Knowledge and surgical strategies for successful laparoscopic caudate lobectomy: a narrative review

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Background and Objective: Laparoscopic approach in patients presenting with caudate lobe lesions has always been considered prohibitive as technically demanding so that the role of minimally invasive surgery for this posterior and deep location is still debated. However, recently some studies presented cases of laparoscopic caudate lobectomy (LCL) discussing how to manage technical challenges and providing excellent results. For this reason, we conducted a comprehensive review of the literature to understand the safety and feasibility of LCL and discuss current and future perspectives.

Methods: Electronic databases were consulted to conduct a literature search including PubMed, Web of Science, and Cochrane; all articles published in English from 1st January 2006 until 31st November 2021 were included.

Key Content and Findings: Four hundred forty-seven articles were identified, duplicates (n=102), articles not published in English (n=33), and those of apparent irrelevance (n=220), review and editorials articles (n=17), articles including a duplication report from the same institution or author (n=22) and articles including extended procedures (n=24) were excluded. Thus, we finally selected 29 articles about laparoscopic caudate lobe resection.

Conclusions: It can be stated that the laparoscopic approach to the caudate lobe is not near future anymore but instead represents the current reality when considered by high-expertise surgeons working in high-volume hepatobiliary centres. However, since the lack of high-quality evidence and the scarcity of cases, prospective clinical trials, and multi-centre randomised controlled trials are needed to standardize this technique.

Keywords: Hepato-pancreato-biliary surgery; minimally invasive surgery; liver surgery; caudate lobe; caudate lobectomy

Introduction

In the last years, many reports have demonstrated the feasibility and safety of laparoscopic liver resections (LLRs), which have been adopted in many centres worldwide, providing excellent short- and long-term results comparable to open liver resections (1,2).

Consequently, indications for LLRs have increased, including a wide variety of benign and malignant lesions. Nonetheless, the posterosuperior segments (I, IVa, VII, VIII) are still considered technically difficult locations, requiring expertise and advanced technical skills (3,4).

Caudate lobe (CL) (Couinaud segment I or Spiegel's lobe) is also called dorsal liver and is located posteriorly, below the hepatic hilum, very close to the ductal and portal bifurcation and the hepatic arteries and above the inferior vena cava (IVC). A laparoscopic caudate lobectomy (LCL) can be associated with resection of other segments for oncological reasons, such as right or left hemi-hepatectomy for Klatskin's tumours. In addition, isolated laparoscopic caudate lobectomy (iLCL) is indicated for some symptomatic benign or malignant (primary or secondary) lesions arising in segment I. Some reports address the results of posterosuperior LLRs compared with the anterolateral ones, but few papers are exclusively focused on iLCL, which accounted for only 2.9% of 102 LLRs enrolled in a prospective Japanese registry (5,6). iLCL has been described in some case series and case reports from single institutions; however, a real standardization of the laparoscopic approach to the dorsal liver, with an appraisal of the technical skills and technology needed, is still lacking (7-12). Furthermore, precise understanding of segment I surgical anatomy and detailed description of the right border of the caudate process is crucial in the definition of an actual "anatomical resection of the caudate lobe". As a result, we present this narrative review of the literature of the last fifteen years, analysing the best surgical strategies for a successful laparoscopic caudate lobe resection in accordance with the Narrative Review reporting checklist (available at https://dmr.amegroups.com/article/view/10.21037/dmr-22-2/rc).

Methods

An electronic literature search of the PubMed, Web of Science, and Cochrane databases was performed using the Boolean operators AND, OR, NOT for the combination of keywords: "Laparoscopic", "Hepatectomy", "Liver resection", "Caudate lobe", or "Segment1". All articles published from 1st January 2006 until 31st November 2021 were included. All English language articles related to LLRs were analysed. The references of selected papers were also screened to identify additional publications that might not have been retrieved from the database search. Duplicated data and review articles without original series were excluded. When the results of a single study were reported in more than one publication, only the most recent and complete data were included. *Table 1* summarises the search strategy.

Results

Four hundred forty-seven articles were identified, duplicates (n=102), articles not published in English (n=33), and those of apparent irrelevance (n=220) were excluded, leaving 92 articles. Out of these 92, we excluded review and editorials articles (n=17), articles including a duplication report from the same institution or author (n=22), and articles including extended procedures, other than resection in the posterosuperior segments (n=24). Thus, we finally selected 29 articles about laparoscopic caudate lobe resection. *Figure 1* shows the flowchart of the literature search.

Concepts of embryology

In order to understand the surgical anatomy of the liver, we should consider that the caudate lobe and the retro-hepatic vena cava develop as a joint entity that is separate from the remaining liver. The dorsal vein, from which the future caudate develops, becomes the portion of inferior vena cava (IVC) between the renal veins and joins the hepato-cardiac channel containing the supra-hepatic veins. The hepatic venous branches to the caudate drain directly into the vena cava, and a few short branches connect the caudate to the main hepatic veins.

Consequently, segment I should be considered a "peculiar entity" that is embryologically separate from the rest of the liver (13). This intimate connection with the IVC and other important vascular structures, such as the portal bifurcation and the hepatic veins, can explain why the laparoscopic approach to the caudate lobe is still not widely adopted.

History, surgical anatomy and the myth of segment IX

In 1966, Couinaud defined the modern segmental anatomy of the liver, with the Spiegel lobe designated as an

Table 1 The search strategy summary

Items	Specification
Date of search	December 1, 2021
Databases and other sources searched	PubMed, Web of Science and Cochrane databases
Search terms used	"Laparoscopic", "Hepatectomy", "Liver resection", "Caudate lobe", "Segment1"
Timeframe	From 1st January 2006 until 31st November 2021
Inclusion and exclusion criteria	Inclusion criteria:
	English-language article;
	Article types were case-report, case-series and any study including original series
	Exclusion criteria:
	Duplicated data;
	Non-English language articles;
	Editorial or review articles without original series;
	Articles including extended procedures other than caudate lobe resection
Selection process	Two independent authors searched for papers
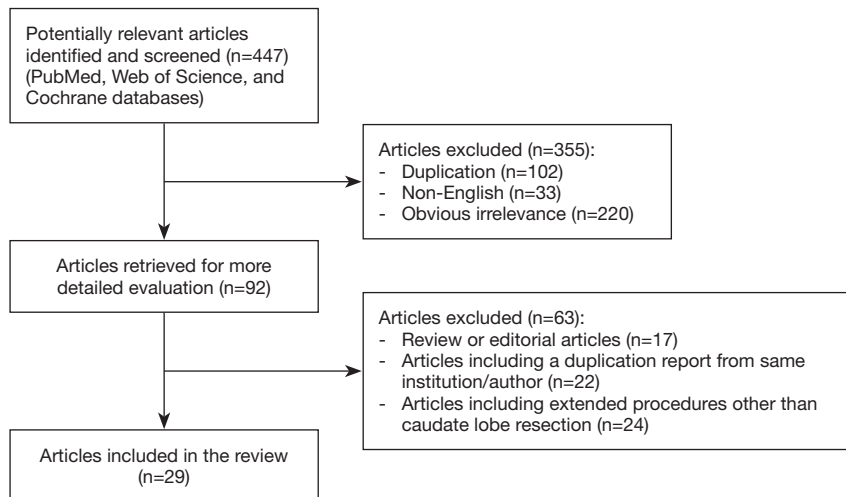
Figure 1 Study selection flow chart according to the PRISMA statement.

independent hepatic segment, named as the dorsal sector, caudate lobe, or Couinaud segment I (14). The caudate lobe lies below the hepatic hilum, very close to the ductal and portal bifurcation, and the hepatic arteries above the inferior vena cava.
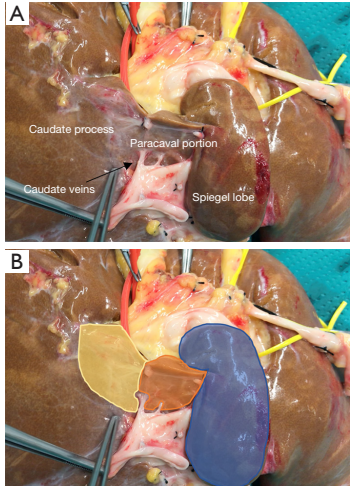
According to the most relevant studies published from 1953 to 2000, the caudate lobe can be divided into three main parts or subsegments (*Table 2*). Kumon's description, which includes the left or Spiegel lobe, the medial pericaval portion, and the right portion or caudate process, is the most adopted terminology.

The first and more easily visible portion of the segment I at laparoscopic exploration is the proper Spiegel lobe, which can be seen to the left of the IVC through the hepato-gastric ligament, protruding from Arantius sulcus, also called the papillary process by Kogure (23).

The birth of the "segment IX" myth is because Couinaud and Filliponi proposed that the part of the caudate lobe to

Table 2 Description of caudate lobe subsegments

Author/year	Caudate lobe subsegments		
	Right	Medial	Left
Healey and Schroy, 1953 (15)	Segment Ir	Segment Ir	Segment II
Couinaud, 1981 (16)	Caudate lobe, segment I	Caudate lobe, segment I	Caudate lobe, segment I
Kumon et al., 1985 (17)	Caudate process	Paracaval portion	Spiegel lobe
Elias et al., 1992 (18)	Caudate process	Central part	Left part, spiegel lobe
Couinaud, 1994 (19)	Segment IX b/c	Segment IX d	Segment I
Couinaud, 1999 (20)	Subsegment RDSb	Subsegment RDSb	Left dorsal sector
Filipponi et al., 2000 (21)	Segment IX right	Segment IX left	Segment I
Kogure et al., 2000 (22)	Caudate process	Paracaval portion	Spiegel lobe, papillary process

RDS, right dorsal sector.

Figure 2 Portal supply of the paracaval portion of caudate lobe.

the right of the middle hepatic vein might be a separate segment: segment IX (19,21). However, further analysis of liver casts showed that the proposed border between pericaval portion of segment I and the postulated segment IX is crossed by overlapping portal pedicles. Given that any portal pedicle should not cross a portal fissure, the same authors propose that the entire dorsal liver be considered a single portal segment with three subsegments: the Spiegel lobe pericaval portion and caudate process. So, we believe that the existence of the so-called segment IX is just a myth.

An average of three (one to six) portal branches supplies the entire caudate and may arise from the left, right, bifurcation, or a combination of the portal branches. For example, a portal branch feeding the paracaval portion of

the caudate lobe is shown in *Figure 2*.

The caudate lobe arteries are multiple small branches arising both from the left and right hepatic artery in about half of individuals, whereas in the rest of the patients, a dominant vascularization from left or right can be observed. Venous drainage of the segment I is provided by one or two thick veins (2 to 3 mm in diameter), usually called the "caudate veins" (*Table 2*, Image A) and several thin veins. The thicker veins enter the IVC, the thinner drain into the IVC or the middle and/or right hepatic vein. This network of hepatic veins forms an anastomotic arcade between the main hepatic veins and vena cava, thus providing venous drainage of the dorsal liver even in case of pathologic thrombosis, also called Budd-Chiari Syndrome. Approximately half of the 2 to 4 ducts from the CL join the right posterior sectorial originating from S6 and S7. The other ducts drain into the left hepatic duct (24).

Caudate lobe resection in consensus conferences, guidelines and difficulty score systems

First Consensus Conference on LLS (Louisville, USA, 2008) stated that the most favourable indications for the laparoscopic resection were a solitary lesion, 5 cm or less, located in peripheral liver segments 2 to 6. In contrast, lesions located in posterior segments (1, 7, and 8) were not

universally accepted as the standard of care (1). No specific recommendations about LCL are included in the Second International Consensus Conference (Morioka, Japan, 2014). Nonetheless, it was agreed that the difficulty of the LLR is determined, among others, by the "tumour location and the proximity to major vessels" (2). During the same Conference, the IWATE difficulty scoring system, which is further discussed, was developed.

The European Guidelines Meeting on Laparoscopic Liver Surgery (Southampton, UK, 2017) included segment I among the so-called "difficult segments" (1, 4a, 7, and 8). The expert panel acknowledged that resections of these segments, especially when anatomical, are "highly complex and require advanced expertise in LLR (25). A new definition of "technically major resection" was applied to LCLs by Halls in 2018. He stated that, even though posterosuperior segments resections would be considered minor (involving only 1 or 2 Couinaud segments), they involve areas of the liver with difficult laparoscopic access (26).

Surprisingly, a formal LCL was not even included in Ban's novel difficulty scoring system for LLR published in 2014 (27). All the same, the author attributed an additional score of 1 to lesions located in the proximity of major vessels (primary or second branches of Glisson's tree, major hepatic veins, and IVC). The original Ban's difficulty scoring system, lacking segment 1 in the tumour location category, had other limitations, such as no separation between segments 4a and 4b and no category for hand-assisted laparoscopic surgery. Because of these limitations, this score was then revised at the Morioka Consensus Conference and renamed the IWATE criteria (an index-based, 4-level classification system) incorporating the difficulty of Segment 1 resection (score 4) (28). Lately, in 2018, Kawaguchi proposed a new difficulty classification of LLR. In this paper, the LCL is included, among other procedures, on posterosuperior segments, in group III, representing the highly advanced level of difficulty.

Laparoscopic approach to caudate lobe resection

LCL has been described in multicentre cohort studies, case series, and case reports, and our review reports a total of 265 patients (*Table 3*).

Laparoscopic resections of lesions located on the segment I were shown to be feasible but remain technically demanding procedures that should be performed by experienced laparoscopic hepatic surgeons.

The main indication for CLC included in our review was HCC (38.5%), followed by benign diseases such as hepatolithiasis, focal nodular hyperplasia (FNH) or adenomas (32.4%); or malignancies like colorectal liver metastasis (CRLM) (20.1%), unspecified tumours (7.5%) and cholangiocarcinoma (1.5%) (*Figure 3*).

It is well recognized that tumor size is a risk factor for conversion and blood loss in LLR. The 2008 Louisville statement recommended that tumours larger than 5 cm in diameter were not candidates for LLR (51). Several reports provided data on the laparoscopic approach for more extensive lesions in recent years despite this recommendation. There is no agreement in the literature on the maximal tumour dimension suitable for laparoscopic caudate resection. In patients considered in our review, the median size of lesions ranged between 12 and 60 mm. Moreover, the possibility of invasion of important structures should be considered in Segment I, especially regarding the paracaval portion (46).

No limitations have been described according to the location of the lesions inside the caudate lobe (caudate process, Spiegel's lobe, and paracaval portion). Usually, partial resections are well accepted for benign lesions, or CRLM, while for malignancies such as HCC or cholangiocarcinoma, a proper anatomical caudate lobectomy is advocated.

The laparoscopic approach combined with a reverse Trendelenburg position offers a "caudal access" that could provide a better view of liver parenchyma in a narrow surgical field.

As stated by Cappelle *et al.*, LCL is safe and feasible when performed in high-volume centres. However, profound anatomical knowledge, advanced laparoscopic skills, and mastering intraoperative ultrasound are essential (29).

A wide range in operative time and blood loss has been observed among all studies taken into consideration, more likely relating to centre and surgeon experience. No outlying value has been observed, and all of them can be considered belonging to an acceptable range of values for hepatic resections.

Conversion to laparotomy has been reported in seven patients, representing 2.6% of the patients included in this review. One conversion was performed because of difficult localization and enhanced bleeding risk, three for technical difficulties, three for active bleeding (one from the IVC).

The oncological radicality achievement was reported in twenty studies, and positive resection margins were observed in 14 patients (7.7%). For what concerns oncological

Table 3 Published case series of iLCL

Ref.	Number of patients	Indications	Subsegment of caudate lobe resected	Median lesion size (mm)	Blood loss (mL)	Median operation time (min)	Morbidity rate	Complications (general and liver specific)	Laparotomy conversion	Days of hospitalization	Oncological outcome
Araki et al. (6)	15	HCC, metastases, benign	CP, SL, PC	19.5	75	150	6.6%	BS, bleeding (massive from major vessels)	0	8	R0
Dulucq et al. (7)	2	2 CRLM	–	–	150	127	–	–	0	9	R0
Koffron et al. (8)	7	HCC, benign	–	–	–	–	–	–	0	–	–
Chen et al. (9)	8	4 HCC, 4 metastases	CP, SL, PC	–	110	248	–	–	0	6.9	R0
Lai and Tang (10)	2	2 HCC	–	15	143	143	–	–	0	4.5	R0
Salloum et al. (11)	5	4 HCC, 1 benign	CP, SL, PC	35	200	240	–	–	0	6	R0
Oh et al. (12)	6	4 HCC, 1 CC, 1 metastases	CP, SL, PC	26.5	242.5	382	–	–	0	8	R0
Cappelle et al. (29)	32	22 CRLM, 1 CC, 4 unspecified malign lesion, 5 benign	SL, PC, SL	22	100	155	6.3%	1 bleeding, 1 LI	9.4%	3	66.6% (R0); 33.3% (R1)
Chai et al. (30)	6	CC, HCC	–	54	260	249	–	1 surgical site infection, 1 pleural effusion	0	7	–
Hayami et al. (31)	6	HCC, CRCM	–	18.3	35	207	–	–	0	8	R0
Ho et al. (32)	1	HCC	–	16	200	270	–	–	0	4	R0
Jin et al. (33)	12	CH, HCC, FNH	CP	55	97	140	–	–	0	9.2	–
Koh et al. (34)	6	HCC, CRLM	–	30	217	318	–	–	0	4	R0
Li et al. (35)	11	MT, HCC, FNH	–	33	133	226	–	–	0	6	R0
Liu et al. (36)	1	HCC	PC	25	–	300	–	–	0	–	–
Machado et al. (37)	1	CRLM	–	–	<50	120	–	–	0	3	R0
Siming et al. (38)	9	HL	–	–	530	310	–	1 bleeding	0	10	–
Vega et al. (39)	1	HCC	SL	36	–	–	–	–	0	–	R0
Wan et al. (40)	1	CC	–	42	180	300	–	–	0	7	R0
Xiang et al. (41)	1	HCC	SL	–	<50	196	–	–	0	6	–
Xu et al. (42)	19	CH, FNH, AD, HCC, CRLM	CL, SL, PC	11.9	75	186.5	–	–	0	6	R0
Ding et al. (43)	10	5 HCC, 5 benign	10 CL	60	50	216	–	–	–	15	–

Table 3 (*continued*)

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Ref.	Number of patients	Indications	Subsegment of caudate lobe resected	Median lesion size (mm)	Blood loss (mL)	Median operation time (min)	Morbidity rate	Complications (general and liver specific)	Laparotomy conversion	Days of hospitalization	Oncological outcome
Peng et al. (44)	31	10 HCC, 4 CRLM, 17 benign	5 SL, 1 SL + PC, 4 PL + PC, 1 SL + PL + PC, 20 tumorectomy	40	100	210	5 16.1%	1 infectious diarrhoea, LI, 2 ascites	23.2%	5	–
Parikh et al. (45)	12	11 HCC, 1 CRLM	CL	20	250	204.5	16.7%	1 bleeding, 1 pleural effusion	0	4	R0
Ruzzenente et al. (46)	42	11 CRLM, 16 HCC, 3 NCRLM, 12 benign	16 HCC, CL, SL, PC	35.7	173	298	14.28%	1 abdominal collection, 1 cardiological, 1 pleural effusion, 3 unknown	7.1%	4.7	13.3% (R1)
Sun et al. (47)	15	5 hemangioma, 4 HCC, 4 FNH, 1 hepatolithiasis, 1 angiomyolipoma	CL, SL, PC	56	400	305	40%	–	0	9	R0
Furukawa et al. (48)	1	CC	CL	10	400	264	–	–	0	9	–
Yasuda et al. (49)	1	HCC	CL	11	10	229	–	–	0	8	R0
Tur-Martinez et al. (50)	1	Hepatocellular adenoma	CL	18	100	120	–	–	0	3	R0

iLCL, isolated laparoscopic caudate lobectomy; HCC, hepatocellular carcinoma; CC, cholangiocarcinoma; BD, benign disease; CRCM, colo-rectal cancer metastases; CH, cavernous hemangioma; FNH, focal nodular hyperplasia; MT, mesenchymal tumours; HL, hepatolithiasis; AD, adenoma; CP, caudate process; SL, Spiegel's lobe; PC, pericaval portion; BL, biliary leakage; BS, biliary stenosis; BL, bleeding; LI, liver insufficiency.
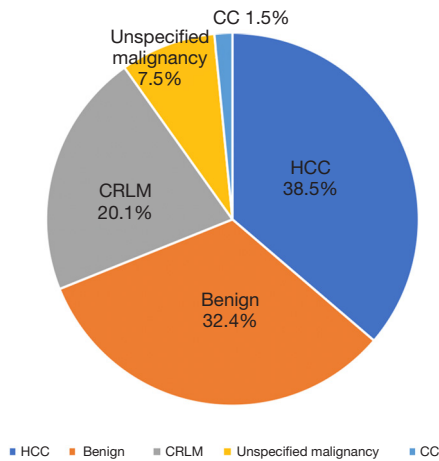
Figure 3 Surgical indications for caudate lobe resection. HCC, hepatocellular carcinoma; CRLM, colorectal liver metastasis; CC, cholangiocarcinoma.

radicality, as considered in the multicentre retrospective study by Cappelle *et al.*, a negative surgical margin, i.e., 1 mm, is still considered the standard (29). However, in high-volume hepatobiliary units, the occurrence of R1 resection in open caudate lobe resection is reported up to 25% (15). Further studies with long-term follow-up are needed to evaluate differences between the open and laparoscopic approaches in terms of negative margin, disease-free survival, and survival rate.

The morbidity rate reported in the studies included in our review was 6.8% (18/265), and no mortality was recorded. Complications reported were: four bleedings, three liver insufficiencies, two ascites, three pleural effusion, one biliary stenosis, one abdominal collection, one surgical site infection, one cardiological complication, one infective diarrhoea and three unknowns. The results are comparable to the complication rate that occurred in open procedures, according to a metanalysis by Ding *et al.* (22).

The median length of hospital stay of patients included in this systematic review was six days, ranging between 3 and 15 days of hospitalization, showing a postoperative recovery in line with other laparoscopic hepatic procedures and shorter than the open approach (52).

Operative techniques and features

LCL operative techniques and features have been described in multicentre cohort studies, case series, and case reports (*Table 4*). All the analysed cases have been

Table 4 Technical and operating features of the published case series of iLCL

Ref.	Number of patients	Operative setting	Patient position	Trocars	CVP intraoperative management	Pringle manoeuvre	Energy devices
Araki et al. (6)	15	Lps	–	–	–	–	Harmonic and Thunderbeat
Dulucq et al. (7)	2	Lps	Supine with split legs	6 trocars	Yes (5 mmHg)	Yes	Ligasure and DISSECTRON
Koffron et al. (8)	7	Lps	Supine	–	Yes	–	Ligasure
Chen et al. (9)	8	Lps	Modified lithotomy position	4 or 5 trocars	–	–	Harmonic
Lai and Tang (10)	2	Lps (robot-assisted)	Supine with split legs and reverse Trendelenburg	5 trocars	Yes (<5 mmHg)	–	–
Salloum et al. (11)	5	Lps	Supine with split legs and reverse Trendelenburg	6 trocars	Yes (<5 mmHg)	Yes	Ligasure and DISSECTRON
Oh et al. (12)	6	Lps	Modified lithotomy position	5 trocars	–	–	–
Cappelle et al. (29)	32	Lps	Supine in 30° reverse Trendelenburg	4 or 5 trocars	Yes	Yes	ENSEAL and CUSA
Chai et al. (30)	6	Lps	Supine with closed legs	5 trocars	–	Yes	–

Table 4 (*continued*)

Table 4 (*continued*)

Ref.	Number of patients	Operative setting	Patient position	Trocars	CVP intraoperative management	Pringle manoeuvre	Energy devices
Hayami et al. (31)	6	Lps	Supine with open legs in 15° reverse Trendelenburg	5 trocars	–	Yes	Harmonic ACE and CUSA
Ho et al. (32)	1	Lps	Lithotomy position	5 trocars	–	–	Harmonic, Ligasure and CUSA
Jin et al. (33)	12	Lps	Supine in 30° reverse	6 trocars	–	Yes	–
Koh et al. (34)	6	Lps	Supine with split legs	5 trocars	Yes (5 mmHg)	Yes	CUSA
Li et al. (35)	11	Lps	Supine	5 trocars	Yes (<5 mmHg)	Yes	Harmonic
Liu et al. (36)	1	Lps	Supine	–	–	Yes	Harmonic, Ligasure and CUSA
Machado et al. (37)	1	Lps	–	4 trocars	–	–	Bipolar
Siming et al. (38)	9	Lps	Supine with split legs	5 trocars	–	–	–
Vega et al. (39)	1	Lps	Supine with split legs	–	Yes	–	–
Wan et al. (40)	1	Lps	Supine with split legs	5 trocars	Yes (<5 mmHg)	Yes	Harmonic, ACE and CUSA
Xiang et al. (41)	1	Lps	Supine with split legs	5 trocars	Yes	–	–
Xu et al. (42)	19	Lps	Supine with split legs	5 trocars	Yes (<5 mmHg)	Yes	CUSA
Ding et al. (43)	10	Lps	Supine with split legs	5 trocars	Yes (between 4–6 mmHg)	Yes	Ultrasonic scalpel
Peng et al. (44)	31	Lps	Supine	5 trocars	Yes (<5 mmHg)	Yes	Harmonic, Ligasure and CUSA
Parikh et al. (45)	12	Lps	Supine	5 trocars	–	–	Harmonic, Ligasure and CUSA
Ruzzenente et al. (46)	42	Lps	Supine	4 trocars	–	Yes	–
Sun et al. (47)	15	Lps	Supine with split legs	5 trocars	Yes (between 3–5 mmHg)	Yes	Ultrasonic scalpel
Furukawa et al. (48)	1	Lps	Supine	–	–	–	Ultrasonic scalpel
Yasuda et al. (49)	1	Lps	Supine	–	–	Yes	Harmonic, CUSA
Tur-Martínez et al. (50)	1	Lps	Supine with split legs	5 trocars	–	Yes	Ligasure

iLCL, isolated laparoscopic caudate lobectomy; CVP, central venous pressure; Lps, laparoscopic; CUSA, cavitron ultrasonic surgical aspirator.

carried out laparoscopically. The most used position of the patient was supine with reverse Trendelenburg with an inclination ranging from 15% to 30%. The exceptions were represented by Ho *et al.*, who suggest a lithotomic position for the patient, and Cappelle *et al.*, who reported using left lateral position in 2 cases in their multicentre study (29,32). The number of trocars needed ranged between four and six, with the first one placed periumbilically in most cases and still not a standardized position of accessory trocars still placed according to surgeon's preference.

Pringle manoeuvre has been applied for better bleeding control during transection of the hepatic parenchyma in most centres (19/31). Notably, encircling the hepatic pedicle also allows better exposition of the operative field by retracting the hepatic hilum to the right or left side depending on the caudate lobe portion to be addressed.

Both left or right approaches are described sharing the same operative steps that can be summarized in caudate lobe exposure; inflow control by clipping/ligating and dividing the portal triad (Arantius plate dissection is crucial on the left side); outflow control by clipping/ligating and dividing the caudate veins draining into IVC (this goal is obtained lifting the caudate lobe and exploiting the laparoscopic caudal view); parenchymal transection. The intra-Glissonean approach to caudate lobe pedicles was the most frequently adopted in almost all the studies included in this review. However, we found a couple of reports describing the extrahepatic Glissonean approach in laparoscopic caudate lobe resection. Cai *et al.* (30) dissected and divided caudate portal triads one at a time in their series of 11 cases. In contrast, a laparoscopic anatomic Spiegel lobectomy using a detailed extrahepatic Glissonean approach (with an edited video) has been reported by Xiang *et al.* (41).

From the technical point of view, it is still controversial whether to isolate and control the main vascular structures (as the left suprahepatic vein) extrahepatically.

Laparoscopic selective clamping of blood supply for visualization of ischemia demarcation line can also be used in anatomical resection of segment I (51).

IOUS has been used for lesion localization, outline major vessel proximity, and resection guidance in almost all reviewed cases.

Surgical instruments for laparoscopic surgery have advanced remarkably in recent years, resulting in safer procedures for LLR, even for resection of lesions in difficult segments.

Innovative technologies applied to resections of difficult hepatic segments include pre-operative 3-D CT-scan reconstructions, ICG green demarcation, and the use of 3-D laparoscopic equipment. In addition, real-time virtual sonography during liver surgery has been reported recently. This new imaging technology detects the spatial position of an ultrasound probe and reconstructs a section of computed tomography and/or magnetic resonance images in accordance with the ultrasound image (52).

The energy devices used in all series included ultrasonic dissector, radiofrequency, bipolar energy. All used advanced dissectors are listed in *Table 3*.

Not everyone opted for intraoperative central venous pressure (CVP) monitoring. Nonetheless, many reports have shown that reduction of cardiac preload leads to a decrease in hepatic vein congestion and reduction of intraoperative blood loss (52-54). Historically central venous pressure was used to evaluate cardiac preload (54). More recently, in the era of mini-invasive surgery, stroke volume variation has been reported as a non-invasive approach to guide fluid management. This approach improves intraoperative outcomes in laparoscopic liver surgery, thus enhancing the benefits of the minimally-invasive approach and fast-track protocols (55).

The site of specimen extraction was either through a trocar enlargement, previous incision, and Pfannenstiel incision. The majority of studies reported the use of one of the previous incisions without specifying the site of extraction used and according to the patient's characteristics and surgeon attitude.

Final considerations

Patients presenting primary hepatic tumours or metastases in the caudate lobe can easily lose the possibility of radical oncological resection because of the easy and early possibility of the inferior vena cava infiltration. Thus, it is crucial to offer them a laparoscopic approach as one of the possible operative techniques. LCL requires a deep anatomic knowledge of the caudate lobe and advanced technical expertise.

As stated by Xu *et al.*, for caudate lobectomy, the laparoscopic technique is a double-edged sword (42). On the one hand, LCL resection can minimize blood loss, decrease post-operative pain and reduce the length of the hospital stay, but on the other hand, the patient can face the risk of massive intra-operative bleeding and a positive tumour margin. As a result, strict patient selection and experienced surgeons who specialize in both open liver surgery and laparoscopic surgery are needed during this

procedure.

A multicenter, propensity score-matched analysis of safety, feasibility, and early outcomes in LCL resection performed in eighteen patients reported that the laparoscopic approach is a feasible choice for resection of lesions located in segment one with acceptable outcome (42).

A multi-institutional propensity score-matched cohort study evaluated the safety and feasibility of LCL in the Italian prospective maintained database on minimally invasive liver surgery (IgoMILS) by comparison with a cohort of patients submitted to open CL resections. LCL compared to open CL had lower intraoperative blood loss, reduced use of abdominal drainage and lower comprehensive complication index (CCI) (45).

Chai *et al.* affirmed that compared with open surgery, the laparoscopic approach could offer a unique viewing angle from below, and the superior magnification and illumination could further increase the visibility of this visually restricted area, which make isolated LCL an ideal oncological resection for tumours confined to the caudate lobe (30).

A recent meta-analysis comparing open and laparoscopic caudate resection found better postoperative outcomes in terms of hospital stay, intraoperative blood loss, operation time, and intraoperative blood transfusion requirements without an increased morbidity rate (22).

Cost-effectiveness analysis of laparoscopic approach compared to the open for CLC is still lacking.

It can be stated that the laparoscopic approach to the caudate lobe is not near future anymore but instead represents the current reality when considered by high-expertise surgeons working in high-volume hepatobiliary centres. However, since the lack of high-quality evidence and the scarcity of cases, prospective clinical trials, and multi-centre randomised controlled trials are needed to standardize this technique.

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Footnote

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