What kind of energy devices should be used for laparoscopic liver resection? -Recommendations from a systematic review

Olivier Scatton, Raffaele Brustia, Giulio Belli, Juan Pekolj, Go Wakabayashi, Brice Gayet

What kind of energy devices should be used for laparoscopic liver resection? – Recommendations from a systematic review

Olivier Scatton, MD, PhD*§; Raffaele Brustia, MD*§; Giulio Belli, MD+; Juan Pekolj, MD#; Go Wakabayashi, MD, PhD§§; and Brice Gayet, MD, PhD**;

* Department of Hepatobiliary and Liver Transplantation Surgery, Hôpital Pitié-Salpêtrière, Assistance Publique-Hôpitaux de Paris, France.

§ Université Pierre et Marie Curie, Paris, France.

+ Department of General, HPB and Emergency Surgery, Nuovo Loreto Hospital, Naples, Italy.

Department of General Surgery, Hospital Italiano de Buenos Aires, Argentina.

§§ Department of Surgery, Iwate Medical University, Japan.

**Department of laparoscopic surgery, Institut Mutualiste Montsouris, Paris, France.

Corresponding author: Olivier SCATTON

Department of HPB surgery and liver transplantation

Hôpital Pitié-Salpêtrière

47-83 Boulevard de l' Hôpital

Paris 75013

Tel: + 33 (1) 42.17.56.52

Fax: + 33 (1) 42.17.56.17

E-mail: olivier.scatton@gmail.com

Section: Review

Key words: Liver Tumor, Laparoscopy, Liver Surgery, Energy Device, Transection, Sealing

Abbreviations: ED Energy Devices, POD Post Operative Day, LLR Laparoscopic Liver Resection, LR Laparoscopic Resection, MQ Moderate Quality, LQ Low Quality, VLQ Very Low Quality, LS LigaSure, US Ultrasonic Scalpel, HS Harmonic Scalpel, Stap Stapler Hepatectomy, RFAD Radio Frequency Assisted Device, ER Electronic resection, VS Vessel Sealer, Conv Converted, Hem & Bil Hemostasis and Biliostasis, M major hepatectomy, m minor hepatectomy

Word count: 2328

The authors declare no conflict of interest

ABSTRACT

Transection methods and hemostasis achievement have an impact on blood loss, and consequently on outcome and survival. Despite, no consensus exist on parenchymal transection or hemostasis techniques in laparoscopic liver resection (LLR). The aim of this review is to clarify the role of energy devices (ED) in LLR.

ED is a generator of mechanic or electric energy transfer to an operating tool, used for transection, sealing or both. Searches were performed in PubMed, PubMed Central, Cochrane, Embase, Google Scholar in human or animal. Each study quality was graded following the GRADE system.

From 1996 to 2014, 30 studies were found: 5 comparative, 1 prospective, 2 case-control, 16 case-series and some case-reports, with level of evidence ranging from Moderate to Very Low.

Since 2012, the Research and Development of new tools raised quicker than clinical studies could follow. The two mains techniques emerged are blind transection versus sharp dissection: due to the low quality and heterogeneity of the studies, no firm conclusion can be drown, but meticulous dissection of vessels usually never leads to vascular damage. As a matter of fact ED, even efficient and reliable, cannot replace the basic skills of hepatic surgery: sharp dissection, vascular control and elective sealing.

Introduction

Blood loss is one of the main cause that affects surgical outcome and survival rates. Transection methods and hemostasis achievement during parenchymal transection have obviously an impact on bleeding. Consequently, addressing the question of energy devices (ED) that might influence hemostasis quality appears a relevant issue. Interestingly, there is no consensual method to perform neither liver transection nor hemostasis by open approach. The Cochrane database recently analyzed 7 trials randomizing 556 patients (1). Only one randomized trial (2) included a significant number of patients and used a wide range of transection methods. This latter trial showed a superiority of the crush technique to reduce blood loss and to enhance transection velocity by open. However, it should be noted that Kellyclasy was mostly associated to Pringle maneuver while sharp dissection using CUSA was performed without clamping. This latter bias (mixing two modalities of clamping) renders this study less powerful.

Drawing recommendations for laparoscopic approach appears then tough, since the overall experience is weaker than open approach, and relies on a shorter follow-up. However, some principles of transection and hemostasis could be proposed based on this initial experience and may guide and help the beginners to start such laparoscopic liver resection (LLR) program. The pneumoperitoneum has a significant conceptual difference from open approach, because of its impact on backflow bleeding. Then, transposing open approach methods to laparoscopic approach should be done with caution. In this view, we realized a comprehensive review of the literature in order to give an overview of the different techniques and results: since ED are a small room, will also address or "cross the line" of transection. It should be emphasized that technology has continuously evolved during the last decade to a point that some tools may already appeared obsolete while others have just come up into the field. This rapid but exciting evolution often leads to report small series even sometime case reports. However, general rules of liver resection should be respected when a LLR is envisioned : meticulous dissection (sharp dissection), vessels and plans identification, elective hemostasis remain the cornerstones and the basic skills of LLR irrespective of the tools used.

Methods:

Digital searches were performed in PubMed, PubMed Central, Cochrane, Embase and Google Scholar among English literature with following keywords: [Energy Devices] AND [Liver Surgery] OR [Laparoscopic Liver Surgery] OR [Laparoscopy Liver], in human or animal experimental models without any chronological limit. A cost analysis is not provided. For each study the Quality of Evidence was assessed on four level scale ranging from Very Low Quality to High Quality, according to the GRADE system (Table 1) (3).

Definition of Energy Devices

For sake of clarity, ED in this study will be defined as any generator responsible of a mechanic or electric energy transfer to an operating tool. ED could be used as transection tools, sealing tools or both. The association of the different types of devices (two ED during the same procedure, or two ED integrated in a unique tool) and the various conditions of use (during a pure, hand assisted or hybrid LLR) lead to confusion. This heterogeneity makes the interpretation of the literature sometime difficult and represents a major limitation of all the publications. Table 2 gives a summary of the different types of devices according to their main function and the energy, which they are based on. We decide to focus on ED that deliver coagulation function. However, these devices could also be used as a dissection tool (bipolar, LigaSure™, Ultracision ™, etc…).

Results

From 1996 to 2014, 30 studies were found and are summarized in Table 3 and 4. To date, neither meta-analysis nor Cochrane review have been focusing on transection or hemostatic ED in laparoscopic liver surgery. Most of the publications report retrospective single-center experience. There are 5 comparative studies with one prospective. Two case-control studies, 16 animals or human case-series and some case reports were found. Only one randomized, prospective, single blind study was found: two groups of 12 patients each were prospectively allocated to a bipolar (LigaSure TM) versus ultrasonic forceps group, but laparoscopic resection was realized only in two patients, one each group. This latter study could not be considered as high-grade trial due to methodological bias. Overall, according to the GRADE system (3), the level of evidence ranges from Moderate to Very Low.

Discussion:

Due to the heterogeneity of the studies and owing to the variety and/or association of the devices, this comprehensive review failed to demonstrate the superiority of a specific technique over another. Overall, two mains techniques have emerged: blind transection using stapler or radiofrequency-assisted device and sharp dissection using ultrasound dissector (CUSA™) or crush with bipolar, sealing or ultrasonic shears. It should be stressed that the former technique may lead to severe bleeding by vascular injury or misfiring, during deep parenchymal transection (12, 20, 23, 25, 27, 31). If a sharp dissection is applied with vessels identification first, followed by control and sealing, no superiority among the different tools can be stated. The efficiency depends on the vessels diameter with new devices allowing to seal up to 7 mm.

Comparing the results of pure LLR with pneumoperitoneum (that may have an independent impact on bleeding) and other assisted techniques (that are theoretically less effective on the venous backflow) (23, 28) render more complex the interpretation of the ED results. Most available data are from case-series, retrospective and comparative studies with only one prospective. The study by Campagnacci *et al.* (26) despite being a randomized control trial highlighting lower blood loss and operative duration with Ligasure™ than Ultracision™, failed to provide high-level evidence because of methodological weakness: neither calculation of the sample size nor end-point criteria were clearly provided and consequently, no firm conclusion can be drawn. This study therefore included only two laparoscopic hepatectomy, being all the others performed by open approach. Although considered as Medium Quality, this unique trial cannot provide robust statements; the overall quality level of all other reported experience is low or very low according to the GRADE system (3).

However, some advices and tendencies could be provided. Meticulous dissection of the vessel usually never leads to vascular damage: for this reason, blind manipulation should never be attempted (7, 23, 34). As well as open liver surgery, respecting the basics with sharp dissection, visualization of the vascular structures, control and their elective sealing appear to be the safest method especially as a beginner. As a matter of fact ED, even efficient and reliable, cannot replace the acquisition of basic skills of hepatic surgery. The main reason to privilege an ED is the ability to provide a precise dissection to separate vascular structures in a controlled fashion: in this context, all the sealing and ED seem equally efficient on vessels hemostasis until to reach 5 mm diameter. For sake of safety, blind use of the ultrasonic shears should be limited to superficial layers of the parenchyma. In the same trend, blind transection and hemostasis using stapler or radiofrequency should be limited to experienced surgeons who can face a massive bleeding with confidence (23, 27). Caution should be made with the use of Argon Beam: particularly for beginners in LLR, we recommend to avoid its use since this latter has been associated to five life-threatening events and 2 deaths, directly related to gas embolism (18). Analysis of the literature and experienced surgeons propose its use respecting some rules: avoiding direct application close to the parenchymal surface, no pulverization on small hepatic veins holes, and venting the abdomen (open trocars) in order to decrease the intraperitoneal pressure (18). No serious bleeding can be controlled by Argon Beam, and it need to be fixed by elective hemostasis, with stiches, clips or bipolar coagulation. Backflow bleeding could be immediately managed by a temporary increase of pneumoperitoneum pressure up-to 20 mmHg. Last, if some of the analyzed ED have been used to transect portal structures, none of them have been clearly assessed for biliostasis (5, 8, 9, 12 – 15, 17, 20, 21, 23, 24, 26, 31, 32). A specific trial focusing on ED and biliostasis is highly required.

Since 2012, the Research and Development of new tools has raised quicker than clinical studies could follow. From this comprehensive review, no specific type of ED has clearly emerged and none is recommended over another, in laparoscopic surgery, according to the literature. The level of evidence is however low, and prospective controlled trials are still required. Respecting basics of HPB surgery is the rule, and emerged as the safest method irrespective of the ED used for transection: sharp dissection, vascular control and elective sealing.

Author Contribution

Study design: Raffaele Brustia, Brice Gayet and Olivier Scatton

Acquisition of data: Raffaele Brustia, Olivier Scatton

Analysis and interpretation: Raffaele Brustia, Olivier Scatton

Manuscript drafted by: Raffaele Brustia, Olivier Scatton

Revision: Raffaele Brustia, Giulio Belli, Juan Pekolji, Go Wakabayashi, Brice Gayet, Olivier Scatton

Statistical advice: not applicable

Raferences

(1) Gurusamy KS, Pamecha V, Sharma D, Davidson BR. Techniques for liver parenchymal transection in liver resection. Cochrane Database Syst Rev. 2009; 21

(2) Lesurtel M, Selzner M, Petrowsky H, McCormack L, Clavien PA. How should transection of the liver be performed?: a prospective randomized study in 100 consecutive patients: comparing four different transection strategies. Ann Surg. 2005;242:814-22

(3) Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE Working Group. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 2008;336:924-6.

(4) Weber JC, Navarra G, Habib NA, Bachellier P, Jaeck D. Laparoscopic radiofrequency-assisted liver resection (Abstract). Surg Endosc 2003; 17: 834

(5) Imura S, Ikegami T, Morine Y. Advanced application of a vessel sealing system for major hepatic resections. Surg Endosc 2008; 22: 272-274

(6) Sotiropulos GC, Stamopoulos P, Charalampoudis P, Molmenti EP, Voutsarakis A, Kouraklis G. Totally left laparoscopic hepatectomy using the torsional ultrasonic scalpel. World J Gastroenterol 2013; 19: 5929-5932

(7) Matern U, Pauly E, Ahrens M, Haberstroh J, Waninger J, Salm R, et al. Laparoscopic liver resection in domestic pigs using an ultrasonic dissector. Min Invas Ther & Allied Technol 1996; 5:5-8

(8) Croce E, Olmi S, Bertolini A, Erba L, Magnone S. Laparoscopic Liver Resection with Radiofrequency. Hepato-gastroenterology 2003; 50: 2088-2092

(9) Felekouras E, Papacostantinou I, Pikoulis E, Kontos M, Georgopoulos S, Papalois A, et al. Laparoscopic liver resection using radio frequency ablation in a porcine model. Surg Endosc 2005; 19:1237-1242

(10) Toyama Y, Miake R, Son K, Yoshida S, Usuba T, Nojiori, et al. Three-port laparoscopic partial hepatectomy using an ultrasonically activated device (USAD). J Hepatobiliary Pancreat Surg 2006; 13:317-322

(11) Bachellier P, Ayav A, Pai M, Weber JC, Rosso E, Jaeck D et al. Laparoscopic liver resection assisted with radiofrequency. 2007 Am J Surg; 193:427-430

(12) Yao P, Gunasegaram A, Ladd LA, Chu F, Morris DL. Inline radiofrequency ablation-assisted laparoscopic liver resection: first experiment with stapling device. ANZ J Surg 2007;

(13) Tsalis K, Blouhos K, Vasiliadis K, Kalfadis S, Tsachalis T, Savvas I, et al. Bloodless laparoscopic liver resection using radiofrequency thermal energy in the porcine model. Surg Laparosc Endoscop Percutan Tech 2007; 17:22-25

(14) Dulucq JL, Wintringer P, Rashid LM. Virtually bloodless laparoscopic liver resection of recurrent hepatoma with a new laparoscopic sealer device. Surg Laparosc Endosc Percutan Tech 2007; 17:413-415

(15) Navarro A, Burdio F, Berjano EJ, Guemes A, Sousa R, Rufas M, et al. Laparoscopic blood-saving liver resection using a new radiofrequency-assisted device: preliminary report of an in vivo study with pig liver. Surg Endosc 2008; 22:1384-1391

(16) Abdouljod MS, Arenas J, Yoshida A, Kim D. New application of bipolar vapour plasma coagulation system for laparoscopic major liver resections. Surg Endosc 2008; 22:426-429

(17) Aldrighetti L, Pulitanò C, Arru M, Catena M, Guzzetti E, Casati M, et al. Ultrasonic-mediated laparoscopic liver transection. Am J Surg 2008; 195:270-272

(18) Ikegami T, Shimada M, Imura S, Nakamura T, Kawahito S, Morine Y, et al. Argon gas embolism in the application of laparoscopic microwave coagulation therapy. J Hepatobiliary Pancreat Surg 2009; 16:394-398

(19) Somasundar P, Boutros C, Helton WS, Espat NJ. Evaluation of a bipolar radiofrequency device for laparoscopic hepatic resection: technique and clinical experience in 18 patients. HPB 2009; 11: 145-149

(20) Akyildiz HY, Morris-Stiff G, Aucejo F, Fung J, Berber E. Techniques of radiofrequency-asssisted precoagulation in laparoscopic liver resection. Surg Endosc 2011; 25:1143-1147

(21) Uchiyama H, Itoh S, Higashi T, Korenaga D, Takenaka K. Pure laparoscopic partial hepatectomy using a newly developed vessel sealing device, biclamp. Surg Laparosc Endosc Percutan Tech 2013; 23:e116-e118

(22) Mortensen MR, Andersen KJ, Kissmeyer-Nielsen P. Acceptable results using small radiofrequency ablation needle for liver parenchyma transection. Dan Med J 2014; 61:A4822

(23) Gumbs AA, Gayet B, Gagner M. Laparoscopic liver resection: when to use the laparoscopic stapler device. HPB 2008; 10:296-303

(24) Slakey DP. Laparoscopic liver resection using a bipolar vessel-sealing device: LigaSure. HPB 2008; 10:253-255.

(25) Sarpel U, Ayo D, Newman E. Choice of device for parenchymal transection in laparoscopic hepatectomy. Reports from Surgical Technology International XXII, 2012.

(26) Campagnacci R, De Sanctis A, Balardelli M, Di Emiddio M, Organetti L, Nisi M, et al. Hepatic resections by means of electrothermal bipolar vessel device (EBVS) LigaSure V: early experience. Surg Endosc 2007; 21:2280-2284

(27) Hompes D, Aerts R, Penninckx B, Topal B. Laparoscopic liver resection using radiofrequency coagulation. Surg Endosc 2007; 21:175-180

(28) Kamiyama T, Kurauchi N, Nakagawa T, Nakanishi K, Kamachi H, Matsushita M, et al. Laparoscopic hepatectomy with the hook blade of ultrasonic coagulating shears and bipolar cautery with a saline irrigation system. J Hepatobiliary Pancreat Surg 2005; 12:49-54

(29) Mbah NA, Brown RE, Bower MR, Scoggins CR, McMasters KM, Martin RC. Differences between bipolar compression and ultrasonic devices for parenchymal transection during laparoscopic liver resection. HPB 2012; 14:126-131

(30) Nanashima A, Abo T, Arai J, Takagi K, Matsumoto H, Takeshita H, et al. Usefulness of vessel-sealing devices combined with crush clamping method for hepatectomy: a retrospective cohort study. Int J Surg 2013;11:891-897

(31) Buell JF, Gayet B, Han HS, Wakabayashi G, Kim HM, Belli G, et al. Evaluation of stapler hepatectomy during a laparoscopic liver resection. HPB 2013;15:845-850

(32) Berber E, Akyuz M, Aucejo F, Aliyev S, Aksoy E, Birsen O, et al. Initial experience with a new articulating energy device for laparoscopic liver resection. Surg Endosc 2014;28:974-978

(33) Frenken C, Lau B, Putchakayala K, DiFronzo LA. Comparison of short-term outcomes in laparoscopic vs open hepatectomy. JAMA Surg 2014 jul 30;

(34) Wakabayashi G, Cherqui D, Geller DA, Han HS, Kaneko H, Buell JF. Laparoscopic hepatectomy is theoretically better than open hepatectomy: preparing for the 2nd International Consensus Conference on Laparoscopic Liver Resection. J Hepatobiliary Pancreat Sci. 2014;21:723-31.

Table 1: GRADE System classification

Table 2: Energy devices classification

Table 3: Case reports, Case series (Human/Animal), Reviews.

Table 4: Randomized Clinical Trial, Comparative, Case-Control studies.

Table 1 **GRADE SYSTEM**

Quality of Evidence	*Definition*
High Quality	*Further research is very unlikely to change our confidence in the estimate of effect*
Medium Quality	*Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate*
Low Quality	*Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate*
Very Low Quality	*Any estimate of effect is very uncertain*

Instrument	Way of use	Drawbacks	Example
Precoagulators	Blind	Structure injuries	Radiotherapy Assisted Device
Ultrasonic shears	Blind or elective	Injury of biliary or vessels structure if blind but applicable for superficial parenchyma Not applicable for diameter larger than 5 mm	Ultracision™
Vessels sealing device			
Bipolar	Elective or crush Sealing or transection tool	Useful for small vessels less than 5 mm Caution on vena cava	Bipolar forceps
Sealing	Elective coagulation or crush Section after coagulation 7mm of diameter possible	Caution when blind dissection with vascular structure	Ligasure™ Enseal™ Thunderbeat™: sealing alone possible, section only with sealing
Sealing simultaneous or sequential section	7 mm possible Elective or crush Efficient on small branches of the vena cava	Caution to Injury when blind and deep transection	Thunderbeat™

TABLE 3. Case reports, Case series (Human/Animal), Reviews.

Author	Ref.	Year	Study type	Animal Human	Study device	Associated devices	Endpoint	Hemostasis Biliostasis	Hepatectomy	Patients			Indication		Blood loss mL (mean)		Surgery Duration min (mean)		GRADE	Conclusions
										n	Lap	Open	Benign	Malign	Lap	Open	Lap	Open		
Weber JC	4	2003	case report	Human	RFAD		Transection Sealing	Hemostasis	?	1	1	\	1	\	75	\	300	\	VLQ	Radiofrequency assisted is useful
Imura S.	5	2008	case report	Human	LS vs CUSA		Transection Sealing	Hem & Bil	M & m	4	?	?	0	4	247	\	350	\	VLQ	Ligasure feasible for sealing glissonian pedicle and hepatic veins UNDER PRINGLE
Sotiropulos GC.	6	2013	case report	Human	US		Transection	Hemostasis	M	1	1	\	1	\	400	\	240	\	VLQ	Ultrasonic scalpel is effective in transection and sealing of small elements
Matern U.	7	1996	case-series	Animal	CUSA		Transection	\	m	7	7	0	\	\	400	\	160	\	LQ	Laparoscopic liver resection is feasible with proper dissection of intrahepatic bile ducts and blood vessels.
Croce E.	8	2003	case-series	Human	LS		Transection Sealing	Hem & Bil	m	7	7	0	5	2	120	\	90	\	LQ	Ligasure laparoscopic hepatectomy is useful
Felekouras E.	9	2005	case-series	Animal	RFAD		Transection Sealing	Hem & Bil	m	8	8	0	\	\	45-60	\	90	\	LQ	Left lateral section is feasible with the Radiofrequency device
Totama Y.	10	2005	case-series	Human	Ultrasonic activated device + Microwave device		Transection Sealing	Hemostasis	m	9	9	0	0	9	77	\	113	\	LQ	Minor laparoscopic hepatectomies with 3 ports is feasible with ultrasonically activated device
Bachellier P.	11	2007	case-series	Human	RFAD	RFAD + scissors	Sealing	Hemostasis	m	18	18	3 (conv)	3	15	121	\	213	\	LQ	Radiofrequency device useful for liver transection and sealing during laparoscopic hepatectomies
Yao P.	12	2007	case-series	Animal	RFAD	RFAD+Diathermy RFA+Stap Diathermy Stap	Sealing	Hem & Bil	M & m	8	8	0	\	\	variable	\	NA	\	LQ	InlineRFA combined with stapler or diathermy coagulation is effective in lowering blood loss during laparoscopic hepatectomy
Tsalis K.	13	2007	case-series	Animal	RFAD	RFAD used as CUSA	Transection Sealing	Hem & Bil	M & m	15	15	0	\	\	27	\	119	\	LQ	Laparoscopic Radiofrequency assisted heaptectomy in animal is feasible and safe
Dulucq JL.	14	2007	case-series	Human	RFAD		Transection Sealing	Hem & Bil	m	2	2	0	0	2	low	\	NA	NA	VLQ	Radiofrequency device render laparoscopic hepatectomies easier

Navarro	15	2008	case-series	Animal	RFAD		Transection Sealing	Hem & Bil	M	8	8	10 (from another study)	\	\	26	70	13	12	LQ	Radiofrequency device is effective in animal laparoscopic, hand assisted, hepatectomy. Greater depth of coagulation than open model.
Abdouljoud MS.	16	2008	case-series	Human	Vapor plasma coagulation	Stapler	Transection	Hemostasis	M & m	11	11	0	11	0	?	\	?	\	VLQ	Vapor plasma device is useful for laparoscopic hepatectomies
Aldrighetti L.	17	2008	case-series	Human	SonoSurg (ultrasonic coagulator and dissector)	Stapler	Transection Sealing	Hem & Bil	M & m	14	14	\	5	9	150	\	340	\	LQ	Device simple, reusable and safe for laparoscopic hepatectomies
Ikegami T.	18	2009	case-series	Human	Argon laser	CUSA	Haemostasis	Hemostasis	?	7	4	3	3	4	NA	NA	NA	NA	VLQ	Argon beam laser can cause life threatening gas embolism; risk factors are pneumoperitoneum, hepatic needle punctures, hepatic veins injuries and direct liver-argon contact
Somasundar P.	19	2009	case-series	Human	Bipolar RFAD	RFAD Stap	Transection Sealing	Hemostasis	M & m	18	18	0	5	13	178	\	114	\	LQ	Bipolar radiofrequency safe and useful
Akyildiz HY	20	2011	case-series	Human	Unipolar RFAD vs Bipolar RFAD		Transection Sealing	Hem & Bil	m	31	31	1 (conv)	3	28	89 vs 224	\	242 vs 224	\	LQ	RF device allows precoagulation "safety margin" of transected section. Disadvantage is fragility of precoagulated liver surface that can break during traction and cause bleeding difficult to control
Uchiyama H.	21	2012	case-series	Human	Bipolar sealing device		Transection Sealing	Hem & Bil	m	9	9	0	1	8	417	\	423	\	LQ	Bipolar sealing device is useful for laparoscopic hepatectomies
Mortensen MR.	22	2014	case-series	Human	RFAD		Transection	Hemostasis	M & m	40	0	40	4	36	\	426	\	52	MQ	Despite low blood loss amount, bile fistula in 6/40 in major hepatectomies and costly procedure lead to abandon the use of RF device for major hepatectomies.
Gumbs AA.	23	2008	review	Human	Stap	CUSA HS Bipolar	Sealing	Hem & Bil	\	\	\	\	\	\	\	\	\	\	VLQ	Lap staper can be useful with other instruments
Slakey DP.	24	2008	review	Human	LS		Transection Sealing	Hem & Bil	\	\	\	\	\	\	\	\	\	\	VLQ	Ligasure is effective for vascular and bile sealing. Ligasure is not the only device needed

Sarpel U.	25	2012	review	Human	Stap RFAD CUSA US LS	Stap RFAD CUSA US LS	Transection	Hemostasis	\	\	\	\	\	\	\	\	\	\	VLQ	No single method of liver trasection is superior to another

MQ Moderate Quality, LQ Low Quality, VLQ Very Low Quality, LS LigaSure, US Ultrasonic Scalpel, HS Harmonic Scalpel, Stap Stapler Hepatectomy, RFAD Radio Frequency Assisted Device, ER Electronic resection, VS Vessel Sealer, Conv Converted, Hem & Bil Hemostasis and Biliostasis, M major hepatectomy, m minor hepatectomy

TABLE 4. Randomized Clinical Trial, Comparative, Case-Control studies.

Author	Ref.	year	study type	Animal human	Study device	Associated devices	Endpoint	Hemostasis Biliostasis	Hepatectomy	Patients			Indication		Blood loss mL (mean)		Surgery Duration min (mean)		GRADE	Conclusions
										n	Lap	Open	Benign	Malign	Lap	Open	Lap	Open		
Campagnacci R	26	2007	RCT	Human	LS vs HS		Transection Sealing	Hem & Bil	M & m	24	2	22	3	21	210 LS vs 485 HS	\	136 LS vs 187 HS	\	MQ	Ligasure hepatectomy is safe and effective with less blood loss
Hompes D	27	2007	Comparative	Human	RFAD	CUSA +/- RFAD	Transection	Hemostasis	M & m	45	42	3	10	35	200 RFAD - vs 200 RFAD +	\	105 RFAD – vs 120 RFAD+	\	LQ	RF assisted device does not reduce blood loss in major hepatectomy (10 pt with intraoperative haemorrhage, blood loss 850 - 4000 ml)
Kamiyama T	28	2005	Comparative	Human	HS Bipolar Stap		Transection Sealing	Hemostasis	m	18	8	10 (from another study)	0	8	177	\	181	\	LQ	Feasibility of Laparoscopic Left lateral section with Harmonic scalpel and bipolar + minilaparotomy and open instruments
Mbah NA	29	2011	Comparative	Human	Bipolar compression device vs US		Transection Sealing	Hemostasis	M & m	54	54	0	0	54	100 bip vs 175 US	\	130 bip vs 180 US	\	LQ	Transection with Bipolar compression device is shorter than Ultrasonic Scalpel in laparoscopic major and minor hepatectomies
Nanashima A	30	2013	Comparative	Human	LS vs crushclamping		Transection Sealing	Hemostasis	M & m	150	21	129	30	120	279 LS vs 1040 crush	\	300 LS vs 418 crush	\	MQ	LS reduce blood loss, transection time and hospital stay.
Buell J	31	2013	Comparative	Human	Electrosurgery vs Stap		Transection Sealing	Hem & Bil	M & m	1499	1471	28 (conv)	738	761	100 Stap vs 200 ER	\	156 Stap vs 186 ER	\	MQ	Lower blood loss, operative time, length of stay, with SH than EH at univariate analysis.
Berber E	32	2013	case-control	Human	Vessel sealer + Vs Vessel sealer -		Transection Sealing	Hem & Bil	m	14	14	\	3	11	194 VS+ vs 233 VS-	\	289 VS+ vs 430 VS-	\	LQ	Shorter transection time with Vessel Sealer
Frenken C	33	2014	case-control	Human	Lap vs Open CUSA or LS	Electrocautery Clips SH	Transection Sealing	Hemostasis	M & m	104	52	52	21	83	237	387	219	198	MQ	Less bleeding in LH

RCT Randomized Clinical Trial, MQ Moderate Quality, LQ Low Quality, VLQ Very Low Quality, LS LigaSure, US Ultrasonic Scalpel, HS Harmonic Scalpel, Stap Stapler Hepatectomy, RFAD Radio Frequency Assisted Device, ER Electronic resection, VS Vessel Sealer, Conv Converted, Hem & Bil Hemostasis and Biliostasis, M major hepatectomy, m minor hepatectomy