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**Brief communication (Original)**

# Hepatic resection using ultrasonic surgical aspirator

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***Background:*** Hepatic resections conducted for malignant tumors can be difficult because of the need to create cancer-free margins.

***Objectives:*** To examine the outcome of hepatic resections after the introduction of a Cavitron Ultrasonic Surgical Aspirator (CUSA).

***Methods:*** A retrospective study of patients who underwent hepatic resection by a single surgeon between April 1999 to March 2013.

***Results:*** We included 101 patients with 104 hepatectomies. Most hepatic parenchymal transections were performed using a CUSA under intermittent hepatic inflow occlusion (Pringle maneuver). Thirty-five patients underwent a right hepatectomy, 11 a left hepatectomy, 6 a right hepatectomy and segment I resection, 6 a right lobectomy, and 46 underwent segmentectomies, wedge resections, or other types of hepatic resections. Biliary-enteric reconstruction with a Roux-en-Y limb of the jejunum to a hepatic duct of the hepatic remnant was performed in 28 patients. Operative time was 90–720 min (median 300 min, mean $327 \pm 149$ min). Operative blood transfusion was 0–17 units (median 3 units, mean $3.9 \pm 3.6$ units). Twenty-one hepatectomies were conducted without blood transfusion. Thirty-four postoperative complications occurred in 30 patients with a 9% reoperation rate. Perioperative mortality was 6%. Age, operative time, operative blood transfusion, reoperation, and complications were significantly associated with mortality.

***Conclusion:*** Careful preoperative diagnosis and evaluation of patients, faultless surgical techniques, and excellent postoperative care are important to avoid potentially serious postoperative complications and mortality. The CUSA is an effective assisting device during hepatic parenchymal transection with a concomitant Pringle maneuver, apparently reducing operative blood loss.

***Keywords***: Cholangiocarcinoma, CUSA, hepatic resection, hepatocellular carcinoma, Pringle maneuver

Hepatic resection is indicated for various benign and malignant lesions of the liver. Since the early report of anatomic hepatic resection (right hepatectomy) in Europe by Lortat-Jacob and Robert in 1952 [1], it has evolved extensively with improved outcomes. Most innovations have been to prevent massive hemorrhage, a major cause of death during the early postoperative period entailing a mortality rate of from 25% to 30% [2-5]. With a better understanding of hepatic anatomy and physiology, including advancements radiology, pharmacology, and anesthesiology; this high mortality has declined to contemporary rate of less than 5% [6-9]. Assisting devices appear to enhance surgical outcome. In 1982, Papachristou and Barters introduced a water jet system for hepatic parenchymal transection, resulting in reduction of blood loss [10]. In 1984, Hodgson and DelGuercio reported the use of an ultrasonic scalpel for anatomic and nonanatomic hepatic resection in 33 patients with satisfactory results [11]. In 1999, the Cavitron Ultrasonic Surgical Aspirator (Cavitron, Stamford, CT, USA) or CUSA, was first introduced into King Chulalongkorn Memorial Hospital with the purpose of enhancing hemostasis during hepatic parenchymal transection. It allowed us to identify small and large vessels and bile ducts, ligate, clip, suture, and divide them in a controlled and safe manner. Since then, the CUSA has been regularly employed during hepatic resection. In 2002, a water jet dissector (Selector, Integra Neurosciences, Hampshire, United Kingdom) was introduced into our institution and used together with the CUSA.

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## Methods

The purpose of this study was to examine, retrospectively, results of hepatic resection performed by the first author from April 1999 to March 2013 since the introduction of CUSA into our institution. Data collection included demographic data, extent of hepatic resection, duration of operation, blood transfusion, final pathological reports, postoperative complications, and perioperative mortality. Factors associated with perioperative mortality were also analyzed.

This study was approved by the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University.

During the study period, the indications for hepatic resection were: (1) hepatocellular carcinoma, (2) intrahepatic and hilar cholangiocarcinoma, (3) metastatic cancer to the liver, (4) carcinoma of the gall bladder, (5) other benign and malignant tumors of the liver, (6) hepatic necrosis following hepatic trauma, and (7) recurrent cholangitis from choledochal cysts or other benign strictures of the bile duct. With the exception of 3 patients who underwent emergency hepatic resection, patients underwent hepatic resection on an elective basis when the following criteria were fulfilled: (1) acceptable anesthetic risks, (2) appropriate indication for surgery, and (3) estimated adequacy of hepatic reserve after resection by preoperative CT scan. No patient in this study underwent preoperative portal vein embolization. In patients who had hilar cholangiocarcinoma with marked jaundice, preoperative biliary drainage was performed by either an endoscopic or percutaneous method to achieve a serum bilirubin level of <2 mg/dL. The three emergency hepatic resections were performed in patients with a ruptured hepatocellular carcinoma resulting in severe ongoing hemorrhage. Operations were conducted after careful preoperative evaluation of the computed tomography (CT) and/or magnetic resonance imaging (MRI), and conferencing between surgeons and radiologists regarding extent of the lesions, their resectability, and the adequacy of the hepatic remnant. Patients who underwent hepatic resection during emergency laparotomy for trauma were excluded from this study.

Operations were performed in the same manner in most cases and included the following steps: (1) bilateral subcostal incision with midline extension to the xiphoid cartilage, (2) extensive mobilization of the targeted hepatic lobe from the diaphragm and the posterior abdominal wall, (3) cholecystectomy, (4) dissection of hepatic hilum, isolation of the left or right hepatic artery and left or right branch of the portal vein, (5) ligation of the left or right hepatic artery supplying the resected hepatic segments, (6) ligation of left or right branch of the portal vein supplying the targeted hepatic segments, (7) identification of line of demarcation on the liver surface, (8) parenchymal transection along the line of demarcation by using CUSA and intermittent hepatic inflow occlusion (Pringle maneuver), (9) ligation and division of the right or middle or left hepatic vein according to type and extent of hepatic resection, (10) division of left or right hepatic duct of the hepatic segments to be removed, (11) complete hemostasis with electrocoagulation on the raw surface of the hepatic remnant, and (12) placement of 2 vacuum drains in the space between the raw surfaces of the resected hepatic segments, the diaphragm, and the posterior abdominal wall.

The above-mentioned steps in hepatic resection were used in right hepatectomy (removal of segment V, VI, VII, and VIII) or left hepatectomy (removal of segment II, III, and IV). These techniques were modified as necessary. With very large tumors, performing right or left hepatectomy were changed owing to anatomic distortion of the bulging tumor making early mobilization dangerous. Extensive mobilization of the liver was not conducted as an early step; instead, ligation of the corresponding hepatic artery and portal vein branches were conducted first to decrease blood supply to the tumor causing shrinkage of the tumor and the respective hepatic segments. Subsequent mobilization of the tumor and the liver could then be performed more easily after deprivation of the blood supply to the liver mass.

Operative procedures were classified as follows: wedge resection (nonanatomic resection of limited normal hepatic parenchyma surrounding the lesion), segmentectomy (removal of one or more hepatic segments from segment I to VIII), right hepatectomy (removal of segments V, VI, VII, and VIII), left hepatectomy (removal of segments II, III, and IV), and right lobectomy or extended right hepatectomy (removal of segments IV, V, VI, VII, and VIII).

Postoperatively, patients were admitted in our surgical intensive care unit (SICU) for 24 hours and then to the ward after stabilizing in the SICU. Special attention was paid to postoperative hemorrhage, which was associated with high mortality if not diagnosed early. Immediate reoperation was conducted when postoperative intra-abdominal hemorrhage was strongly suspected or diagnosed.

Perioperative mortality was defined as death within the hospital after hepatic resection or death resulting from postoperative complications. Causes of perioperative mortality were analyzed. Results were described as range, median, and mean ± SD. Statistical analyses of significance of variables associated with mortality were made using a Student *t* test and a Chi square test when appropriate. $P < 0.05$ was considered significant.

## Results

During the 14-year retrospective period, 101 patients with 104 hepatectomies were included into the study. Three patients had 2 hepatectomies performed at different times. Fifty-nine patients were men and 42 were women. Their age ranged from 28 to 81 years (median 56 years, mean 55.1 ± 11.5 years). Patients' pathological diagnoses were hepatocellular carcinoma 32, hilar cholangiocarcinoma 25, peripheral cholangiocarcinoma 17, metastatic carcinoma to the liver 11, carcinoma of the gall bladder 5, cystadenocarcinoma of the liver 1, and other benign pathologies 10 (**Table 1**). Seventy-two resections (69%) were composed of tumors ranging from 1 to 25 cm in diameter (median 6 cm, mean 7.02 ± 5.52 cm). In the remaining 32 resections (31%), the size of lesions were not reported because of the infiltrative nature of the tumors, nonmass forming pathology, or incomplete data in some patients. Of the 32 patients who had hepatocellular carcinoma (34 resections), 21 (66%) had cirrhosis, 10 (31%) were carriers of hepatitis B virus, and 1 (3%) was a carrier of hepatitis C virus. Two patients, aged 75 and 80 years old, had hilar cholangiocarcinoma and cirrhotic livers. Both underwent right hepatectomy with biliary-enteric reconstruction by Roux-en-Y left hepaticojejunostomy. One (aged 75) recovered well, the other (aged 80) died from multisystem organ failure 12 days postoperatively.

**Table 1.** Diagnoses

| Pathological diagnosis | Number of patients | |
|---|---|---|
| **Primary malignant tumors** | | |
| Hepatocellular carcinoma | 32 | |
| Hilar cholangiocarcinoma | 25 | |
| Peripheral cholangiocarcinoma | 17 | |
| Carcinoma of the gallbladder | 5 | |
| Cystadenocarcinoma of the liver | 1 | |
| **Metastatic malignancy to the liver** | | |
| Colorectal | 9 | |
| Carcinoma of the breast | 1 | (10%) |
| Carcinoma of the endometrium | 1 | |
| **Benign pathology** | | |
| ***Liver*** | | |
| Giant hemangioma | 1 | |
| Focal nodular hyperplasia | 1 | |
| Cystadenoma | 1 | |
| Large symptomatic simple cyst | 1 | |
| Benign cyst | 1 | |
| ***Biliary tract*** | | (10%) |
| Choledochal cyst | 1 | |
| Primary biliary stones | 1 | |
| Biliary cyst | 1 | |
| Posttraumatic bile fistula | 1 | |
| Intrahepatic biliary papillomatosis with sclerosing cavernous hemangioma | 1 | |
| **Total** | 101 | |

Operations were conducted on an elective basis in all except 3 patients, who had emergency hepatic resection because of a ruptured hepatocellular carcinoma. Right hepatectomy was the most common operative procedure, followed in order by left hepatectomy, right hepatectomy and segment I resection, right lobectomy, segment II and III resection, segment VI resection, wedge resection, and other combinations of resections (**Table 2**). Biliary-enteric reconstruction was performed after right or left hepatectomy or right lobectomy in 28 patients. The biliary-enteric reconstruction was performed using a 40–60 cm long Roux-en-Y limb of the jejunum anastomosed to the left or right hepatic duct after hepatic resection. In 25 patients who had hilar cholangiocarcinoma, additional resection of the extrahepatic bile duct and lymphadenectomy of the hepatoduodenal ligament were performed concurrently with the hepatic resection before reconstruction of the biliary-enteric anastomosis.

The operative time ranged from 90 to 720 min (median 300 min, mean 327 ± 149 min). Operative blood transfusion ranged from 0 to 17 units (median 3 units, mean 3.9 ± 3.6 units). Twenty-one hepatectomies (20%) were conducted without blood transfusion. Intermittent hepatic inflow occlusion (the Pringle maneuver) was performed during hepatic parenchymal transection in 93 resections (89%). The ischemic time during intermittent hepatic inflow occlusion ranged from 5 to 105 min (median 40 min, mean 43.29 ± 20.72 min). CUSA was used during hepatic parenchymal transection in 90 resections (87%). In 8 resections (8%), the hepatic parenchymal transection was performed by using water jet. No assisting device for hepatic parenchymal transection was used in 6 resections (6%).

Thirty-four complications occurred in 30 patients (29%). Details of complications are shown in **Table 3**. Reoperation was performed in 9 patients (reoperation rate 9%). The causes for reoperation were intra-abdominal bleeding 5, bleeding duodenal ulcer 1, small bowel obstruction 1, intra-abdominal sepsis 1, and biliary obstruction 1 (**Table 3**). Six patients in this study died (**Table 4**). The perioperative mortality was 6%. Univariate analyses of factors associated with mortality conducted using a Student *t* test or a Chi square test revealed a significant difference in age, operative time, operative blood transfusion, reoperation, and complication in patients who had perioperative mortality compared with patients who survived operations (**Table 5**).

**Table 2.** Operative procedures

| Operative procedure | Number of operations | |
|---|---|---|
| Right hepatectomy | 35 | |
| Left hepatectomy | 11 | |
| Right hepatectomy and segment I resection | 6 | |
| Right lobectomy | 6 | |
| Segment II and III resection | 6 | |
| Segment IV resection | 6 | |
| Wedge resection | 6 | |
| Segment V resection | 5 | |
| Segment V and VI resection | 5 | |
| Segment VII resection | 3 | |
| Segment VIII resection | 2 | |
| Segment IVB and V resection | 2 | |
| Right hepatectomy and wedge resection | 2 | |
| Left hepatectomy and segment I resection | 2 | |
| Right lobectomy and segment I resection | 1 | (6.8%) |
| Segment V, VI, and VII resection | 1 | |
| Segment VI and VII resection | 1 | |
| Segment II,III and wedge resection | 1 | |
| Segment V, VI and wedge resection | 1 | |
| Segment IV resection | 1 | |
| **Total** | 104 | |

**Table 3.** Complications after hepatic resection

| Complication | Number of complications**** | Reoperation | Result |
|---|---|---|---|
| Wound infection | 7 | no | good recovery |
| Intra-abdominal collection | 5 | 1 patient | reoperated patient died from MSOF*. |
| Intra-abdominal bleeding | 5 | all | 4 died from MSOF*. |
| Transient jaundice | 4 | no | good recovery |
| Pleural effusion | 3 | no | good recovery |
| Postoperative hepatic failure | 3 | all** | all 3 died from MSOF*. |
| Bile fistula | 3 | no | good recovery |
| Duodenal ulcer bleeding | 1 | yes | died from MSOF*. |
| Small bowel obstruction | 1 | yes | good recovery |
| Intra-operative cardiac arrest | 1 | no | died |
| Biliary obstruction | 1 | yes*** | good recovery |
| Total | 34 | | |

MSOF* = multi-system organ failure. ** = All postoperative hepatic failure occurred after reoperation for intra-abdominal bleeding. *** = Reconstruction with Roux-en-Y left hepaticojejunostomy. **** = Some patients had more than one complication

## Discussion

Hepatic resection is a major operation with potentially disastrous complications and fatal outcomes. Although hepatectomies are indicated for various benign and malignant conditions of the liver, they are conducted mainly in patients with primary or metastatic tumors of the liver. For resection of malignant tumors, an adequate tumor free margin is important for long-term survival. This may be very difficult to achieve. Such situations include a large tumor close to major vascular structures, hilar cholangiocarcinoma, and limited hepatic reserve from cirrhosis or a small hepatic remnant after resection. Three of 6 our patients who succumbed perioperatively had underlying cirrhosis and subsequent hepatic failure. Although the significance of liver cirrhosis and mortality could not be demonstrated statistically in this study, surgery on cirrhotic patients is dangerous and such a decision requires careful preoperative analysis. Two of our patients died from multisystem organ failure after massive blood loss during and after surgery, which was caused by unexpected difficulties and technical factors during surgery. Such fatal bleeding complications emphasized the importance of careful and faultless surgical technique. Perioperative hemorrhage is well known to be associated with hepatic resections [12-14]. However, current outcomes of hepatic resection have been greatly improved and mortality has decreased in many high-volume centers [6-9]. However, such mortality still exists when the complexity of the operations conducted is augmented by underlying cirrhosis and extensive pathology. Prolonged operative time and intraoperative blood transfusion have been shown in the current study to be significantly associated with perioperative mortality. Experience of the surgical team is unquestionably a major factor contributing to satisfactory outcomes, especially when dealing with complex liver surgery [9].

The safety of major hepatic resection has been enhanced by development of innovations, i.e. intermittent hepatic inflow occlusion (Pringle maneuver) and hepatic parenchymal transection assisting devices. In 1908, J. Hogarth Pringle from Glasgow wrote a classical article “Notes on the arrest of hepatic hemorrhage due to trauma” published in the Annals of Surgery [15]. He noted that when the portal vein and hepatic artery were compressed at the hepatoduodenal ligament with a finger and thumb in a patient with bleeding from traumatic rupture of the liver, the bleeding completely stopped and surgeons were able to clear the blood and clots and examine the wound. Subsequently, temporary control of the hepatic inflow by compression at the hepatoduodenal ligament with a finger and a thumb, a vascular clamp, or a Rummel tourniquet was generally recognized as the “Pringle maneuver”. Thus, the Pringle maneuver is widely employed in controlling hemorrhage from the injured liver during exploratory laparotomies

**Table 4.** Perioperative mortality

| No | Age | Sex | Date of operation | Diagnosis | Operative procedure | Op time (min) | Op Bl Tx (unit) | CUSA or jet | Cirrhosis | Complication | Reop | Cause of death | Death POD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 53 | M | 23/11/00 | hilar CHCA | lt lobectomy with rt hepatico-jejunostomy Roux-en-Y | 570 | 7 | yes | no | post op. bleeding, liver failure | yes | MSOF | 5 |
| 2 | 45 | F | 3/1/01 | peripheral CHCA | rt hepatectomy | NA | 0 | yes | no | intra op. cardiac arrest | no | intra op. cardiac arrest | 0 |
| 3 | 66 | M | 24/9/01 | HCC | segment VII resection | 700 | 17 | yes | yes | intra op. bleeding, liver failure | yes | MSOF | 14 |
| 4 | 73 | M | 21/2/05 | hilar CHCA | rt hepatectomy with lt hepatico-jejunostomy Roux-en-Y | 540 | 10 | yes | no | post op. DU bleeding, liver failure | yes | MSOF | 47 |
| 5 | 80 | M | 24/3/08 | hilar CHCA | rt hepatectomy with lt hepatico-jejunostomy Roux-en-Y | 450 | 15 | yes | yes | post op. bleeding, liver failure | yes | MSOF | 13 |
| 6 | 71 | M | 27/2/12 | HCC | Rt hepatectomy | 210 | 0 | yes | yes | post op. bleeding | yes | MSOF | 38 |

Reop = reoperation, POD = postoperative day, CHCA = cholangiocarcinoma, MSOF = multi-system organ failure, HCC = hepatocellular carcinoma, DU = duodenal ulcer, Op Bl Tx = operative blood transfusion, NA = not available

**Table 5.** Univariate analyses of factors associated with mortality

| Variable | Alive (n = 95) | | Dead (n = 6) | *P* | Test |
|---|---|---|---|---|---|
| Age (year, mean ± SD) | 54.45 ± 11.19 | | 64.67 ± 13.19 | 0.034 | Student *t* test |
| Liver cirrhosis | yes | 20 | 3 | NS* | Chi square test |
| | no | 75 | 3 | | |
| Biliary-enteric | yes | 25 | 3 | NS* | Chi square test |
| reconstruction | no | 70 | 3 | | |
| Operative time (minute, mean ± SD) | 318.33 ± 142.85 | | 494 ± 182.29 | 0.009 | Student *t* test |
| Operative blood transfusion (unit, mean ± SD) | 3.57 ± 3.16 | | 9.8 ± 6.76 | 0.000 | Student *t* test |
| Reoperation | yes | 5 | 4 | <0.001 | Chi square test |
| | no | 90 | 2 | | |
| Complication | yes | 24 | 6 | <0.001 | Chi square test |
| | no | 71 | 0 | | |

NS* = not significant

for abdominal trauma [16, 17]. In elective hepatic resection, the Pringle maneuver is used during hepatic parenchymal transection to reduce blood loss and minimize the necessity for blood transfusion, associated with worse outcomes [18, 19]. It is now recognized that the technique of intermittent hepatic inflow occlusion by clamping the hepatoduodenal ligament for 15 minutes and releasing it for 5 minutes and repeating this until the hepatic parenchymal transection is completed can save many lives [20-23]. However, the safe time limit for total occlusion has not been clarified. In practice, prolonged ischemic injury to the liver should be avoided, and the shortest time possible must be applied. Intermittent hepatic inflow occlusion time in our patients ranged from 5 to 105 minutes (median 40, mean 43.3 ± 20.7) and we did not observe any direct detrimental effects of the Pringle maneuver in our patients postoperatively. An obvious advantage of the Pringle maneuver is a bloodless operative field during hepatic parenchymal transection. With the aid of a CUSA, precise ligations of intrahepatic vessels and bile ducts could be made without difficulty. Numerous comments have been published concerning the Pringle maneuver. Some reported adverse effects to the liver in cirrhotic patients [24]. Some authors have reported acceptable outcomes after hepatic resection without the use of the Pringle maneuver [25-27]. Man et al. reported that the Pringle maneuver was associated with less blood loss and better preservation of hepatic function postoperatively [28].

The purpose of the CUSA and the water jet employed as assisting devices during hepatic parenchymal transection is to dissect away the liver tissue by using a high-frequency ultrasonic dissector (CUSA) or high-pressure stream of water (jet) [10, 11, 29-32]. Both devices are currently employed worldwide with various modifications from the original models and decreased intraoperative blood loss and blood transfusion requirements have been reported [33, 34]. CUSA was introduced into our institution before the water jet and this explains why CUSA was employed more frequently than a water jet in the present study. We found that these two devices were both efficacious and could be used interchangeably with equal outcomes.

Despite advances in instrumentation and surgical technology, hepatic resection remains a major operation with potentially disastrous complications and relatively high mortality rates. Certain underlying pathologies carry a higher surgical risk for curative resection, such as hilar cholangiocarcinoma or a large tumor size near the inferior vena cava, the hepatic veins, or the portal pedicle. Hence, complex surgery of the liver continues to be a challenge. Our perioperative mortality of 6% was comparable to current outcomes reported from other high-volume centers [6-9]. Although this mortality rate is at the upper level of the currently acceptable range, we were satisfied with these results because approximately 90% of our patients had primary and secondary malignant tumors of the liver. Furthermore, about two-thirds of these malignant tumors in our study underwent major hepatic resection and one-third biliary-enteric reconstruction. Major complications and mortalities were thus expected. Nevertheless, we realize that with continuous improvement of preoperative, operative, and postoperative care, better outcomes may be achieved.

In conclusion, hepatic resection continues to be a challenging operation with a wide range of complexity. The procedure may be quite simple with negligible mortality or may be a formidable one with a dreadful result. Careful preoperative patient selection for major hepatic resection and meticulous operative techniques are important for good results. CUSA and the Pringle maneuver, in our opinion, are very helpful adjuncts during hepatic parenchymal transection resulting in less blood loss. The experience of the surgical team is also a major factor for acceptable outcome.

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## References

1. Lortat-Jacob JL, Robert HG. Well defined technic for right hepatectomy. Presse Med. 1952; 60:549-51.
2. Brunschwig A. Hepatic lobectomy for metastatic cancer. Cancer. 1963; 16:277-82.
3. Gans H, Koh SK, Aust JB. Hepatic resection. Results in 39 patients operated upon during the 11-year period from 1952 to 1963. Arch Surg. 1966; 93:523-30.
4. Balasegaram M. Hepatic resection. Br J Surg. 1968; 55: 168-74.
5. Foster JH, Lawler MR Jr, Welborn MB Jr, Holcomb GW Jr, Sawyers JL. Recent experience with major hepatic resection. Ann Surg. 1968; 167:651-66.
6. Cescon M, Vetrone G, Grazi GL, Ramacciato G, Ercolani G, Ravaioli M, et al. Trends in perioperative outcome after hepatic resection: analysis of 1500 consecutive unselected cases over 20 years. Ann Surg. 2009; 249:995-1002.
7. Aloia TA, Fahy BN, Fischer CP, Jones SL, Duchini A, Galati J, et al. Predicting poor outcome following hepatectomy: analysis of 2313 hepatectomies in the NSQIP database. HPB (Oxford). 2009; 11:510-5.
8. Kamiyama T, Nakanishi K, Yokoo H, Kamachi H, Tahara M, Yamashita K, et al. Perioperative management of hepatic resection toward zero mortality and morbidity: analysis of 793 consecutive cases in a single institution. J Am Coll Surg. 2010; 211:443-9.
9. Zimmitti G, Roses RE, Andreou A, Shindoh J, Curley SA, Aloia TA, et al. Greater complexity of liver surgery is not associated with an increased incidence of liver-related complications except for bile leak: an experience with 2,628 consecutive resections. J Gastrointest Surg. 2013; 17:57-64.
10. Papachristou DN, Barters R. Resection of the liver with a water jet. Br J Surg. 1982; 69:93-4.
11. Hodgson WJ, DelGuercio LR. Preliminary experience in liver surgery using the ultrasonic scalpel. Surgery. 1984; 95:230-4.
12. Gozzetti G, Mazziotti A, Grazi GL, Jovine E, Gallucci A, Gruttadauria S, et al. Liver resection without blood transfusion. Br J Surg. 1995; 82:1105-10.
13. Nagasue N, Yukaya H. Liver resection for hepatocellular carcinoma: results from 150 consecutive patients. Cancer Chemother Pharmacol. 1989; 23 (Suppl): S78-82.
14. Thompson HH, Tompkins RK, Longmire WP Jr. Major hepatic resection. A 25-year experience. Ann Surg. 1983; 197:375-88.
15. Pringle JH. V. Notes on the arrest of hepatic hemorrhage due to trauma. Ann Surg. 1908; 48:541-9.
16. Pachter HL, Feliciano DV. Complex hepatic injuries. Surg Clin North Am. 1996; 76:763-82.
17. Feliciano DV, Pachter HL. Hepatic trauma revisited. Curr Probl Surg. 1989; 26:453-524.
18. Matsumata T, Ikeda Y, Hayashi H, Kamakura T, Taketomi A, Sugimachi K. The association between transfusion and cancer-free survival after curative resection for hepatocellular carcinoma. Cancer. 1993; 72:1866-71.
19. Nagorney DM, van Heerden JA, Ilstrup DM, Adson MA. Primary hepatic malignancy: surgical management and determinants of survival. Surgery. 1989; 106: 740-8.
20. Fan ST, Lai EC, Lo CM, Chu KM, Liu CL, Wong J. Hepatectomy with an ultrasonic dissector for hepatocellular carcinoma. Br J Surg. 1996; 83:117-20.
21. Hardy KJ, Tancharoen S, Shulkes A. Comparison of continuous versus intermittent ischaemic-reperfusion during liver resection in an experimental model. Br J Surg. 1995; 82:833-6.
22. Isozaki H, Adam R, Gigou M, Szekely AM, Shen M, Bismuth H. Experimental study of the protective effect of intermittent hepatic pedicle clamping in the rat. Br J Surg. 1992; 79:310-3.
23. Horiuchi T, Muraoka R, Tabo T, Uchinami M, Kimura N, Tanigawa N. Optimal cycles of hepatic ischemia and reperfusion for intermittent pedicle clamping

during liver surgery. Arch Surg. 1995; 130:754-8.
24. Huguet C, Nordlinger B, Galopin JJ, Bloch P, Gallot D. Normothermic hepatic vascular exclusion for extensive hepatectomy. Surg Gynecol Obstet. 1978; 147:689-93.
25. Taniguchi H, Takahashi T, Shioaki Y, Itoh A, Oguro A. Vascular inflow exclusion and hepatic resection. Br J Surg. 1992; 79:672-5.
26. Yamaoka Y, Morimoto T, Inamoto T, Tanaka A, Honda K, Ikai I, et al. Safety of the donor in living-related liver transplantation–an analysis of 100 parental donors. Transplantation. 1995; 59:224-6.
27. Nagasue N, Uchida M, Kubota H, Hayashi T, Kohno H, Nakamura T. Cirrhotic livers can tolerate 30 minutes ischaemia at normal environmental temperature. Eur J Surg. 1995; 161:181-6.
28. Man K, Fan ST, Ng IO, Lo CM, Liu CL, Wong J. Prospective evaluation of Pringle maneuver in hepatectomy for liver tumors by a randomized study. Ann Surg. 1997; 226:704-11.
29. Scheele J. Segment-oriented liver resection. Principle–technic–status. Chirung. 1989; 60:251-65. (Article in German)
30. Persson BG, Jeppsson B, Tranberg KG, Roslund K, Bengmark S. Transection of the liver with a water jet. Surg Gynecol Obstet. 1989; 168:267-8.
31. Une Y, Uchino J, Horie T, Sato Y, Ogasawara K, Kakita A, et al. Liver resection using a water jet. Cancer Chemother Pharmacol. 1989; 23(Suppl):S74-7.
32. Belghiti J, Noun R, Malafosse R, Jagot P, Sauvanet A, Pierangeli F, et al. Continuous versus intermittent portal triad clamping for liver resection: a controlled study. Ann Surg. 1999; 229:369-75.
33. Rau HG, Buttler ER, Baretton G, Schardey HM, Schildbery FW. Jet-cutting supported by high frequency current: new technique for hepatic surgery. World J Surg. 1997; 21:254-9.
34. Palavecino M, Kishi Y, Chun YS, Brown DL, Gottumukkala VN, Lichtiger B, et al. Two-surgeon technique of parenchymal transection contributes to reduced transfusion rate in patients undergoing major hepatectomy: analysis of 1,557 consecutive liver resections. Surgery. 2010; 147:40-8.