World Journal of
Hepatology

Submit a Manuscript: http://www.wjgnet.com/esps/
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
DOI: 10.4254/wjh.v6.i5.347

World J Hepatol 2014 May 27; 6(5): 347-357
ISSN 1948-5182 (online)

SYSTEMATIC REVIEW

Central hepatectomy for centrally located malignant liver tumors: A systematic review

Ser Yee Lee

Ser Yee Lee, Department of Hepatopancreatobiliary and Transplant Surgery, Singapore General Hospital, Singapore 169608, Singapore
Ser Yee Lee, Department of Surgical Oncology, National Cancer Centre, Singapore 169610, Singapore
Ser Yee Lee, Duke - National University of Singapore Graduate Medical School, Singapore 169857, Singapore
Author contributions: Lee SY solely contributed to this paper.
Correspondence to: Dr. Ser Yee Lee, MBBS, MMed, MSc, FAMS, FRCS(Ed), Department of Surgical Oncology, National Cancer Centre, 11 Hospital Drive, Singapore 169610, Singapore. lee.ser.yee@nccs.com.sg
Telephone: +65-64368000 Fax: +65-62257559
Received: December 4, 2013 Revised: February 23, 2014
Accepted: May 8, 2014
Published online: May 27, 2014

Abstract

AIM: To study whether central hepatectomy (CH) can achieve similar overall patient survival and disease-free survival rates as conventional major hepatectomies or not.

METHODS: A systematic literature search was performed in MEDLINE for articles published from January 1983 to June 2013 to evaluate the evidence for and against CH in the management of central hepatic malignancies and to compare the perioperative variables and outcomes of CH to lobar/extended hemihepatectomy.

RESULTS: A total of 895 patients were included from 21 relevant studies. Most of these patients who underwent CH were a sub-cohort of larger liver resection studies. Only 4 studies directly compared Central *vs* hemi-/extended hepatectomies. The range of operative time for CH was reported to be 115 to 627 min and Pringle's maneuver was used for vascular control in the majority of studies. The mean intraoperative blood loss during CH ranged from 380 to 2450 mL. The reported morbidity rates ranged from 5.1% to 61.1%, the most common surgical complication was bile leakage and the most common cause of mortality was liver failure. Mortality ranged from 0.0% to 7.1% with an overall mortality of 2.3% following CH. The 1-year overall survival (OS) for patients underwent CH for hepatocellular carcinoma ranged from 67% to 94%; with the 3-year and 5-year OS having a reported range of 44% to 66.8%, and 31.7% to 66.8% respectively.

CONCLUSION: Based on current literature, CH is a promising option for anatomical parenchymal-preserving procedure in patients with centrally located liver malignancies; it appears to be safe and comparable in both perioperative, early and long term outcomes when compared to patients undergoing hemi-/extended hepatectomy. More prospective studies are awaited to further define its role.

Key words: Central hepatectomy; Segment orientated liver resection; Mesohepatectomy; Middle hepatic lobectomy; Central bisegmentectomy

Core tip: Central hepatectomy, defined as anatomical segment 4, 5, 8 ± 1 liver resection, is a promising parenchymal-preserving procedure in patients with centrally located liver malignancies. Based on current evidence, it appears to be safe and comparable in both perioperative, early and long term surgical and oncological outcomes when compared to patients undergoing traditional resections such as hemi-/extended hepatectomy.

Lee SY. Central hepatectomy for centrally located malignant liver tumors: A systematic review. *World J Hepatol* 2014; 6(5): 347-357 Available from: URL: http://www.wjgnet.com/1948-5182/full/v6/i5/347.htm DOI: http://dx.doi.org/10.4254/wjh.v6.i5.347

INTRODUCTION

Surgical resection is the optimal treatment of choice and potential cure for most malignant tumors of the liver if possible[1,2]. With recent improvements in surgical techniques of liver resection, anesthesia and postoperative care, morbidity ranges from 5% to 25% and mortality has improved significantly and has approached zero[3-6]. Centrally located malignancies of the liver such as hepatocellular carcinoma (HCC), Cholangiocarcinoma (CCA) and liver metastases in segments 4, 5, 8 may require extensive resections because of their relationship to major vascular and biliary structures and deep location[7,8]. Traditionally, these centrally located tumors are resected by major resections such as right, left, extended right or extended left hemihepatectomies. Extended or anatomical resections are recommended for oncological reasons; however, these carry a risk of not only significant blood loss, longer operative time but also postoperative liver failure in patients with cirrhosis or poor liver functional reserve or even in patients without cirrhosis[9-11]. Non-anatomical resection is an alternative approach for parenchymal preservation, but it is hindered by intraoperative hemorrhage and betrays oncological principles evident by higher rates of margin positivity and poorer survival outcome[12,13]. With the perpetual lack of donor organs, long waiting time, along with other limitations of liver transplantation, anatomical parenchymal-preserving procedures have an increasing role in treatment of primary and secondary liver malignancies[14].

Central hepatectomy (CH), also known as mesohepatectomy, was first performed for gallbladder cancer in 1972 and is used to describe the operative procedure to resect segments 4, 5, 8 ± 1 (Figure 1)[15-20]. Other synonymous terms used in the literature include central hepatic resection, middle hepatectomy, middle hepatic lobectomy, central bisegmentectomy and central bisectionectomy[20-27]. Regardless of the technical term used, the principle behind this procedure is the same and was not commonly carried out till more recently. In the Brisbane Terminology of Liver Anatomy and Resections by the International Hepatopancreatobiliary Association (IHPBA) in 2000, there was no definition of this surgical procedure[15,16].

The theoretical risks of CH compared to traditional major liver resections such as extended- or hemihepatectomy are obvious. These include a longer operating time, greater intraoperative blood loss, higher risk of biliary and vascular complications, all mainly attributed to the proximity to the hilar structures and the presence of 2 significant resection planes instead of a single plane. Despite this, previous reports showed that CH is safe and achieves comparable complication rates and overall survival rates as conventional major hepatectomies but harbors the advantages of: (1) preserving liver parenchyma with the aim of decreasing the risk of postoperative liver failure; (2) no proven oncological compromises as long as margins are negative and adequate; and (3) increases the opportunity for future repeat resection, if warranted, in cases of recurrent malignancies such as colorectal or neuroendocrine liver metastases[7,8,22,23,25].

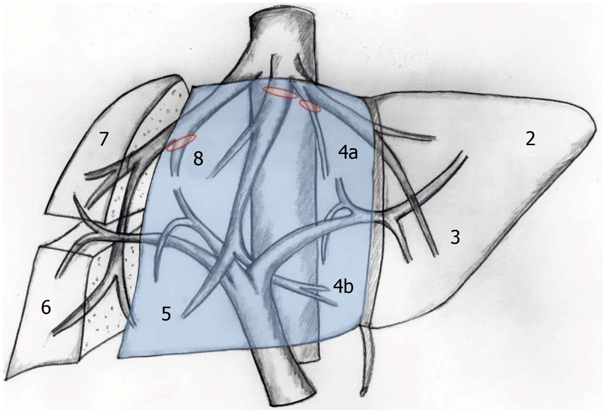

Figure 1 Central hepatectomy-segment orientated resection. Couinaud segments are labeled 2-8; Caudate lobe (Segment 1) is not labelled in this diagram. here) Area shaded blue are the Central segments of 4, 5, 8 which are the segments resected in central hepatectomy (CH). Red rings indicate where the vascular outflow is encountered and ligated during CH.

The current literature directly comparing patients undergoing extended hemi-hepatectomy and CH is lacking[9,15,17,23,25]. There is only one study in the current literature with more than 100 patients (Table 1)[3,7-9,17-20,22,23,25,27-37]. The aim of this review is to analyze and compare the perioperative, early and long- term results of patients with centrally located liver malignancies, between those treated with CH and those treated with hemi-/extended hepatectomy.

MATERIALS AND METHODS

A systematic literature search was performed in MEDLINE (PubMed) from January 1983 to June 2013 to evaluate the evidence supporting CH as a safe procedure for the management of central hepatic tumors and to compare the perioperative, short and long term results of CH to extended/lobar hemihepatectomy. The search used the following medical subgroup headings (MeSH) terms combined with Boolean operators: mesohepatectomy, central hepatectomy, central liver resection, segmentectomy, bisegmentectomy, central trisegmentectomy, bisectionectomy, segmental liver resection and segment oriented liver resection. References of the identified articles were reviewed to identify additional relevant studies. Only full articles published in the English language reporting a series of more than 10 cases were included in the review and effort was made to exclude studies with significant overlap of the same patient cohorts. The literature search was conducted according to PRISMA (preferred reporting items for systematic reviews and meta-analyses) recommendations(Figure 2)[38]. Definitions and nomenclature for liver resections was based on the 2000 IHPBA Brisbane terminology[15,16]. Namely, resection of segments 5 and 8 was named right anterior sectionectomy, while resection of segments 4a and 4b was named left medial sectionectomy. The procedure of segments 4, 5 and 8 resection has now predominantly been termed

Table 1 Characteristics and results of studies on central hepatectomy (1983-2013) *n* (%)

Ref.	Year	*n*	Diagnosis	Operative time (min)	Vascular control	Blood loss (mL)	Morbidity	Mortality	Survival outcome	
Hasegawa *et al*[27]	1989	16	HCC, CRM	300-660	Pedicle occlusion	600-7500	7 (50)	1 (6)	Median OS 34 mo	
Makuuchi *et al*[28]	1993	17	HCC, CCA, CRM	412	NA	1482	7 (41.1)	1 (5.8)	NA	
Nagino *et al*[29]	1998	15	Hilar CCA	NA	NA	NA	NA	NA	NA	
Wu *et al*[17]	1999	15	HCC	474	Pringle's maneuver or pedicle occlusion	2450	3 (20)	0 (0)	1-yr OS 67% 3-yr OS 44% 6-yr OS 30%	1-yr DFS 53% 3-yr DFS 31% 5-yr DFS 21%
Scudamore *et al*[19]	2000	18	HCC, CRM, GBC	238	Pringle's maneuver	914	11 (61.1)	0 (0)	NA	NA
Yamashita *et al*[30]	2001	16	HCC, CCA, metastases, hemangioma, others	NA	NA	NA	NA	NA	NA	NA
[3]Jarnagin *et al*[3]	2002	15	Benign and malignant lesions	NA	NA	NA	NA	NA	NA	NA
Wu *et al*[22]	2002	58	HCC, CCA, metastases	409	Total hepatic flow clamping (28 patients)	1685	8 (8.5)	0 (0)	NA	NA
				399	Selective clamping of ipsilateral blood flow (30 patients)	1159	10 (33.3)	0 (0)	NA	NA
Hu *et al*[23]	2003	52	HCC	265	NA	1030	9 (17)	0 (0)	Median OS 51 mo	Median DFS 23 mo
Chouillard *et al*[25]	2003	19	HCC, metastases, CCA, benign tumor	280	Pringle's maneuver ± hepatic vein clamping	NA	NA	0 (0)	NA	NA
[1]Chen *et al*[18]	2006	118	HCC	128	Pringle's maneuver ± IVC occlusion	592	36 (30.5)	1 (0.8)	NA	NA
Kim *et al*[31]	2006	35	HCC, CCA, hepatic sarcoma	331	Extraglissonian approach and parenchymal Kelly crushing	516	2 (5.7)	1 (2.8)	1-yr OS 94% 2-yr OS 72% 5-yr OS 62%	NA
Giuliante *et al*[32]	2007	18	HCC, metastases	448	Intermittent pedicle clamping	NA	6 (33.3)	0 (0)	NA	NA
[1]Chen *et al*[33]	2007	246	HCC	177 (with preoperative TACE)	Pringle's maneuver ± IVC control	790	31 (34.8)	3 (3.4)	1-yr OS 87.1% 3-yr OS 62.9% 5-yr OS 46.2%	1-yr DFS 75% 3-yr DFS 46.2% 5-yr DFS 31.8%
				115 (without)		420	38 (24.2)	1 (0.6)	1-yr OS 82.2% 3-yr OS 54.4% 5-yr OS 31.7%	1-yr DFS 69.6% 3-yr DFS 38% 5-yr DFS 16.5%
[1]Chen *et al*[7]	2008	256	HCC	174	Pringle's maneuver ± IVC control	750 (Pringle only); 380 (Pringle with IVC control)	72 (28.1)	1 (0.4)	1-yr OS 77.0% 3-yr OS 49.8% 5-yr OS 35.1%	1-yr DFS 59.1% 3-yr DFS 28.8% 5-yr DFS 17.0%
Mehrabi *et al*[34]	2008	48	HCC, metastases, CCA, GBC, hemangioma, other	238	Pringle's maneuver in 9 patients	1120	13 (27.1)	1 (2)	NA	3-yr DFS 47.9%
Lee *et al*[20]	2008	27	HCC	330	Pedicle ligation	1400	12 (44.4)	2 (7.9)	NA	NA

Arkadopoulos *et al*[35]	2012	36	HCC, metastases	180	Selective hepatic vascular exclusion/ Pringle's maneuver (16 patients)	650	6 (37.5)	0 (0)	NA	NA
				150	Sequential hemihepatic vascular control (20 patients)	400	9 (45)	0 (0)	NA	NA
Gallagher *et al*[36]	2013	21	HCC	627	Intermittent Pringle's maneuver	1590	4 (19)	1 (4.8)	1-yr OS 90.5% 3-yr OS 66.8% 5-yr OS 66.8%	1-yr DFS 65% 3-yr DFS 34.8% 5-yr DFS 34.8%
Cheng *et al*[8]	2012	63	HCC	230	Pringle's maneuver	500	8 (12.7)	5 (7.9)	1-yr OS 87.5% 5-yr OS 53.1%	1-yr DFS 50% 5-yr DFS 15%
[3]Yang *et al*[37]	2013	150	HCC	NA	Pringle maneuver	NA	NA	NA	NA	
Total number		895[2]	range	115-627		380-2450	Overall morbidity: 27.5% (range: 12.7%-61.1%)	Overall mortality: 2.3% (range: 0%-7.1 %)		

[1]Indicates multiple studies with overlapping study periods from a single institution; [2]Total number calculated after excluding studies with repeat patients; [3]Limited data available as CH patients were a subset of a larger group of patients undergoing various types of hepatic resections. Overall morbidity and mortality was calculated by considering the number of events as a percentage of the total number of patients in included studies. HCC: Hepatocellular carcinoma; CRM: Colorectal metastases; CCA: Cholangiocarcinoma; GBC: Gallbladder carcinoma; IVC: Inferior vena cava; NA: Not available; OS: Overall survival; DFS: Disease-free survival; TACE: Transarterial chemoembolization; CH: Central hepatectomy.

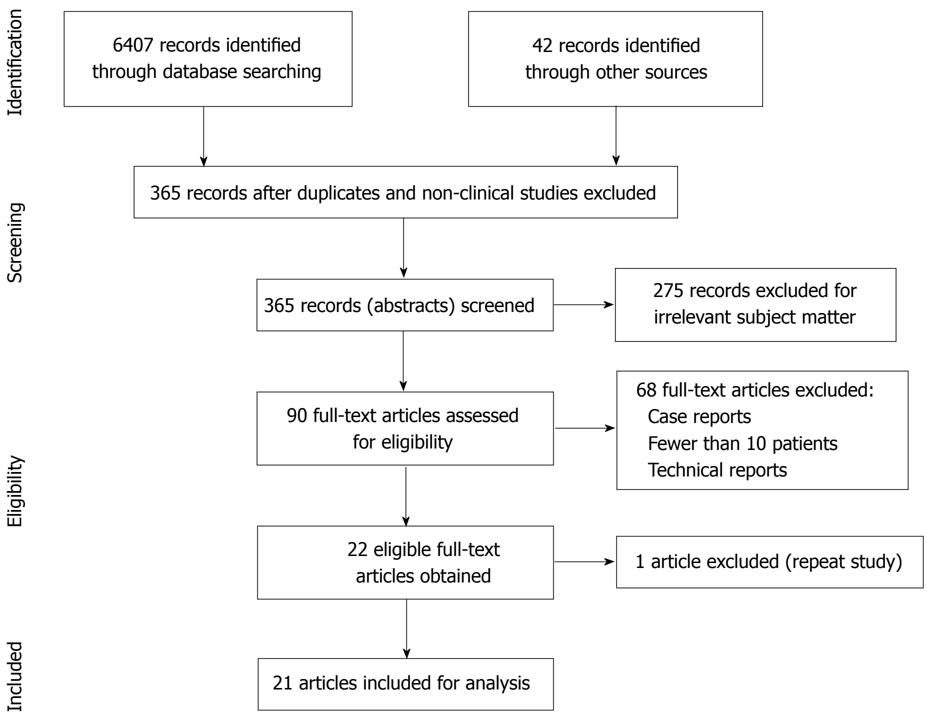

Figure 2 Identification and screening of articles according to preferred reporting items for systematic reviews and meta-analyses recommendations.

central hepatectomy or mesohepatectomy[9,14,17].

When calculating the overall morbidity and mortality, this was calculated as the number of events reported as a percentage of the total number of patients in included studies. In considering individual complications, the number of events or incidences was calculated as a percentage of the total number of complication events in which this data was available. Weighted means were calculated when outcomes were expressed as a mean value.

RESULTS

A literature search on MEDLINE (PubMed) and review of references of relevant articles yielded a total of 90

Table 2 Summary of case-control studies comparing central hepatectomies and lobar/extended hepatectomies *n* (%)

Ref.	Year	Resection type	*n*	Operative time (min)	Blood loss (mL)	Mortality	Morbidity	Complications (*n*)
Wu *et al*[17]	1999	Central hepatectomy	15	474	2450	0 (0)	3 (20)	Bile leak (1), pleural effusion (1), ascites (1)
		Extended hepatectomy	25	348	1863	1 (4)	6 (24)	Bile Leak (2), pleural effusion (1), ascites (1), prolonged jaundice (2), intra-abdominal abscess (2), wound infection (1)
			P value	0.09	0.23	0.43	0.99	-
Scudamore *et al*[19]	2000	Central hepatectomy	18	238	914	0 (0)	1_{intra} (5.5)	Intraoperative bleeding (1), pneumonia (2), intra-abdominal fluid collection (2), fever longer than 48 hours (2), transient fever (2), bile leak (1), late intra-abdominal fluid collection (1)
		Lobar hepatectomy	71	222	1025	1 (1.4)	9_{early} (50) 1_{late} (5.6) 6_{intra} (8.5) 29_{early} (40.8) 3_{late} (4.2)	NA
		Extended hepatectomy	43	304	1628	0 (0)	2_{intra} (4.7) 21_{early} (48.9) 9_{late} (20.9)	NA
			P value	< 0.001	0.009 for extended *vs* central	-	0.05 for late complications	-
Hu *et al*[23]	2003	Central hepatectomy	52	265	NA	0 (0)	9 (17)	Bile leak (3), pleural effusion (3), 1 postoperative massive ascites (1), subphrenic abscess (1)
		Conventional or extended hepatectomy	63	264	NA	2 (3.1)	12 (19)	Bile leak (2), wound infection (4), pneumonia (2), liver failure (2), subphrenic abscess (1), pleural effusion (1)
			P value	0.953		0.408	0.491	-
Cheng *et al*[8]	2012	Central hepatectomy	63	230	500	5 (7.9)	8 (12.7)	Liver failure (2), bile leak (1)[1]
		Hemi-/ extended hepatectomies	41	316	750	3 (7.3)	6 (14.6)	Liver failure (2), bile leak (1)
			P value	< 0.001	0.004	1.000	0.777	-
Total		Central hepatectomy	148	Mean 268	Mean 882	3.4% (0%-7.9%)	20.90% (range: 20%-66.7%)	
		Hemi-/ extended hepatectomies	243	Mean 299	Mean 1352	2.9% (0%-7.3%)	38.70% (range: 14.6%-74.4%)	

[1]Other complications described included gastrointestinal bleeding, intra-abdominal hematoma, abscess, intra-abdominal bleeding, pneumonia, wound infection, but did not specify the treatment group in which it occurred. Weighted means were calculated for operative time and blood loss. NA: Not available.

articles on central hepatectomy after exclusion of irrelevant articles (Figure 2). Of these, 22 articles were published in English and included more than 10 patients. Of these, one study was excluded from analysis because results of these patients were also reported in a later series by the same author[17,39]. Three articles by Chen *et al*[7,18,33] reported on patients undergoing CH at a single institution with overlapping study periods, with the latest 2008 study of 256 patients constituting the largest reported series of CH at a single institution to date. Of the 21 articles included for analysis, 3 studies were comparative studies between 2 different methods of vascular control during CH, 4 studies compared the results of CH *vs* conventional forms of hepatectomies (hemi- or extended hemihepatectomy), 1 looked at results of CH in patients who had pre-operative transarterial chemoembolization (TACE) as compared to those who did not have preoperative TACE and 1 compared the outcomes of patients who had huge HCC of 10 cm or greater in size, as to compared to that of HCC measuring 5 to 10 cm[19,33,37]. The remaining papers were descriptive and non-comparative studies. The results of these 21 studies, including number of patients, operative time, method of vascular control, operative blood loss, mortality, morbidity and survival data (where available) are summarized in Table 1. The 4 studies which compared the outcomes of CH *vs* conventional hepatectomies are summarized in Table 2.

Table 3 Type and frequency of complications reported following central hepatectomy

Type of complication[1]	Number reported (n = 200)	Frequency (%)
Surgical complications		
Bile leakage/biloma	36	18
Intra-abdominal abscess	16	8
Wound infection	7	3.5
Bleeding	4	2
Intestinal perforation	1	0.5
Medical complications		
Pleural effusion/empyema	62	31
Ascites	29	14.5
Pneumonia/pulmonary infection	13	6.5
Pulmonary edema	6	3
Fever	4	2
Upper gastrointestinal bleeding	3	1.5
Urinary tract infection	3	1.5
Transient hepatic dysfunction/ prolonged jaundice	3	1.5
Hepatic necrosis/liver failure	3	1.5
Acute renal failure	2	1
Stroke	1	0.5
Arrhythmia	1	0.5
Deep vein thrombosis	1	0.5
Other (not specified)	4	2

[1]Calculated out of a total of 200 events.

Study characteristics and operative details

A total of 1259 patients from 21 studies were reported after undergoing CH in the literature. However, after excluding studies with potential repeat patients (due to recruitment with significant overlapping study periods at a single institution), a total of 895 unique patients who had CH were obtained. The indication for central hepatectomy was detailed in 14 studies comprising a total of 659 patients. The main indication for CH was HCC, occurring in 565 patients (85.7%), but was also performed in conditions such as centrally-located liver metastases which accounted for 58 cases (most commonly colorectal in origin). Other diagnoses included CCA/ gallbladder carcinoma (25 cases), hepatic sarcoma (1 case), hemangiomas (2 cases) and occasionally for other benign lesions (4 cases).

The range of operative time for CH was reported to be 115 to 627 min, and Pringle's maneuver was used for vascular control in the majority of studies. The mean intraoperative blood loss during CH ranged from 380 to 2450 mL.

Mortality and morbidity

Data on mortality was available in 16 articles with mortality rates ranging from 0.0% to 7.1%. In nearly half of these studies (7 studies) had zero postoperative mortality following CH. A total of 16 deaths in 17 unique studies comprising 689 patients have been reported, giving an overall mortality of 2.3% following CH. The most common cause of death following CH was liver failure. Concomitant contributing factors that have been reported included sepsis, pneumonia, post-operative bleeding, disseminated intravascular coagulopathy and multi-organ failure. Data on complications following CH were available in 15 studies, with reported morbidity rates ranging from 5.1% to 61.1%. After excluding repeat studies, there were a total of 187 patients reported to have morbidity following CH, out of a total of 680 patients. This gave an overall complication rate of 27.5% (including early and late complications) following CH. A detailed breakdown of the type of complications experienced was available in 13 studies, which accounted for a total of 200 complication events. The most commonly reported surgical complication was bile leakage or biloma formation, which accounted for 18% (36 events) of all complications reported. Bile leakage resolved with conservative treatment in the majority of cases. Other surgical complications reported included wound infection, intra-abdominal abscess, intra-abdominal bleeding/hematoma, and intestinal perforation. Medical complications described following CH included transient hepatic dysfunction/prolonged jaundice/liver failure, ascites, pneumonia/pulmonary infection, pleural effusion/empyema, urinary tract infection, fever, upper gastrointestinal bleeding, renal failure, stroke and deep vein thrombosis (Table 3).

Overall survival

Overall survival (OS) data was available in 8 studies[7,8,17,23,27,31,33,36]. Median survival for HCC treated with CH was reported in 2 studies: this was 34 mo in Hasegawa *et al*[27] (patient diagnosis included both HCC and colorectal liver metastases) and 51 mo in Hu *et al*[23] and Hasegawa *et al*[27] (HCC patients only), Wu *et al*[17] reported a 6-year OS of 30% (HCC, CCA and other liver metastases); Chen *et al*[33] reported a 5-year OS of 31.7% in the group of patients with HCC who did not have preoperative TACE, as compared to the group who had TACE prior to CH with a significantly better 5-year OS of 46.2% (P = 0.043). Overall, the CH group for HCC had 1-year OS ranging from 67% to 94%, with 3-year and 5-year OS having a reported range of 44% to 66.8%, and 31.7% to 66.8% respectively.

Disease-free survival

Seven studies reported disease-free survival[7,8,17,23,33,34,36]. The median Disease-free survival (DFS) in Hu *et al*[23] was 23 mo for HCC. In the remaining HCC studies with DFS data, the range for 1-, 3- and 5-year DFS was 50% to 75%, 28.8% to 46.2% and 15% to 31.8% respectively.

Comparative studies of CH vs hemi-/extended hepatectomies

Of the 21 studies on CH, 4 of these were case-control studies that compared the outcomes following CH *vs* hemi- or extended hepatectomies at their institutions (Table 2)[8,17,19,23]. A total of 148 patients underwent CH and 243 had hemi- or extended hepatectomies performed for their disease in these 4 studies.

Operative time for CH was shown to be not significantly different from that of extended hepatectomies in the series by Hu *et al*[23] and Wu *et al*[17], while in 2 studies, Scudamore *et al*[19] and Cheng *et al*[8], patients who underwent CH had significantly shorter operative time (238 and 230 min respectively) as compared to extended hepatectomies (304 and 316 min respectively). The overall weighted mean operative time in these 4 studies for CH was 268 min *vs* 299 min for lobar/extended hemihepatectomy. Also, significantly less blood loss was experienced in CH as compared to extended hepatectomies in Cheng *et al*[8] (500 mL in CH *vs* 750 mL for extended hepatectomies, $P = 0.004$) and in Scudamore *et al*[19] (917 mL *vs* 1628 mL, $P = 0.009$). The overall weighted mean intraoperative blood loss in these 4 studies for CH was 882 mL *vs* 1352 mL for lobar/extended hemihepatectomy.

The morbidity rates between CH and hemi-/extended hepatectomy groups were also not significantly different individually in these studies, with the exception of late complications in Scudamore *et al*[19] which was studied as a subgroup. In study by Scudamore *et al*[19], the rate of late complications in extended hepatectomies (20.9%) was found to be higher than that in CH or lobar hepatectomies ($P < 0.05$). The overall morbidity in our review of CH was comparable: 20.9% (range: 20% to 66.7%) for CH *vs* 38.7% (range: 20% to 66.7%) for the hemi-/extended hepatectomy group. There was no statistically significant difference in mortality of patients who underwent CH and hemi/extended hepatectomy groups in any of the 4 studies. Notably, there was zero mortality in 3 out of 4 CH groups, however, there was mortality in the corresponding control groups (hemi-/extended hepatectomy). The overall mortality in the 2 groups were also similar: 3.4% (range: 0.0% to 7.9%) for CH group *vs* 2.9 % (range: 0.0% to 7.3%) for the hemi-/extended hepatectomy group (Table 2).

DISCUSSION

Advances in imaging technology have contributed to the improvements in the understanding of liver anatomy that is based on functional segmental anatomy and forms the foundation for segment-orientated liver surgery[9,12]. Central hepatectomy removes most or the entire left medial sector (segments 4a and 4b) and all or most part of the right anterior sector (segments 5 and 8) with or without segment 1 (Figure 1). It represents an alternative and attractive option for those patients with limited functional liver reserve especially those with liver cirrhosis or those with chemotherapy associated steatohepatitis, because it removes the tumor-bearing segments in entirety while preserving the rest of the liver without necessarily compromising on recurrence or survival outcome[9,40].

In the presence of a large and/or a deep seated tumor located in the central part of the liver (Couinaud segments 4, 5, 8), the resection is more technically challenging due to its proximity to important hilar structures. Central hepatectomy is more surgically daedalean than the conventional anatomical major liver resection because it has 2 resection planes instead of one, the need for preservation of the bilateral peripheral segments and its vasculature and the potential need for 2 bilioenteric anastomoses (*e.g.* for perihilar CCA). It involves the resection of liver territory drained by the middle hepatic vein (HV) along 3 lines of transection planes: the right intersectional plane (to the left of the Right HV), the left intersectional plane (falciform ligament) and the coronal transection plane being above the hilum and anterior to the right posterior sectoral pedicle, the root of the middle HV vein is divided at the bottom of the right and left plane of the parenchymal division; as such, it may require longer vascular occlusion time and alternative pedicle clamping may be required (Figure 1)[22,25]. This is especially pertinent in a cirrhotic liver for parenchymal preservation to minimize the risks of post-operative liver failure. Injury or improper division of these important structures during parenchymal division in CH may result in ischemia or necrosis of the residual peripheral liver leading to liver failure and increased mortality[23].

Preoperative evaluation of hepatic functional reserve includes clinical assessment, liver function test, platelet count, coagulation profile and Child-Pugh classification[14]. The Indocyanine Green (ICG[15]) test has been found to be helpful in predicting the safe limit of liver resection along with Computed tomography volumetric evaluation of the adequate remnant liver volume to minimize post-hepatectomy liver failure[14]. For patients with chronic liver cirrhosis being considered for major resection (⩾ 3 segments), pre-operative portal vein embolization (PVE) is a reasonable option to hypertrophy the future liver remnant to minimize risk of post-operative liver failure[14]. Ipsilateral PVE is a feasible preoperative strategy facilitating extended or staged resections, however, with centrally located tumors it is often difficult to determine which side of the portal vein should be embolized; in addition, livers with limited functional reserve will also have lower than expected response to PVE, further limiting its role[41].

Does the preservation of an extra 20% to 25% of liver (40% to 60% parenchymal resection by CH *vs* 60% to 85% resection by extended/lobar hemihepatectomies) justify the increased technical demands of CH? Liver surgery has evolved significantly in past decades. Increased cumulative experience in hepatectomy, improved techniques such as different techniques of vascular occlusion(*e.g.*, Pringle's, total vascular occlusion, sequential vascular occlusion) and the liver hanging maneuver, aided by the advent of advanced surgical technology such as the cavitational ultrasonic surgical aspirator (CUSA, Integra LifeSciences Corporation) and various energy devices (*e.g.*, LigaSure™, Covidien Ltd; Aquamantys®, Medtronic Advanced Energy; Harmonic Scalpel™, Ethicon Endo-Surgery, Inc. Johnson and Johnson Medical Ltd) during liver resection, surgical morbidity and mortality rates have declined markedly as compared with historic data[4,14,23,42-47]. Major vessels and bile ducts in the resection plane can be well visualized, skeletonized, and controlled meticulously during division of the liver parenchyma with these devices (CUSA, LigaSure™, Aquamantys®, Harmonic Scalpel™) as an adjunct to traditional methods such as Kelly clamps, surgical clips and staples. The additional routine use of intraoperative ultrasonography further allows the major vessels and intrahepatic bile ducts to be identified and controlled confidently, as a result, minimizing unexpected major blood loss from vessel injury and avoiding major bile duct injuries[48]. In view of the complexity of CH, sequential or alternative hemihepatic vascular control has been advocated by some authors to minimize clamping time *i.e.*, warm ischemic time of the remnant liver. Arkadopoulos and colleagues demonstrated in a recent study looking at CH comparing 16 patients with selective hepatic vascular exclusion (Pringle's maneuver with hepatic vein outflow occlusion) *vs* 20 patients with sequential hemihepatic vascular control, in which they demonstrated that patients with sequential vascular control received fewer blood transfusions, had less intraoperative blood loss, shorter liver warm ischemic time and lower postoperative transaminitis[35]. Chen *et al*[18] had similar results when they compared 2 cohorts of patients (n = 58 *vs* 60) undergoing CH: they demonstrated that utilizing Pringle's maneuver with IVC occlusion resulted in less blood loss, lower transfusion requirements and less liver damage than Pringle's maneuver alone. In the hands of experienced hepatobiliary surgeons, operative times were also not increased during these procedures, as seen in our review (Table 2: 256 min in CH group *vs* 305 min in the lobar/extended hepatectomy group). Application of a modified Belghiti's liver hanging maneuver (Double liver hanging maneuver) has also been described to help guide the transection planes for CH[44,49]. These newer techniques make central hepatectomy a feasible and safe procedure, especially in experienced hands[9,23,42,50]. More recently, central hepatectomy has also been reported to be performed *via* minimally invasive techniques (laparoscopic or robotic approach)[51-54].

There are 2 main techniques for performing CH. The first involves ligation and division of the central pedicles supplying segment 4, 5 and 8 of the liver segments during liver parenchyma transection under a Pringle's maneuver, while the second involves extrahepatic individual ligation and division of the vessels supplying the segments 4, 5, and 8 prior to parenchyma transection of the liver with or without temporary total hepatic inflow/outflow occlusion[54,55].

Stratopoulos *et al*[9] in 2007 performed a literature review of major series of central hepatectomies. That review encompassed studies published till 2006, and this current review expands on those studies and includes more recent publications on this topic. The surgical mortality rate reported in this earlier review was between 0% and 6.25%. Our review revealed similar mortality rates of 0% to 7.1 % with an overall mortality rate of 2.3%. Consistent with our review, Stratopoulos *et al*[9]'s review reported that the most common cause of perioperative death was liver failure followed by hemorrhage. In our review, the most common surgical complication was bile leak/biloma. Postoperative early morbidity rates were as high as 61% contributed in most part by surgical events such as bile leakage/biliary fistula, hemorrhage/intra-abdominal hematoma, wound infection, intra-abdominal abscess and intestinal perforation as well as medical complications such as liver failure/dysfunction leading to ascites and hepatic encephalopathy, pulmonary infection/pleural effusion/empyema, urinary tract infection, sepsis, upper gastrointestinal bleeding, renal failure, stroke and deep vein thrombosis.

Biliary leakage is one of the most frequently reported intra-abdominal complications after liver resection[30,45,56-58]. The rate of bile leakage in the literature after liver resection has been reported to range from 0% to 11%[23,46,47,59-61]. In hepatectomy without bilioenteric anastomosis, the principal causes of bile leakage are bile oozing from the transected liver surface and intraoperative biliary injury. There are reports that identified central hepatectomy as an independent risk factor for bile leakage because of the presence of two transection planes and exposure of the hepatic hilum[30,56]. In the 4 comparative studies comparing CH *vs* lobar or extended hemihepatectomies, there were no statistically significant differences in bile leak.

In previous reports, CH has been associated with a higher risk of bleeding than conventional major resections[17,32]. Our review revealed that median intraoperative blood loss during CH ranged from 380 to 2450 mL, which is comparable in large liver resection series with major conventional resections[3,4,62].

Most of the patients with reported survival data in this review underwent CH for diagnosis of HCC. The 1-year OS for these patients ranged from 67% to 94%, with 3-year and 5-year OS having a reported range of 44% to 66.8%, and 31.7% to 66.8% respectively. This is comparable to the results from a recent review of survival outcomes looking at 17 studies with more than a total 13000 patients with HCC treated by liver resection, they reported a 1- year survival rate ranging from 67% to 97%, a 3- year survival rate ranging from 34% to 84% and a 5-year survival rate of 17 to 72% was reported[14,63]. A recent study on CH for HCC by Jeng *et al*[40] reported that even with narrow margins (< 5 mm) after CH, there was no negative impact on recurrence and overall survival. Conversely, Nagino *et al*[64] recently commented in a review of over three decades of their experience in the evolution of surgical treatment for perihilar CCA; they reported that limited resections such a CH for perihilar CCA decreased significantly from almost 30% to less than 3% over almost 4 decades with a corresponding improved survival due to more R_0 resections from extended resections. The role of CH for central HCC and perihilar CCA remains to be defined.

Because of the breadth of the current review and the limited available literature of CH as a procedure, the types of studies and the highly descriptive nature of much of the data reviewed, no assessment of the grade quality of individual studies or presence of bias and confounders were performed in this review. These studies have inherent selection biases and there is a degree of publication bias as well that is not avoidable due to the retrospective nature of these studies. In addition, because of the lack of high-level evidence and prospective or randomized studies, no objective grading was performed for any specific intervention. The oncological outcomes of HCC in these studies of CH are generalized and not conclusive when compared to HCC undergoing conventional resections due to the lack of detailed clinical and pathological data and risk factors in these studies that determines prognosis and provide strong valid comparison. The literature search was limited to English-language studies within the defined search period and included more recent papers in the past decade that remain highly relevant today. The review nonetheless serves as an updated collection and summary of the cumulative experiences in this relatively novel procedure and approach to segment-orientated liver resection.

Further high-quality and prospective studies with large sample sizes or randomized controlled trials to ascertain the utility and feasibility of central hepatectomy would be important in defining its role in the treatment of centrally-located liver tumors.

In conclusion, this review shows that central hepatectomy can achieve similar overall patient survival and disease-free survival rates as conventional major hepatectomies. Our findings suggest that central hepatectomy may be considered an acceptable procedure for treatment of centrally located malignances and may be the procedure of choice in patients with compromised liver function. It has the advantages of preserving parenchyma and seemingly without oncological compromise however, validation of CH as an oncologically safe procedure requires further prospective studies.

COMMENTS

Background

Central hepatectomy (CH) has similar perioperative outcomes with lobar and extended liver resections and achieves similar overall patient survival and disease-free survival rates as conventional major hepatectomies. Current evidence suggests that CH may be considered an acceptable procedure for treatment of centrally located malignances and may be the procedure of choice in patients with compromised liver function.

Research frontiers

More prospective studies including randomized controlled trials need to be conducted to validate the procedure as an oncologically equivalent and safe operation, specific to different cancer such as hepatocellular carcinoma and colorectal liver metastases, when compared to standard, traditional hepatectomy

Innovations and breakthroughs

Improved surgical and anesthesia experience and better technology has improved the morbidity and mortality of major liver resection and paved the way for safe parenchymal preserving surgery especially in patients with limited liver reserve.

Applications

CH may be applicable in selected patients with central tumors where parenchymal preserving surgery is indicated or preferred.

Terminology

CH also known as mesohepatectomy or central liver resection is used to describe the operative procedure for anatomical liver resection of segments 4, 5, 8 ± 1.

Peer review

In the present manuscript the authors performed a meta-analysis to evaluate the implication of CH for the management of central hepatic malignancies and to compare the perioperative, short and long term results of CH to lobar/extended hemihepatectomy. The authors concluded that CH is a promising option for anatomical parenchymal preserving procedure in patients with centrally located liver malignancies; it is safe and comparable in both perioperative, early and long term outcomes when compared to patients undergoing hemi-/extended hepatectomy.

REFERENCES

1 **Agrawal S**, Belghiti J. Oncologic resection for malignant tumors of the liver. *Ann Surg* 2011; **253**: 656-665 [PMID: 21475004 DOI: 10.1097/SLA.0b013e3181fc08ca]

2 **Bruix J**, Sherman M. Management of hepatocellular carcinoma: an update. *Hepatology* 2011; **53**: 1020-1022 [PMID: 21374666 DOI: 10.1002/hep.24199]

3 **Jarnagin WR**, Gonen M, Fong Y, DeMatteo RP, Ben-Porat L, Little S, Corvera C, Weber S, Blumgart LH. Improvement in perioperative outcome after hepatic resection: analysis of 1,803 consecutive cases over the past decade. *Ann Surg* 2002; **236**: 397-406; discussion 406-407 [PMID: 12368667 DOI: 10.1097/01.sla.0000029003.66466.b3]

4 **Fan ST**, Lo CM, Liu CL, Lam CM, Yuen WK, Yeung C, Wong J. Hepatectomy for hepatocellular carcinoma: toward zero hospital deaths. *Ann Surg* 1999; **229**: 322-330 [PMID: 10077043]

5 **Itoh S**, Shirabe K, Taketomi A, Morita K, Harimoto N, Tsujita E, Sugimachi K, Yamashita Y, Gion T, Maehara Y. Zero mortality in more than 300 hepatic resections: validity of preoperative volumetric analysis. *Surg Today* 2012; **42**: 435-440 [PMID: 22200757 DOI: 10.1007/s00595-011-0108-2]

6 **Kamiyama T**, Nakanishi K, Yokoo H, Kamachi H, Tahara M, Yamashita K, Taniguchi M, Shimamura T, Matsushita M, Todo S. Perioperative management of hepatic resection toward zero mortality and morbidity: analysis of 793 consecutive cases in a single institution. *J Am Coll Surg* 2010; **211**: 443-449 [PMID: 20822741 DOI: 10.1016/j.jamcollsurg.2010.06.005]

7 **Chen XP**, Qiu FZ, Lau WY, Zhang BX, Chen YF, Zhang WG, He SQ. Mesohepatectomy for hepatocellular carcinoma: a study of 256 patients. *Int J Colorectal Dis* 2008; **23**: 543-546 [PMID: 18193241 DOI: 10.1007/s00384-007-0411-y]

8 **Cheng CH**, Yu MC, Wu TH, Lee CF, Chan KM, Chou HS, Lee WC. Surgical resection of centrally located large hepatocellular carcinoma. *Chang Gung Med J* 2012; **35**: 178-191 [PMID: 22537933]

9 **Stratopoulos C**, Soonawalla Z, Brockmann J, Hoffmann K, Friend PJ. Central hepatectomy: the golden mean for treating central liver tumors? *Surg Oncol* 2007; **16**: 99-106 [PMID: 17583496 DOI: 10.1016/j.suronc.2007.05.002]

10 **Vauthey JN**, Baer HU, Guastella T, Blumgart LH. Comparison of outcome between extended and nonextended liver resections for neoplasms. *Surgery* 1993; **114**: 968-975 [PMID: 8236022]

11 **Wanebo HJ**, Chu QD, Vezeridis MP, Soderberg C. Patient selection for hepatic resection of colorectal metastases. *Arch Surg* 1996; **131**: 322-329 [PMID: 8611099]

12 **Billingsley KG**, Jarnagin WR, Fong Y, Blumgart LH. Segment-oriented hepatic resection in the management of malignant neoplasms of the liver. *J Am Coll Surg* 1998; **187**: 471-481 [PMID: 9809562]

13 **DeMatteo RP**, Palese C, Jarnagin WR, Sun RL, Blumgart LH, Fong Y. Anatomic segmental hepatic resection is superior to wedge resection as an oncologic operation for colorectal liver metastases. *J Gastrointest Surg* 2000; **4**: 178-184 [PMID: 10675241]

14 **Lee SY**, Kluger MD, Cherqui D. Surgical management of hepatocellular carcinoma. In: Kee, Murthy, Madoff, editors. Clinical Interventional Oncology: Management and Practice. 1st ed. Philadelphia, PA: Elsevier, 2014: 66-76
15 **Pang YY**. The Brisbane 2000 terminology of liver anatomy and resections. HPB 2000; 2: 333-39. *HPB* (Oxford) 2002; **4**: 99; author reply 99-100 [PMID: 18332933 DOI: 10.1080/136518202760378489]
16 **Strasberg SM**, Phillips C. Use and dissemination of the brisbane 2000 nomenclature of liver anatomy and resections. *Ann Surg* 2013; **257**: 377-382 [PMID: 22895397 DOI: 10.1097/SLA.0b013e31825a01f6]
17 **Wu CC**, Ho WL, Chen JT, Tang CS, Yeh DC, Liu TJ, P'eng FK. Mesohepatectomy for centrally located hepatocellular carcinoma: an appraisal of a rare procedure. *J Am Coll Surg* 1999; **188**: 508-515 [PMID: 10235579]
18 **Chen XP**, Zhang ZW, Zhang BX, Chen YF, Huang ZY, Zhang WG, He SQ, Qiu FZ. Modified technique of hepatic vascular exclusion: effect on blood loss during complex mesohepatectomy in hepatocellular carcinoma patients with cirrhosis. *Langenbecks Arch Surg* 2006; **391**: 209-215 [PMID: 16565854 DOI: 10.1007/s00423-006-0043-7]
19 **Scudamore CH**, Buczkowski AK, Shayan H, Ho SG, Legiehn GM, Chung SW, Owen DA. Mesohepatectomy. *Am J Surg* 2000; **179**: 356-360 [PMID: 10930479]
20 **Lee JG**, Choi SB, Kim KS, Choi JS, Lee WJ, Kim BR. Central bisectionectomy for centrally located hepatocellular carcinoma. *Br J Surg* 2008; **95**: 990-995 [PMID: 18574845 DOI: 10.1002/bjs.6130]
21 **La Quaglia MP**, Shorter NA, Blumgart LH. Central hepatic resection for pediatric tumors. *J Pediatr Surg* 2002; **37**: 986-989 [PMID: 12077755]
22 **Wu CC**, Yeh DC, Ho WM, Yu CL, Cheng SB, Liu TJ, P'eng FK. Occlusion of hepatic blood inflow for complex central liver resections in cirrhotic patients: a randomized comparison of hemihepatic and total hepatic occlusion techniques. *Arch Surg* 2002; **137**: 1369-1376 [PMID: 12470103]
23 **Hu RH**, Lee PH, Chang YC, Ho MC, Yu SC. Treatment of centrally located hepatocellular carcinoma with central hepatectomy. *Surgery* 2003; **133**: 251-256 [PMID: 12660635 DOI: 10.1067/msy.2003.102]
24 **Carceller A**, Blanchard H, Champagne J, St-Vil D, Bensoussan AL. Surgical resection and chemotherapy improve survival rate for patients with hepatoblastoma. *J Pediatr Surg* 2001; **36**: 755-759 [PMID: 11329582 DOI: 10.1053/jpsu.2001.22953]
25 **Chouillard E**, Cherqui D, Tayar C, Brunetti F, Fagniez PL. Anatomical bi- and trisegmentectomies as alternatives to extensive liver resections. *Ann Surg* 2003; **238**: 29-34 [PMID: 12832962 DOI: 10.1097/01.sla.0000075058.37052.49]
26 **Yanaga K**. Central bisectionectomy (bisegmentectomy) of the liver (with video). *J Hepatobiliary Pancreat Sci* 2012; **19**: 44-47 [PMID: 21947576 DOI: 10.1007/s00534-011-0449-7]
27 **Hasegawa H**, Makuuchi M, Yamazaki S, Gunvén P. Central bisegmentectomy of the liver: experience in 16 patients. *World J Surg* 1989; **13**: 786-790 [PMID: 2560286]
28 **Makuuchi M**, Hashikura Y, Kawasaki S, Tan D, Kosuge T, Takayama T. Personal experience of right anterior segmentectomy (segments V and VIII) for hepatic malignancies. *Surgery* 1993; **114**: 52-58 [PMID: 8356527]
29 **Nagino M**, Nimura Y, Kamiya J, Kanai M, Uesaka K, Hayakawa N, Yamamoto H, Kondo S, Nishio H. Segmental liver resections for hilar cholangiocarcinoma. *Hepatogastroenterology* 1998; **45**: 7-13 [PMID: 9496478]
30 **Yamashita Y**, Hamatsu T, Rikimaru T, Tanaka S, Shirabe K, Shimada M, Sugimachi K. Bile leakage after hepatic resection. *Ann Surg* 2001; **233**: 45-50 [PMID: 11141224]
31 **Kim KH**, Kim HS, Lee YJ, Park KM, Hwang S, Ahn CS, Moon DB, Ha TY, Kim YD, Kim KK, Song KW, Choi ST, Kim DS, Jung DH, Lee SG. Clinical analysis of right anterior segmentectomy for hepatic malignancy. *Hepatogastroenterology* 2006; **53**: 836-839 [PMID: 17153435]
32 **Giuliante F**, Nuzzo G, Ardito F, Vellone M, De Cosmo G, Giovannini I. Extraparenchymal control of hepatic veins during mesohepatectomy. *J Am Coll Surg* 2008; **206**: 496-502 [PMID: 18308221 DOI: 10.1016/j.jamcollsurg.2007.09.019]
33 **Chen XP**, Hu DY, Zhang ZW, Zhang BX, Chen YF, Zhang WG, Qiu FZ. Role of mesohepatectomy with or without transcatheter arterial chemoembolization for large centrally located hepatocellular carcinoma. *Dig Surg* 2007; **24**: 208-213 [PMID: 17522469 DOI: 10.1159/000102901]
34 **Mehrabi A**, Mood ZA, Roshanaei N, Fonouni H, Müller SA, Schmied BM, Hinz U, Weitz J, Büchler MW, Schmidt J. Mesohepatectomy as an option for the treatment of central liver tumors. *J Am Coll Surg* 2008; **207**: 499-509 [PMID: 18926451 DOI: 10.1016/j.jamcollsurg.2008.05.024]
35 **Arkadopoulos N**, Kyriazi MA, Theodoraki K, Vassiliou P, Perelas A, Vassiliou I, Smyrniotis V. Central hepatectomy under sequential hemihepatic control. *Langenbecks Arch Surg* 2012; **397**: 1283-1288 [PMID: 23011293 DOI: 10.1007/s00423-012-0984-y]
36 **Gallagher TK**, Chan AC, Poon RT, Cheung TT, Chok KS, Chan SC, Lo CM. Outcomes of central bisectionectomy for hepatocellular carcinoma. *HPB* (Oxford) 2013; **15**: 529-534 [PMID: 23750496 DOI: 10.1111/j.1477-2574.2012.00615.x]
37 **Yang L**, Xu J, Ou D, Wu W, Zeng Z. Hepatectomy for huge hepatocellular carcinoma: single institute's experience. *World J Surg* 2013; **37**: 2189-2196 [PMID: 23665818 DOI: 10.1007/s00268-013-2095-5]
38 **Moher D**, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; **6**: e1000097 [PMID: 19621072 DOI: 10.1371/journal.pmed.1000097]
39 **Wu CC**, Hwang CJ, Yang MD, Liu TJ. Preliminary results of hepatic resection for centrally located large hepatocellular carcinoma. *Aust N Z J Surg* 1993; **63**: 525-529 [PMID: 8391252]
40 **Jeng KS**, Jeng WJ, Sheen IS, Lin CC, Lin CK. Is less than 5 mm as the narrowest surgical margin width in central resections of hepatocellular carcinoma justified? *Am J Surg* 2013; **206**: 64-71 [PMID: 23388427 DOI: 10.1016/j.amjsurg.2012.06.010]
41 **van Lienden KP**, van den Esschert JW, de Graaf W, Bipat S, Lameris JS, van Gulik TM, van Delden OM. Portal vein embolization before liver resection: a systematic review. *Cardiovasc Intervent Radiol* 2013; **36**: 25-34 [PMID: 22806245 DOI: 10.1007/s00270-012-0440-y]
42 **Qian NS**, Liao YH, Cai SW, Raut V, Dong JH. Comprehensive application of modern technologies in precise liver resection. *Hepatobiliary Pancreat Dis Int* 2013; **12**: 244-250 [PMID: 23742768]
43 **Franco D**, Capussotti L, Smadja C, Bouzari H, Meakins J, Kemeny F, Grange D, Dellepiane M. Resection of hepatocellular carcinomas. Results in 72 European patients with cirrhosis. *Gastroenterology* 1990; **98**: 733-738 [PMID: 2153601]
44 **Belghiti J**, Guevara OA, Noun R, Saldinger PF, Kianmanesh R. Liver hanging maneuver: a safe approach to right hepatectomy without liver mobilization. *J Am Coll Surg* 2001; **193**: 109-111 [PMID: 11442247]
45 **Tsao JI**, Loftus JP, Nagorney DM, Adson MA, Ilstrup DM. Trends in morbidity and mortality of hepatic resection for malignancy. A matched comparative analysis. *Ann Surg* 1994; **220**: 199-205 [PMID: 8053742]
46 **Thompson HH**, Tompkins RK, Longmire WP. Major hepatic resection. A 25-year experience. *Ann Surg* 1983; **197**: 375-388 [PMID: 6299217]
47 **Iwatsuki S**, Starzl TE. Personal experience with 411 hepatic resections. *Ann Surg* 1988; **208**: 421-434 [PMID: 3178330]
48 **Castaing D**, Emond J, Kunstlinger F, Bismuth H. Utility of operative ultrasound in the surgical management of liver tumors. *Ann Surg* 1986; **204**: 600-605 [PMID: 3021072]

49 **Nanashima A**, Tobinaga S, Araki M, Nonaka T, Abo T, Hidaka S, Takeshita H, Sawai T, Nagayasu T. Double liver hanging manoeuvre for central hepatectomy. *HPB* (Oxford) 2009; **11**: 529-531 [PMID: 19816619 DOI: 10.1111/j.1477-2574.2009.00098.x]

50 **Hu JX**, Dai WD, Miao XY, Zhong DW, Liu W, Wei H. Bisegmentectomy VII-VIII for hepatocellular carcinoma in cirrhotic livers. *Hepatogastroenterology* 2007; **54**: 1311-1314 [PMID: 17708243]

51 **Han HS**, Yoon YS, Cho JY, Hwang DW. Laparoscopic Liver Resection for Hepatocellular Carcinoma: Korean Experiences. *Liver Cancer* 2013; **2**: 25-30 [PMID: 24159593]

52 **Giulianotti PC**, Coratti A, Sbrana F, Addeo P, Bianco FM, Buchs NC, Annechiarico M, Benedetti E. Robotic liver surgery: results for 70 resections. *Surgery* 2011; **149**: 29-39 [PMID: 20570305 DOI: 10.1016/j.surg.2010.04.002]

53 **Yoon YS**, Han HS, Cho JY, Kim JH, Kwon Y. Laparoscopic liver resection for centrally located tumors close to the hilum, major hepatic veins, or inferior vena cava. *Surgery* 2013; **153**: 502-509 [PMID: 23257080 DOI: 10.1016/j.surg.2012.10.004]

54 **Machado MA**, Kalil AN. Glissonian approach for laparoscopic mesohepatectomy. *Surg Endosc* 2011; **25**: 2020-2022 [PMID: 21136102 DOI: 10.1007/s00464-010-1483-2]

55 **Machado MA**, Herman P, Machado MC. Intrahepatic Glissonian approach for pedicle control during anatomic mesohepatectomy. *Surgery* 2007; **141**: 533-537 [PMID: 17383531 DOI: 10.1016/j.surg.2006.07.023]

56 **Ishii H**, Ochiai T, Murayama Y, Komatsu S, Shiozaki A, Kuriu Y, Ikoma H, Nakanishi M, Ichikawa D, Fujiwara H, Okamoto K, Kokuba Y, Sonoyama T, Otsuji E. Risk factors and management of postoperative bile leakage after hepatectomy without bilioenteric anastomosis. *Dig Surg* 2011; **28**: 198-204 [PMID: 21540607 DOI: 10.1159/000324042]

57 **Simons JP**, Hill JS, Ng SC, Shah SA, Zhou Z, Whalen GF, Tseng JF. Perioperative mortality for management of hepatic neoplasm: a simple risk score. *Ann Surg* 2009; **250**: 929-934 [PMID: 19855257 DOI: 10.1097/SLA.0b013e3181bc9c2f]

58 **Taylor M**, Forster J, Langer B, Taylor BR, Greig PD, Mahut C. A study of prognostic factors for hepatic resection for colorectal metastases. *Am J Surg* 1997; **173**: 467-471 [PMID: 9207156]

59 **Kyoden Y**, Imamura H, Sano K, Beck Y, Sugawara Y, Kokudo N, Makuuchi M. Value of prophylactic abdominal drainage in 1269 consecutive cases of elective liver resection. *J Hepatobiliary Pancreat Sci* 2010; **17**: 186-192 [PMID: 19727544 DOI: 10.1007/s00534-009-0161-z]

60 **Sun HC**, Qin LX, Lu L, Wang L, Ye QH, Ren N, Fan J, Tang ZY. Randomized clinical trial of the effects of abdominal drainage after elective hepatectomy using the crushing clamp method. *Br J Surg* 2006; **93**: 422-426 [PMID: 16491462 DOI: 10.1002/bjs.5260]

61 **Midorikawa Y**, Kubota K, Takayama T, Toyoda H, Ijichi M, Torzilli G, Mori M, Makuuchi M. A comparative study of postoperative complications after hepatectomy in patients with and without chronic liver disease. *Surgery* 1999; **126**: 484-491 [PMID: 10486600]

62 **Imamura H**, Seyama Y, Kokudo N, Maema A, Sugawara Y, Sano K, Takayama T, Makuuchi M. One thousand fifty-six hepatectomies without mortality in 8 years. *Arch Surg* 2003; **138**: 1198-1206; discussion 1206 [PMID: 14609867 DOI: 10.1001/archsurg.138.11.1198]

63 **Takayama T**. Surgical treatment for hepatocellular carcinoma. *Jpn J Clin Oncol* 2011; **41**: 447-454 [PMID: 21411469 DOI: 10.1093/jjco/hyr016]

64 **Nagino M**, Ebata T, Yokoyama Y, Igami T, Sugawara G, Takahashi Y, Nimura Y. Evolution of surgical treatment for perihilar cholangiocarcinoma: a single-center 34-year review of 574 consecutive resections. *Ann Surg* 2013; **258**: 129-140 [PMID: 23059502 DOI: 10.1097/SLA.0b013e3182708b57]

P- Reviewers: Chau GY, Cucchetti A, Li LQ, Riehle KJ
S- Editor: Ma YJ **L- Editor**: A **E- Editor**: Wang CH

Published by **Baishideng Publishing Group Inc**
8226 Regency Drive, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
http://www.wjgnet.com