussed the advantages of robotic-assisted liver resection for HCC. In a study by Magistri *et al.* (14), a comparison between robotic and LLR demonstrated a robotic approach's superiority with minor postoperative complications rates, balancing the high costs derived from the investment on robot purchase and the learning curve with a shorter postoperative hospital stay. Operative time was longer than in conventional LLR because of the docking time and the initial robotic surgery experience. The non-systematic review published by Rodrigues *et al.* (62) showed that robotic assistance could overcome many limitations that laparoscopic surgery presents. However, robotic hepatectomy still hasn't spread worldwide due to the high cost and different learning levels required. Moreover, hospital stay, morbidity, and EBL are similar between laparoscopic and robotic resection. Patriti *et al.* (31) investigated the robotic approach's role for right posterior resection compared with open surgery, observing that both techniques are equally safe and feasible, without differences in overall postoperative morbidity contributing to short patient hospitalizations.

Compared to conventional laparoscopy, the robotic platform's significant advantage is the technology itself, which adds value when precise vessel dissection or major suturing is needed (63,64). Robotic systems provide the surgeon with a full range of motion, with a global range of movements within the abdomen similar to open surgery and the ergonomic advantage, especially when angulated or curved lines of the section are needed parenchyma-sparing principle could be performed (65).

All liver segments can be resected with a minimally invasive approach and, the first size limitation described in the Consensus Conference and the Guidelines (1,4) has been overpassed (66). According to these results, size and locations are no more a contraindication for HCC resection. Moreover, the minimally invasive approach is a protective factor for salvage liver transplantation, allowing better survival than an open approach (67). Besides all the considerations regarding the surgical technique, Aldrighetti *et al.* (58) highlight that the three main causes of conversion to open technique is intraoperative bleeding (34.4%), concerns for oncological radicality (26.1%), and technical difficulties (23.8%). Still, the purpose of reaching oncological radicality is the only statistically significant reason (P value =0.02) for conversion in surgeons who fully completed their learning curve.

This study's main limitation is the access to new techniques and only retrospective data available in the literature; however, publication bias and selection bias could be present in this analysis. Because the articles selected are all retrospective analyses of prospective data, this review is not designed to prove the superiority of laparoscopic or robotic approach, but we intend to demonstrate that both robotic and laparoscopic approaches are a feasible and valid option also in technically demanding liver segments resections, including extremely fragile patients such as the cirrhotic ones. Thus, a prospective randomized trial is ideally needed to investigate which technique may be the best.

Conclusions

LLR and RLR for HCC can be safely achieved in all segments with the outcomes of open surgery. Each technique has specific advantages, besides those familiar to minimally invasive surgeries and rapid recovery patients. In the case of a minimally invasive resection of a lesion located in an unfavorable segment, the surgeon's experience is fundamental. It is necessary to gradually increase the skills of laparoscopic or robotic surgery according to the experience level before performing technically demanding procedures. When the oncological radicality is not achieved, a conversion to an open approach is still essential.

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Footnote

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