

## Outcomes of simple saline-coupled bipolar electrocautery for hepatic resection

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### Abstract

**AIM:** To evaluate the application of bipolar coagulation (BIP) in hepatectomy by comparing the efficacy of BIP alone, cavitron ultrasonic surgical aspirator (CUSA) + BIP and conventional clamp crushing (CLAMP).

**METHODS:** Based on our database of patient records, a total of 380 consecutive patients who underwent hepatectomy at our hospital were retrospectively studied for the efficacy of BIP alone, CUSA + BIP and CLAMP. Of all the patients, 75 received saline-coupled BIP (Group A), 53 received CUSA + BIP (Group B), and 252 received CLAMP (Group C). The pre-, mid-, and postoperative clinical manifestations were compared, and the effects of those maneuvers were evaluated.

**RESULTS:** There was no obvious difference among the preoperative indexes between the different groups. The operative time was longer in Groups A and B than in

Group C ( $P < 0.001$  for both). The amount of bleeding and the rate of transfusion during the operation were significantly higher in Group C than in Groups A and B ( $P < 0.001$  for all). The incidence of postoperative complications in Group C (46.43%) was higher than that in Groups A (30.67%,  $P = 0.015$ ) and B (28.30%,  $P = 0.016$ ). The patients' liver function recovery and postoperative hospital stay were not significantly different. BIP could decrease intraoperative hemorrhage and postoperative complications compared to CLAMP.

**CONCLUSION:** Simple saline-coupled BIP should be considered a safe and reliable technique for liver resection to decrease intraoperative hemorrhage and postoperative complications.

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**Key words:** Hepatectomy; Surgical procedures; Blood loss; Complications; Hospital stay; Comparative study

**Core tip:** The aim of this clinical study is to recommend a simplified and feasible surgical technique for liver resection. In this study, we found that simple saline-coupled bipolar electrocautery (BIP) could reduce blood loss, blood transfusion and complications compared with clamp crushing. Therefore, saline-coupled BIP can accomplish hepatectomy excellently and would be a safe and reliable technique that is easily applied in liver resection.

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## INTRODUCTION

Hepatectomy and its related surgical complications remain major concerns for surgeons operating on the liver. Controlling hemorrhage, shortening the time of inflow occlusion, and performing anatomical limited resections are important strategies for safe and careful dissection of the liver parenchyma. For patients with hepatocellular carcinoma (HCC), massive hemorrhage and blood transfusions are the powerful determinants of early liver failure and immune repression, which cause adverse effects, often leading to early tumor recurrence, and seriously affecting long-term survival after resection<sup>[1,2]</sup>.

Advancements in the theory and practice of liver surgery have led to the invention of different approaches, such as the cavitron ultrasonic surgical aspirator (CUSA), water jet scalpel, monopolar floating ball, ligasure, microwave and other procedures to transect the liver parenchyma favorably. CUSA combined with bipolar coagulation (BIP) and conventional clamp crushing (CLAMP) are favored by most surgeons at many medical centers<sup>[3-6]</sup>. Notably, it is critical to expose vasculature and decrease blood loss during hepatic resection. As a device for hemostasis, BIP has aroused increased interest because of its excellent hemostatic effect and low thermal damage to surrounding tissues. Because of these potential benefits, increasing numbers of surgeons are also applying BIP in hepatectomy as a preferred method. Although various BIP devices and techniques have been developed in some centers, the efficacy of BIP alone is actually unclear, hindering its wide adoption. This retrospective cohort analysis investigated the efficacy of BIP alone, CUSA + BIP and CLAMP.

## MATERIALS AND METHODS

### Patient characteristics

Between April 2011 and May 2013, data from 380 consecutive patients who underwent liver resection at our hospital were collected, based on our database of patient records. Through CT, MRI or pathologic examinations of these patients, the following was detected: 245 malignant tumors (including 179 HCC), 47 benign tumors (such as hemangioma, hamartoma, and focal nodular hyperplasia), 70 cases of hepatolithiasis and 18 cases of other diseases (such as liver abscess, polycystic liver, and hepatic hydatid). Detailed characteristics of those patients are shown in Table 1. This study was approved by the ethics board of The First Affiliated Hospital of Chongqing Medical University, and written informed consent was obtained from all patients.

### Study design

Patients were divided into 3 groups: Group A, patients treated by BIP, with BIP administered by Shuyou surgical instrument Inc, Zhejiang, China, and Force EZ Electrosurgical Generator; Covidien Inc, Boulder, Colo, United States; bipolar, 70W, Figure 1; Group B, patients treated by CUSA, with CUSA administered by Cavitron

Ultrasonic Surgical Aspirator System 200; Valleylab Inc, Boulder, Colo, United States; amplitude, 70W; and Group C, patients receiving combined treatment of BIP and CLAMP. All patients received general anesthesia. For fair comparison and avoidance of the potential for patient selection bias with these various techniques by different surgeons, three experienced hepatic surgeons in our unit performed all operations. We chose one technique over the other due to equipment availability or change over time. CUSA and CLAMP were performed between April 2011 and April 2012, and BIP was performed from April 2012 to May 2013. There is no significant difference in the characteristics of the three groups of patients ( $P > 0.05$ ), including the fibrotic or cirrhotic liver and tumor condition. Except for BIP, no other hemostatic device (*i.e.*, argon beam coagulator) was used on any of these patients undergoing hepatic resection. The operation time (min), intraoperative bleeding (mL), the rate of blood transfusion and the amount of packed red blood cells transfusion (the amount of bleeding more than 25% of the blood volume or hemoglobin lower than 70 g/L was the indication of transfusion) were analyzed.

### Surgical procedure

Hepatectomy was performed following standard procedures. The hemostatic forcep tip was moved vertically to the resectional line when transecting the parenchyma by CLAMP. The clamp held approximately 1 cm of the liver parenchyma each time. Hepatic parenchyma cells were disrupted and emulsified by vibration, and the bile ducts and vessels were preserved using CUSA; hemostasis was performed by BIP. The procedure of hepatic resection by saline-coupled BIP alone had water dripping from two sides of the bipolar electrocoagulator, and the power was set at 70 watt. BIP was combined with scissors and sucker for disruption, washing, hemostasis and suction. However, vessels of more than 3 mm in diameter were exposed to ligate, and vessels less than 3 mm in diameter were coagulated (Figure 2). Our results demonstrated that most of the hepatectomies did not require blocking the portal vein blood supply.

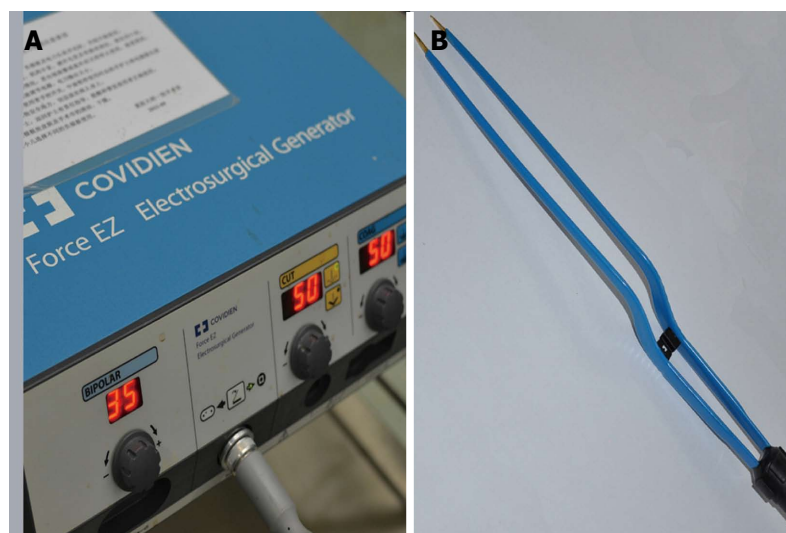
### Postoperative management

Postoperatively, all patients were admitted to the ICU ward for rehabilitation. Postoperative outcomes included recovery of liver function, length of postoperative hospitalization, and the rate of complications. To monitor liver function, albumin (ALB, g/L), total bilirubin (TB,  $\mu\text{mol/L}$ ), alanine transaminase (ALT,  $\mu\text{mol/L}$ ), and aspartate aminotransferase (AST,  $\mu\text{mol/L}$ ) levels were measured on days 1 and 3 after resection. Complications for monitoring included: abdominal cavity infection, bile leakage, acute hepatic failure, respiratory failure, severe hemorrhage, reoperation within 30 d of surgery, hyperbilirubinemia, sepsis, intestinal obstruction, pulmonary embolism, hepatorenal syndrome, death within 30 d of surgery, pleural effusion, incision infection, incision dehiscence, pulmonary infection, delayed recovery of liver

**Table 1 Characteristics of patients undergoing liver resection *n* (%)**

Baseline characteristic		BIP ( <i>n</i> = 75)	CUSA + BIP ( <i>n</i> = 53)	CLAMP ( <i>n</i> = 252)	<i>P</i> value	
Age <sup>1</sup> (yr)		54.1 (17-81)	50.7 (16-85)	53.7 (19-81)	0.256	
Sex	Male	47 (62.67)	33 (62.26)	155 (61.51)	0.981	
Cause of surgery	HCC	38 (50.67)	20 (37.74)	121 (48.02)	0.868	
	Other malignancy	14 (18.67)	9 (16.98)	43 (17.06)		
	Benign tumour	8 (10.66)	10 (18.87)	29 (11.51)		
	Intrahepatic stone	12 (16.00)	11 (20.75)	47 (18.65)		
	Others	3 (4.00)	3 (5.66)	12 (4.76)		
Child-Pugh	A	56 (74.67)	41 (77.36)	210 (83.33)	0.196	
	B	19 (25.33)	12 (22.64)	42 (16.67)		
ICG-R15	< 15	67 (89.33)	46 (86.79)	219 (86.90)	0.849	
	≥ 15	8 (10.67)	7 (13.21)	33 (13.10)		
Background liver	Normal	31 (41.33)	31 (58.49)	130 (51.58)	0.359	
	Chronic hepatitis	24 (32.00)	12 (22.64)	61 (24.21)		
	Cirrhosis	20 (26.67)	10 (18.87)	61 (24.21)		
Level of surgeon	Chief doctor	31 (20.67)	29 (27.36)	127 (25.20)	0.069	
	Deputy director doctor	56 (37.33)	40 (37.74)	226 (44.84)		
	Attending doctor	63 (42.00)	37 (34.90)	151 (29.96)		
Type of resection	Extended	13 (17.33)	8 (15.09)	35 (13.89)	0.347	
	Hemihepatectomy					
	Hemihepatectomy	33 (44.00)	20 (37.74)	108 (42.85)		
	Lobectomy	29 (38.67)	21 (39.62)	92 (36.51)		
	Segmentectomy	0	4 (7.55)	13 (5.16)		
	Wedge resection	0	0	4 (1.59)		
	Tumor	Yes	60 (80.00)	39 (73.58)		193 (76.59)
Tumor condition	Size, < 30 mm	14 (23.33)	7 (17.95)	56 (29.02)	0.300	
	≥ 30 mm	46 (76.67)	32 (82.05)	137 (70.98)		
	Single	36 (60.00)	31 (79.49)	115 (59.59)		0.059
	Multiple	24 (40.00)	8 (20.51)	78 (40.41)		
	Superficial	36 (60.00)	28 (71.79)	141 (73.06)		
Deep	24 (40.00)	11 (28.21)	52 (26.94)			

<sup>1</sup>*P* analysis of variance (*F*). HCC: Hepatocellular carcinoma; BIP: Bipolar coagulation; CUSA: Cavitron ultrasonic surgical aspirator; CLAMP: Conventional clamp crushing; ICG-R15: Indocyanine green retention rate at 15 min.



**Figure 1 Operative devices used for single saline-coupled bipolar electrocautery.** A: Force EZ electrocautery generator; B: Bipolar electrocautery (bilateral dribbling water) for hepatectomy.

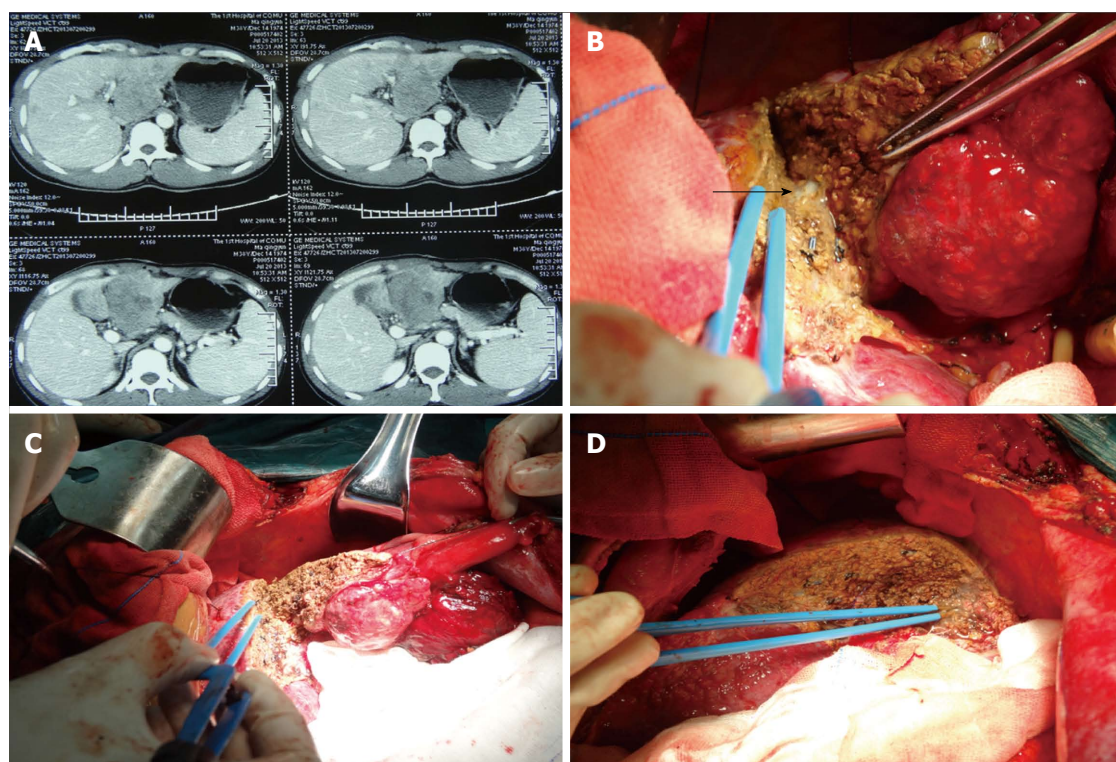
function, seroperitoneum, pulmonary atelectasis and deep vein thrombosis.

**Statistical analysis**

For statistical analysis, measurement values are expressed

as mean with standard deviation or median with inter-quartile range. The differences in the measurement values were detected by ANOVA (*F*) or Kruskal-Wallis (*H*) rank test. The differences in enumeration data were compared by  $\chi^2$  or Kruskal-Wallis (*H*) rank test. The difference





**Figure 2** A representative case with left liver cancer resected by single saline-coupled bipolar electrocautery. A: Computerized tomography imaging on admission; B-D: The surgical process of hepatectomy by single bipolar electrocautery (BIP). The arrow indicates a liver vessel exposed by BIP.

**Table 2** Surgical outcomes *n* (%)

Outcome	BIP ( <i>n</i> = 75)	CUSA+BIP ( <i>n</i> = 53)	CLAMP ( <i>n</i> = 252)	<i>P</i> value
Blood loss <sup>1</sup>				
≤ 1000 mL	73 (97.33)	48 (90.57)	192 (76.19)	< 0.001
> 1000 mL	2 (2.67)	5 (9.43)	60 (23.81)	
Intraoperative transfusion <sup>1</sup>	12 (16.00)	7 (13.21)	117 (46.43)	< 0.001
Blood loss (mL) median <sup>2</sup>	315 (50-1800)	328 (50-2000)	583 (50-5000)	< 0.001
Transfusion of RBC (mL) median	37 (0-800)	56 (0-1200)	69 (0-2800)	< 0.001
Operative time (min) median	315 (105-965)	335 (80-730)	265 (60-590)	< 0.001

<sup>1</sup>*P* ( $\chi^2$ ); <sup>2</sup>Variables are expressed as median (minimum-maximum). *P*: Multiple samples rank sum test (*H*). BIP: Bipolar coagulation; CUSA: Cavitron ultrasonic surgical aspirator; CLAMP: Conventional clamp crushing.

between both groups was determined *via* Bonferroni correction. *P* < 0.05 was considered statistically significant. All data were analyzed using SPSS Version 17.0.

## RESULTS

### Patient characteristics

A total of 380 consecutive patients underwent liver resection. Preoperative data for patients in each group are presented in Table 1. The following was not significantly different between each group (*P* > 0.05 for all): age, gender, the cause of operation, liver function, indocyanine clearance (ICG-R15), liver disease, tumor condition (tumors located 2 cm or less from the liver surface were defined as superficial; those more than 2 cm from the surface were defined as deep), and extent of liver resection (resection range: right trilobectomy, extended

left hepatectomy, right hepatectomy; right anterior lobe, right posterior lobe, left liver, central portion resection, S5+7, S5+6; Couinaud lobectomy; local hepatectomy; enucleation).

### Blood loss

Intraoperative data are shown in Table 2. Median blood loss during surgery was 315 mL in Group A, 328 mL in Group B and 583 mL in Group C (*P* < 0.001). The percentage of patients whose hemorrhage volume was more than 1000 mL was 2.67% in Group A, 9.43% in Group B and 23.81% in Group C (*P* < 0.001). The blood transfusion rate was 16.00% for Group A, 13.21% for Group B and 46.43% for Group C (*P* < 0.001). The median amount of transfusion with packed red cells was 37 mL in Group A, 56 mL in Group B and 69 mL in Group C (*P* < 0.001). There was no significant difference between

**Table 3 The differences in indexes between the groups *n* (%)**

BIP (A), CUSA + BIP (B), CLAMP (C)	(A vs B)	(B vs C)	(A vs C)
	<i>P</i> value	<i>P</i> value	<i>P</i> value
Blood loss, > 1000 mL	0.973	< 0.001	< 0.001
Intraoperative transfusion	0.662	< 0.001	< 0.001
Blood loss (mL), median	0.670	< 0.001	< 0.001
Transfusion of RBC (mL), median	0.731	< 0.001	< 0.001
Operative time (min), median	0.409	< 0.001	< 0.001
Complications Yes	0.773	0.016	0.015
Abdominal infection	1.000	0.153	0.130
Bile leak	0.635	0.260	0.108
Ascites	0.760	0.149	0.014

BIP: Bipolar coagulation; CUSA: Cavatron ultrasonic surgical aspirator; CLAMP: Conventional clamp crushing; RBC: Red blood cell.

Group A and B (*P* > 0.05, Table 3).

**Postoperative complications**

Postoperative complications of each group were compared and are presented in Table 4. The incidence of total complications in Group C was higher than that in Groups A and B (46.43% vs 30.67% vs 28.30%, *P* = 0.007). There were significant differences in single complication rates including abdominal infection (group A 2.67% vs Group B 1.89% vs Group C 8.73%, *P* = 0.035), bile leakage (Group A 1.33% vs Group B 1.89% vs Group C 7.14%, *P* = 0.039) and seroperitoneum (Group A 1.33% vs Group B 3.77% vs Group C 11.51%, *P* = 0.002). The results demonstrated that significant differences existed between Groups A and C for seroperitoneum (1.33% vs 11.51%, *P* = 0.014). Deaths within 30 d of surgery were not statistically significant among the groups. In Group A, one patient died from pulmonary embolism. No patient died in Group B. In Group C, one patient died from severe hemorrhage and multiple organ dysfunction (1.33% vs 0% vs 0.79%, *P* = 0.710). The incidence of other complications was not significantly different among the three groups (*P* > 0.05 for all).

Postoperative recovery conditions are shown in Table 5. No differences were noted in ALB, TB, ALT or AST levels on postoperative day 3 and preoperation (all *P* > 0.05). Elevated ALB levels were found in Group B when compared to Groups A and C (preoperative: 40.9 ± 5.3 vs 37.5 ± 6.1 vs 39.4 ± 5.8, *P* = 0.003; day 1: 29.4 ± 4.3 g/L vs 26.9 ± 5.6 g/L vs 26.2 ± 4.9 g/L, *P* < 0.001; day 3: 29.9 ± 4.8 g/L vs 27.2 ± 4.3 g/L vs 27.5 ± 4.3 g/L, *P* < 0.001). ALT levels were lower in Group C than in Groups A and B on postoperative day 1 (200 μmol/L vs 314 μmol/L vs 279 μmol/L, *P* < 0.001). There was no significant difference among the groups for other liver function recovery tests.

**Operation time and hospitalization**

These results demonstrated that the operation time in Group C was shorter than that in the other two groups (median time: 315 min in Group A, 335 min in Group B, 265 min in Group C, *P* < 0.001). There was no difference between Groups A and B (*P* = 0.409). There was no sig-

**Table 4 Postoperative complications *n* (%)**

Complication	BIP	CUSA + BIP	CLAMP	<i>P</i> value
	( <i>n</i> = 75)	( <i>n</i> = 53)	( <i>n</i> = 252)	
Yes	23 (30.67)	15 (28.30)	117 (46.43)	0.007
Abdominal infection	2 (2.67)	1 (1.89)	22 (8.73)	0.035
Bile leak > 2 wk	1 (1.33)	1 (1.89)	18 (7.14)	0.039
Acute liver failure	1 (1.33)	0	2 (0.79)	0.710
Return to operating room	0	1 (1.89)	3 (1.19)	0.577
Respiratory failure	0	1 (1.89)	2 (0.79)	0.448
Bleeding > 500 mL within 24 h	1 (1.33)	1 (1.89)	7 (2.78)	0.725
Hyperbilirubinemia	3 (4.00)	5 (9.43)	8 (3.17)	0.181
Sepsis	0	0	2 (0.79)	1.000
Ileus	0	0	3 (1.19)	1.000
Pulmonary embolism	1 (1.33)	0	1 (0.40)	0.561
Hepatorenal syndrome	0	0	1 (0.40)	1.000
30-d postoperative death	1 (1.33)	0	2 (0.79)	0.710
Deep venous thrombosis	0	0	1 (0.40)	1.000
Pleural effusion	4 (5.33)	3 (5.66)	24 (9.52)	0.370
Wound infection	16 (21.33)	12 (22.64)	50 (19.84)	0.884
Wound dehiscence	0	0	2 (0.79)	1.000
Pneumonia	2 (2.67)	2 (3.77)	16 (6.35)	0.359
Hepatic insufficiency	7 (9.33)	2 (3.77)	20 (7.94)	0.432
Ascites	1 (1.33)	2 (3.77)	29 (11.51)	0.002
Atelectasis	1 (1.33)	1 (1.89)	3 (1.19)	0.928

BIP: Bipolar coagulation; CUSA: Cavatron ultrasonic surgical aspirator; CLAMP: Conventional clamp crushing.

nificant difference for hospital stays after surgery (Group A 16.6 ± 7.4 d vs Group B 15.3 ± 9.2 d, vs Group C 16.5 ± 9.6 d; *P* = 0.666).

**DISCUSSION**

Controlling bleeding and choosing the appropriate technique to transect the liver are the key points in hepatectomy<sup>[7-9]</sup>. For CLAMP, the whole surgical procedure is simple and fast during parenchyma transaction. However, the operation is relatively rough and can easily lead to severe liver damage. For CUSA + BIP, the surgeon can gradually grind and suction out parenchyma with clear anatomical structure under direct vision. Obviously, blood loss and postoperative complications were decreased using this method. Although Takayama *et al.*<sup>[10]</sup> reported hepatectomy with CLAMP, which was associated with a significantly higher grade and appearance of the landmark hepatic vein on the cut surface than CUSA + BIP. Of note, the results of that study were based on the surgeon's familiarity with CLAMP. Not every surgeon has such skilled operation levels. Therefore, some research centers could not fully agree with them<sup>[11,12]</sup>. Moreover, other methods to transect the liver parenchyma, such as water jet scalpel, habib procedures, monopolar floating ball and ligasure are not commonly used worldwide<sup>[13-16]</sup>. To our best knowledge, this is the first report about comparative analysis of the application of saline-coupled BIP alone in hepatectomy for the excellent hemostasis and satisfactory surgical results.

The majority of bleeding for liver resection comes from the process of transecting the liver parenchyma.

**Table 5** Laboratory values and hospital stay *n* (%)

Recovery evaluation		BIP ( <i>n</i> = 75)	CUSA + BIP ( <i>n</i> = 53)	CLAMP <sup>1</sup> ( <i>n</i> = 251)	<i>P</i> value
TB (μmol/L)	Pre-	15.2 (4.3-360.7)	15.5 (4.9-313.9)	13.5 (3.5-358.9)	0.425
	Day 1	26.5 (4.3-292.1)	23.4 (4.3-292.3)	25.9 (5.5-321.4)	0.771
	Day 3	22.1 (3.9-215.4)	18.3 (6.6-422.0)	21.9 (5.6-294.6)	0.325
	ΔTB <sup>2</sup>	6.4 (-189.9-160.3)	2.9 (-135.3-261.9)	6 (-137.7-156.9)	0.585
ALT (μmol/L)	Pre-	32 (11-337)	48 (10-579)	36 (7-984)	0.187
	Day 1	314 (21-1616)	279 (32-1760)	200 (16-3449)	< 0.001
	Day 3	136 (17-1717)	135 (27-2246)	130 (10-1114)	0.272
	ΔALT <sup>2</sup>	85 (-174-1691)	84 (-449-2183)	84 (-808-1065)	0.388
AST (μmol/L)	Pre-	35 (14-261)	40 (6-531)	33 (8-698)	0.693
	Day 1	323 (43-1591)	294 (20-3182)	247 (14-3750)	0.109
	Day 3	88 (15-1404)	59 (20-2388)	72 (12-940)	0.143
	ΔAST <sup>2</sup>	38 (-133-1372)	24 (-510-2350)	31 (-617-853)	0.168
ALB (g/L) <sup>3</sup> mean ± SD	Pre-	37.5 ± 6.1	40.9 ± 5.3	39.4 ± 5.8	0.003
	Day 1	26.9 ± 5.6	29.4 ± 4.3	26.2 ± 4.9	< 0.001
	Day 3	27.2 ± 4.3	29.9 ± 4.8	27.5 ± 4.3	< 0.001
	ΔALB <sup>2</sup>	10.3 ± 6.0	11.0 ± 6.2	12.0 ± 5.9	0.078
Hospital stay (d) mean ± SD		16.6 ± 7.4	15.3 ± 9.2	16.5 ± 9.6	0.666

<sup>1</sup>One case in group C who died from massive bleeding and multiple organ failure was excluded; <sup>2</sup>Δtotal bilirubin (TB, μmol/L) = TB (day 3 - pre-), Δalanine transaminase (ALT, μmol/L) = ALT (day 3 - pre-), Δaspartate aminotransferase (AST, μmol/L) = AST (day 3 - pre-), Δalbumin (ALB, g/L) = ALB (pre- - day 3); <sup>3</sup>Variables are expressed as mean ± SD, PANOVA (*F*). Pre-: Pre-operation; BIP: Bipolar coagulation; CUSA: Cavitron ultrasonic surgical aspirator; CLAMP: Conventional clamp crushing.

The present study demonstrated that liver resection was relatively rough by CLAMP, especially for deep tissue. Because of long and large hemostatic forceps and its small operative field, the maneuver results in unnecessary vascular damage. For the rate of blood transfusion, BIP and CUSA + BIP were lower than CLAMP. A meta-analysis performed by Liu *et al.*<sup>[17]</sup> revealed that perioperative blood transfusion was associated with adverse clinical outcomes for HCC. Moreover, blood loss of more than 2000 mL was also a poor prognostic factor for HCC<sup>[18]</sup>. Our results support that BIP and CUSA + BIP could improve quality of life and survival of HCC patients. Further comparison between BIP and CUSA + BIP showed that BIP could get the same effect for blood loss, blood transfusion, operational security and prognosis after simplified surgical procedures. Our results demonstrate that the incidence of postoperative complications, such as abdominal infection, bile leakage and seroperitoneum, were higher in the CLAMP group compared to the BIP and CUSA + BIP groups. The reason for that phenomenon was less blood transfusion and section integrity<sup>[19-21]</sup>. Delva *et al.*<sup>[22]</sup> supported that the recovery of liver function was related to the Pringle maneuver length, cirrhosis, the quantity and quality of the remnant liver parenchyma and blood transfusion. Massive parenchyma was grasped and stitched with the clamp. Stable fibrillar structure features were formed, vessels and biliary ducts were closed ideally and less thermal damage was made by BIP. Postoperative complications were associated with operational technique, blood loss, blood transfusion and individual differences for surgery<sup>[23-26]</sup>. Therefore, BIP could be safer and decrease the risk of complications for hepatectomy.

Our results showed that, for an experienced hepa-

tobiliary surgeon, the intrahepatic bile duct could be clearly freed by a single BIP without CUSA. Because the resectional extent of the ultrasonic section device was approximately 4 mm, it was easy to expose the tumor using CUSA when the surgeon could not ensure the distance between the section and tumor. There was a potential danger of spreading hepatitis when CUSA disrupted hepatic cells<sup>[27]</sup>.

Compared to CLAMP, the cutting speed by BIP was lower, and the operative time was prolonged approximately 20%-30%. It is actually not surprising that the use of these instruments resulted in increased operative time because there is more attention paid to dissecting out blood vessels and coagulating or ligating them before dividing them. However, the operative time of BIP could be decreased if performed by highly skilled surgeons. BIP could not only separate the liver parenchyma but also reduce hemorrhage. Additionally, the operative time in the BIP group was an independent prognostic factor for postoperative complications.

In conclusion, simple saline-coupled BIP could reduce blood loss, blood transfusion and complications compared to CLAMP. Therefore, saline-coupled BIP would be a safe and reliable technique easily applied in liver resection.

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## COMMENTS

**Background**

Liver resections are high risk procedures, the key points in which are controlling bleeding and choosing appropriate technique. Advancements in the theory and practice of liver surgery have led to the invention of multiple approaches to transect liver parenchyma. For these reasons, choosing a safe and reliable method of hepatectomy is important in decreasing intraoperative hemorrhaging and postoperative complications.

**Research frontiers**

Cavitron ultrasonic surgical aspirator (CUSA) combined with bipolar coagulation (BIP) and conventional clamp crushing (CLAMP) are favored by most surgeons at many medical centers. As a device for hemostasis, more and more surgeons are applying BIP in hepatectomy as a preferred method. However, compared to CUSA and CLAMP, the efficacy of BIP alone is actually unclear.

**Innovations and breakthroughs**

The present study is the first report about comparative analysis of the application of saline-coupled BIP alone in hepatectomy for excellent hemostasis and satisfactory surgical results.

**Applications**

The study results suggest that saline-coupled BIP could reduce blood loss, blood transfusion and complications compared to CLAMP. Saline-coupled BIP can accomplish hepatectomy excellently and would be a safe and reliable technique easily applied in liver resection.

**Terminology**

CUSA is a powerful ultrasonic aspirator that allows the surgeon to accomplish tissue resection with accurate control while fragmentation, suction, and irrigation occur simultaneously; BIP is a technique for surgical dissection and hemostasis that consists of two tips with current pass confined in a small amount of tissue.

**Peer review**

This is an interesting manuscript describing outcomes of three different methods of parenchymal transection in hepatic surgery. As with any retrospective study, it has its inherent flaws but does show that liver transection can be safely performed by various methods.

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