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Research Article

Evaluation of liver resection using cavitron ultrasonic surgical aspirator (CUSA) combined with harmonic scalpel

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Abstract

Introduction: Control of intraoperative hemorrhage has been one of the principle technical problems in advancing liver surgery. Excess blood loss and intraoperative blood transfusions are associated with increased perioperative mortality and morbidity. Myriads of techniques have been developed to help decreasing intraoperative blood loss thus decreasing morbidity & mortality. **Methods:** prospective and retrospective study was conducted in Minia university hospital including 20 patients with hepatic lesions who underwent liver resection using CUSA combined with harmonic scalpel from Dec. 2019 to May. 2022. **Results:** During the study period, 20 patients have under-went liver resections, the mean amount of total operative blood loss was 374 ml (SD 74.9 ml with range 270 ml to 620 ml) and the mean blood loss during parenchymal transection was 132.5 ml (SD 33.3 ml with range 80 ml to 230 ml). The median total operative time was 216 min (SD 40.8 min with range 145 min to 300 min) and the mean parenchymal transection time was 42.5 min (SD 8.95. min with range 25 min to 65 min). The rate of blood transfusions was (5%) and the mean post-operative hospital stay was 5.25 days (SD 2.17 days with range 3 days to 12 days). complications occurred in one case (5%). **Conclusion:** combined technique of CUSA and harmonic scalpel for liver resection is a safe method for both major and minor liver resections, associated with decreased blood loss, reduced postoperative morbidity, and minimal mortality rates.

Keywords: Liver resection, Blood loss, Complications, Cavitron ultrasonic surgical aspirator (CUSA), Harmonic scalpel

Introduction

The mode of parenchymal transection in hepatic resection has been a topic of great debate for decades. Many resections have now evolved into laparoscopic and robotic-assisted procedures to limit morbidity.[1] Morbidity and mortality after hepatic resection has progressively improved over the years due to improved equipment, operative technique, and anesthetic management.[2] .

Control of intraoperative hemorrhage has been one of the principle technical problems in advancing liver surgery[3]. Excess blood loss and intraoperative blood transfusions have been shown to be associated with increased perioperative mortality and morbidity [4] including an increased rate of hepatocellular carcinoma recurrence. Transfusions are also associated with increased infections and with increased cost.[5, 6]

Without the knowledge of the relationship between the tumor and the major intrahepatic structures, unexpected damage to such structures can occur during transection[7] leading to massive bleeding or bile duct injuries, and sometimes tumor exposure at the transection plane.[8]

In general, a tumor-free margin of 1 cm is considered necessary for curative purpose, although the exact significance of tumor margin in hepatic resection for liver cancers, especially hepatocellular carcinoma, remains controversial. In cirrhotic patients with borderline liver function reserve, preservation of liver parenchyma may take priority over a wide resection margin.[9].

Better understanding of the segmental anatomy of the liver has led to a wider practice of segmental resection, which sacrifices less liver parenchyma compared with a formal right or left hepatectomy, while it improves the chance of tumor clearance compared with a non-anatomical wedge resection.[10]

Clamping of the vascular pedicles to demonstrate the ischemic demarcation and intrahepatic glissonian access to the biliovascular pedicle are also useful in delineation of the transection plane for segmental resection.[11]
Myriads of techniques have been developed to help in decreasing intraoperative blood loss thus decreasing morbidity & mortality with many devices are now available to surgeons for division of the liver parenchyma in both open and minimally invasive surgery including: the CUSA (Tyco Healthcare, Mansfield, MA), Harmonic Scalpel (Ethicon Endo-Surgery, Cincinnati, OH, USA), Ligasure (Valley Lab, Tyco Healthcare, Boulder, CO, USA), Tissue Link (Salient Surgical Technologies, Portsmouth, NH), water-jet dissection, radiofrequency, microwave assisted resection, vascular staplers, and others. [12]

Patients and methods

prospective and retrospective study study was conducted in El-Minia university hospital including 20 patients with hepatic lesions who underwent liver resection using the cavitron ultrasonic surgical aspirator (CUSA) combined with the harmonic scalpel from Dec. 2019 up to May. 2022.

Inclusion criteria: patients needing liver resection in normal liver and cirrhotic liver child-pough A and early B with: Age > 6 and < 70 years old, One or two small (5 cm or less) hepatic lesions confined to the liver with no extra hepatic involvement, Patients with -ve markers for viral hepatitis.

Exclusion criteria: patients with age < 6 or > 70 years old, liver cirrhosis Child-pough C, liver cell failure, very large lesions including most of the liver tissue, hepatic lesions with vascular invasion, evidence of metastasis in cases with HCC, and patients with +ve markers for viral hepatitis.

Operative Design:

- All Patients underwent the following: Complete history taking and clinical examination focusing on: presenting symptoms, symptoms of chronic liver diseases (chronic hepatitis, liver cirrhosis) and jaundice, history of any preceding disease or previous operations and history of travelling to endemic areas.
Laboratory investigation: Complete blood picture, Liver function tests: Albumin, bilirubin, ALT, AST, Coagulation profile, Renal function tests and Tumor markers: Alpha fetoprotein (AFP), CEA, and CA 19-9.
Radiological evaluation: Abdominal ultrasound and Tri-phasic CT Abdomen
ERCP: was performed in patients presented clinically with jaundice

Surgical technique

A- Basis of surgical technique

The operation was divided into 3 phases: laparotomy and hepatic mobilization phase, The parenchyma transection phase, and The hemostasis phase
Anesthesia: General anesthesia and with central venous catheter was inserted.

B- Position and draping

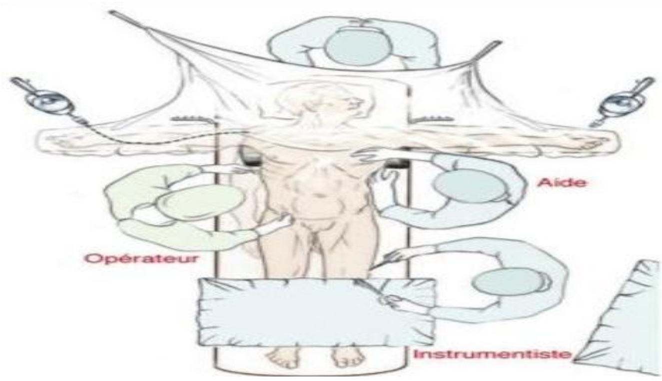

Figure 1: Patient positioning [13]

C- Type of incisions

Three types of incision were usually used: J-shaped incision, upper median incision and inverted T-shaped incision (Mercedes star shaped).

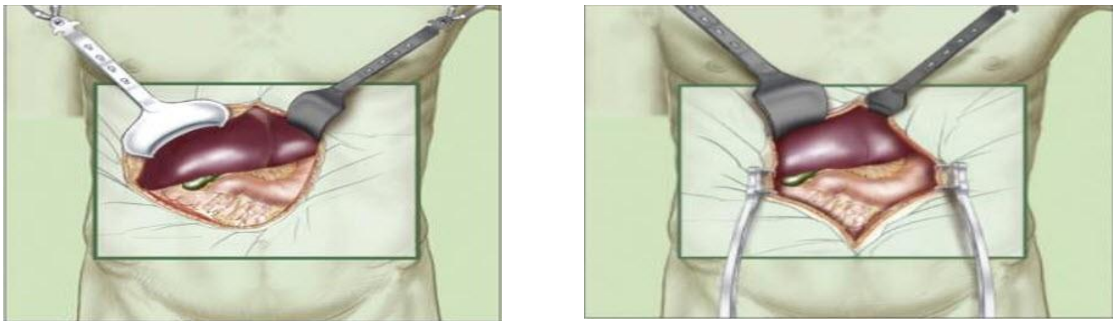

Figure 2: Makuuchi's incision or J incision and Midline incision[13]

D- Mobilization of the liver

The falciform ligament was divided halfway between the abdominal wall and liver until visualization of suprahepatic IVC, then the right triangular, right anterior, and right posterior coronary ligaments were divided medially to the level of IVC. For the left lobe lesion segment II or III, the falciform ligament was divided, and left triangular ligament was divided to the level of left hepatic vein.

E- Identification of the segment to be resected

Segmental resections were undertaken after portal pedicle anatomy was defined by using topographical landmarks as described by Couinaud. The intraoperative anatomic definition of the limits of segments and sectors to be resected was obtained by external anatomic landmarks including umbilical fissure (the round and falciform ligaments) and gallbladder fossa.

F- Parenchymal transection

Dissection of liver parenchyma was done by CUSA and harmonic scalpel. Vessels more than 3or 4 mm were clipped or ligated. The resected surface was covered by packs to control bleeding. After completion of resection diathermies of the raw surface of liver by argon beams, the resected segment was retrieved un-fragmented and was opened outside with scalpel to ensure the pathology.

No drugs for protecting the liver from ischemic injury were used during resection.

G- Abdominal closure Anatomical closure with one tubal drain sub-hepatic only or adding another pelvic drain. Tubal drain preferred to allow for actual measurement of discharge.

Intraoperative recorded data: Site and size of lesion, Extent of resection, Blood loss (during transection and total operative blood loss)-

measured from the soaked gauze and blood collected from the containers of the suction apparatus during and after resection. The volume of irrigation fluid was deduced accordingly, Need for transfusion, Total Operative time, and Transection time.

Post-operative follow-up: all patients admitted to ICU for at least 1 day, In hospital mortality (30-day mortality), Perioperative morbidity as reoperation for bleeding or bile leak, and Drain care: providing no bile leakage was detected in the drain, the abdominal drains were gradually removed from day 3.

Postoperative recorded data: Liver enzymes postoperative days 1, 3, 5 and 7, Length of postoperative hospital stay, the need for blood transfusion, and complications: (Clinically significant air embolism, Hyperbilirubinemia, Biliary fistula was diagnosed when bile drainage was apparent from the abdominal wound and drain, Sub phrenic or intra-abdominal abscess. Ascites or pleural effusion and in hospital mortality).

Methods: statistical analysis; The analysis of the data was carried out using the IBM SPSS 26.0 statistical package software (IBM;

Armonk, New York, USA). Normality of the data was tested using the Shapiro-Wilk tests. Data were expressed as mean, and standard deviation for quantitative measures, in addition to both number and percentage for categorized data. Mann-Whitney U test for non-parametric data were used for comparison between two independent group, Kruskal-Wallis Test for comparison of multiple independent groups The Chi-square test or Fisher's exact test were used to compare categorical variables. A p-value less than 0.05 was considered significant.

Results

The current study included 20 patients; 7 of them were males (35%) and 13 were females (65%). Their age ranged from 1.5 years to 63 years. **Table (1),** The lesions were: Hydated cyst 7 cases (35%), Hamangioma 5 cases (25%), HCC 3 cases (15%), cholangiocar-cinoma 1case (5%), biliary Cystadenoma 1case (5%), post-traumatic necrosis 1case (5%), GB carcinoma 1case (5%), and Adenocarcinoma 1case (5%). 14 cases with normal liver (70%), 4 cirrhotic (20%) and 2 steatotic (10%) **Table (2).** The mean amount of total operative blood loss was 374 ml (SD 74.9 ml with range 270 ml to 620 ml) and the mean blood loss during parenchymal transection was 132.5 ml (SD 33.3 ml with range 80 ml to 230 ml). The median total operative time was 216 min (SD 40.8 min with range 145 min to 300 min) and the mean parenchymal transection time was 42.5 min (SD 8.95. min with range 25 min to 65 min). The rate of blood transfusions was (5%). **Table (3)** The mean post-operative hospital stay was 5.25 days (SD 2.17 days with range 3 days to 12 days). **Table (5)** complications occurred in one case (5%). **Table (6)**

Table 1: demographic data of the studied group

Demographic data	**Studied group (n = 20)**
Age (yrs.)	
• Mean ± SD	42.5 ± 14.25
• Range	8 - 63
Sex N (%)	
• Male	7 (35%)
• Female	13 (65%)

Table 2: Pre-operative imaging (US & CT) for diagnosis and liver state of the studied group.

Diagnosis	**Studied group (n = 20) N (%)**
Hydatid	7 (35%)
Hemangioma	5 (25%)
HCC	3 (15%)
Cholangiocarcinoma	1 (5%)
biliary cystadenoma	1 (5%)
post traumatic necrosis	1 (5%)
GB carcinoma	1 (5%)
Adenocarcinoma	1 (5%)
State of liver	
Normal	14 (70%)
Cirrhotic	4 (20%)
Steatotic	2 (10%)

Table 3: Intra operative data of the studied group (Type of resection, Blood loss, Operative time and need for transfusion in the studied group)

Blood loss	**Mean ± SD**	**Range**
Total operative Bl. Loss (ml)	374. ± 74.9	270 – 620
Bl. Loss during transection (ml):	132.5 ± 33.3	80 – 230
• <100 ml	• 1 (5%)	
• 100 – 150 ml	• 9 (45%)	
• 150 – 200 ml	• 8 (40%)	
• >200 ml	• 2 (10%)	
Operative time	**Mean ± SD**	**Range**
Total operative time (min):	216 ± 40.8	145 – 300
Parenchymal transection time (min):	42.5 ± 8.95	25 – 65
• < 30 min	• 1 (5%)	
• 30 – 40 min	• 9 (45%)	
• 41 – 50 min	• 8 (40%)	
• >50 min	• 2 (10%)	
Blood loss	**Mean ± SD**	**Range**
Total operative Bl. Loss (ml)	374. ± 74.9	270 – 620
Bl. Loss during transection (ml):	132.5 ± 33.3	80 – 230
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Parenchymal transection time (min):	42.5 ± 8.95	25 – 65
• < 30 min	• 1 (5%)	
• 30 – 40 min	• 9 (45%)	
• 41 – 50 min	• 8 (40%)	
• >50 min	• 2 (10%)	
Blood transfusion	**Studied group (n = 20) N (%)**	
During operation: * **No**	19 (95%)	
• **Yes**	1 (5 %)	
Post-operative blood transfusion: ***No**	19 (95%)	
• **Yes**	1 (5 %)	

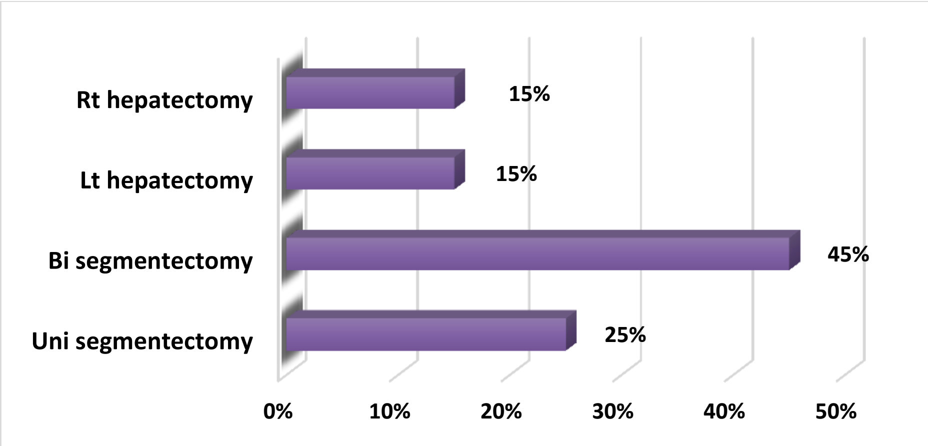

Figure 3: type of resection of the studied group

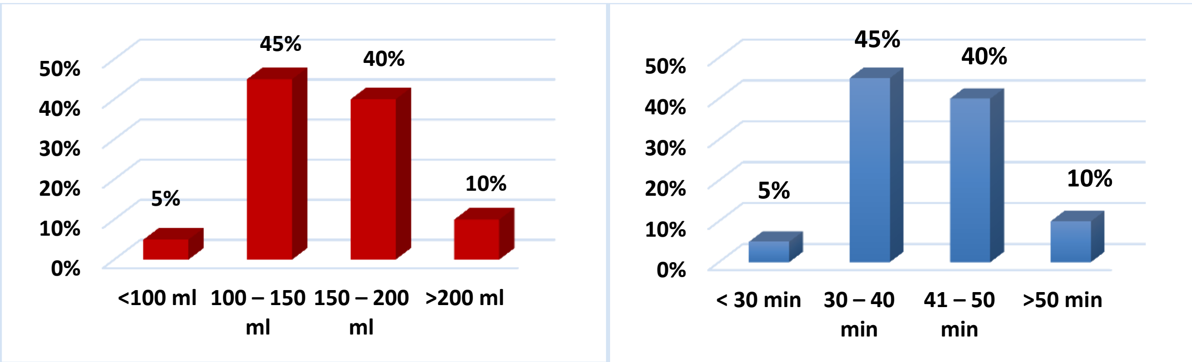

Figure 4: blood loss during parenchymal transection and parenchymal transection time.

Table 4: correlation between blood loss during transection and transection time with Type of hepatectomy and with liver state in the studied group.

Studied group (n = 20)	**Minor hepatectomy (n=14)**	**Major hepatectomy (n=6)**	**p value**
Blood Loss during transection (ml)			
➢ **Mean**	139.28 ± 34	116.6 ± 28	
➢ **Range**	90 – 230	80 - 150	**0.244**
Parenchymal transection time (min)			
➢ **Mean**	42.8 ± 8.92	41.6 ± 9.83	
➢ **Range**	30 – 65	25 – 55	**0.932**

Studied group (n = 20)	**Normal (n=14)**	**Cirrhotic (n=4)**	**Steatotic (n=2)**	**p value**
Blood Loss during transection (ml)				
➢ **Mean**	127.14 ± 36.8	135 ± 12.9	165 ± 21.2	
➢ **Range**	80 - 230	120 - 150	150 - 180	**0.123**
Parenchymal transection time (min)				
➢ **Mean**	40 ± 7.59	45 ± 7.07	42.5 ± 3.53	
➢ **Range**	25 - 50	40 - 55	40 - 45	**0.193**

Analyzed by Kruskal-Wallis Test *: Significant difference at P value < 0.05

Table 5: Post-operative hospital stay and correlation between Total operative blood loss and hospital stay in the studied group

Hospital stay (day)		
• Mean ± SD • Range	5.25 ± 2.17 3 – 12	
Total operative Blood Loss		
	p value	**r value**
Hospital stay	**0.014***	**0.539**

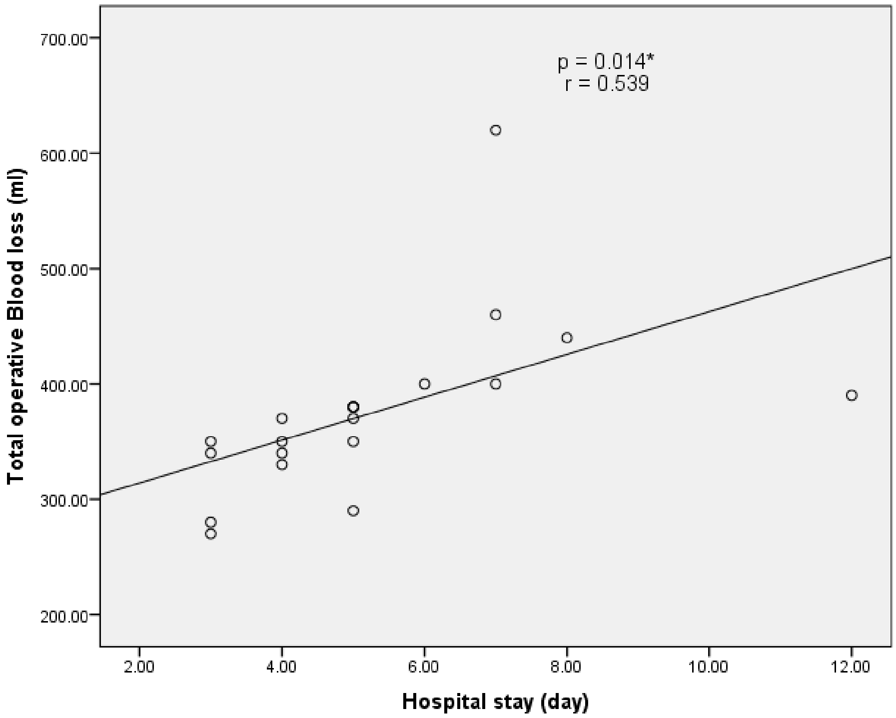

Figure 5: correlation between Total operative blood loss and hospital stay

Table 6: Complications of the studied group

Complications	Studied group (n = 20) N (%)
Free	19 (95%)
Biliary leakage	1 (5%)
Ileus	0 (0%)
Bleeding	0 (0%)
Wound infection	0 (0%)
Ascites	0 (0%)
Incisional hernia	0 (0%)
Lung atelectasis	0 (0%)

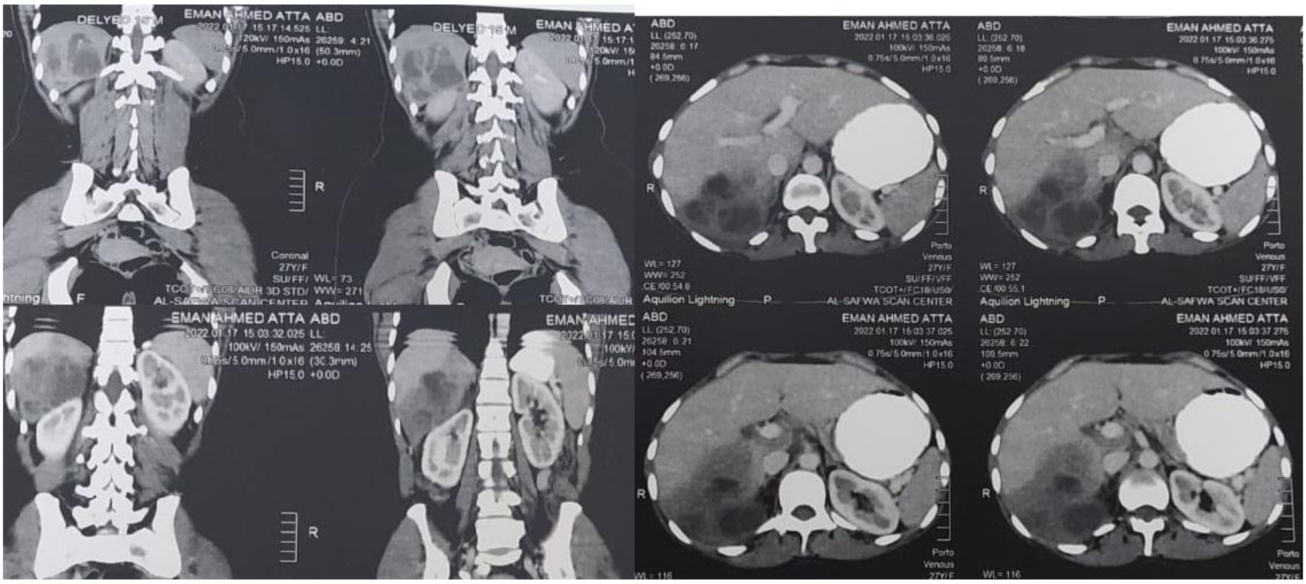

Figure 6: C.T abdomen showing multilocular hepatic cystic lesion in segment VI and VII

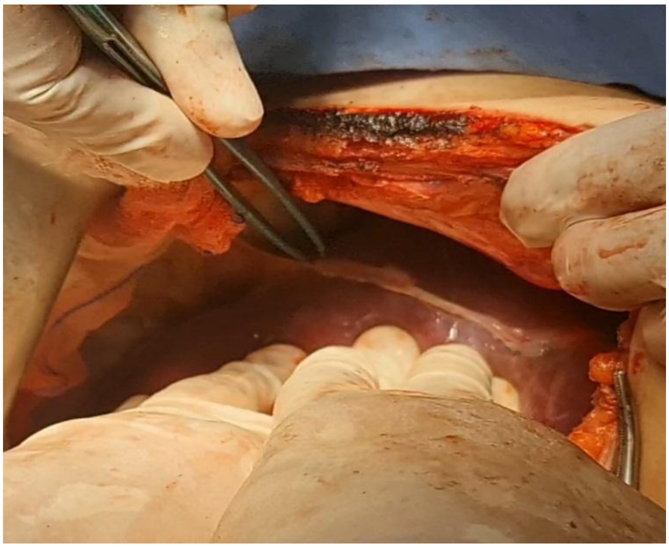

Figure 7: Division of falciform ligament (Mobilization of the liver)

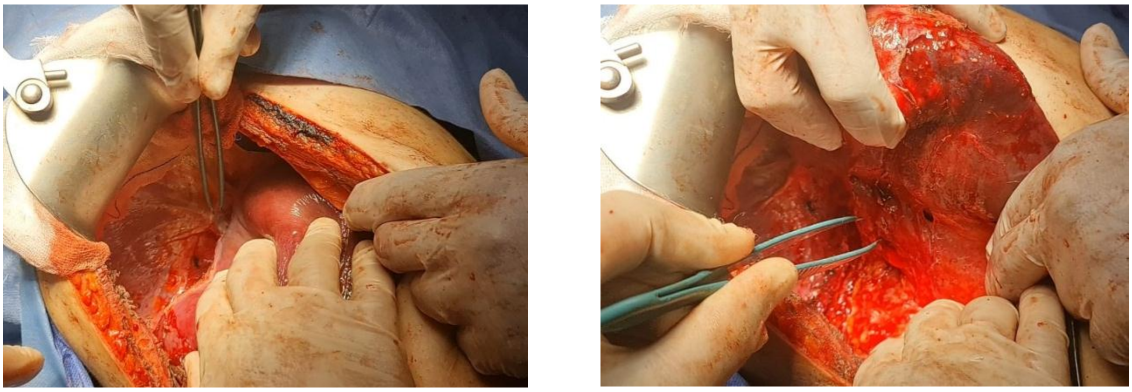

Figure 8: IVC & Figure 4: RT. Hepatic vei

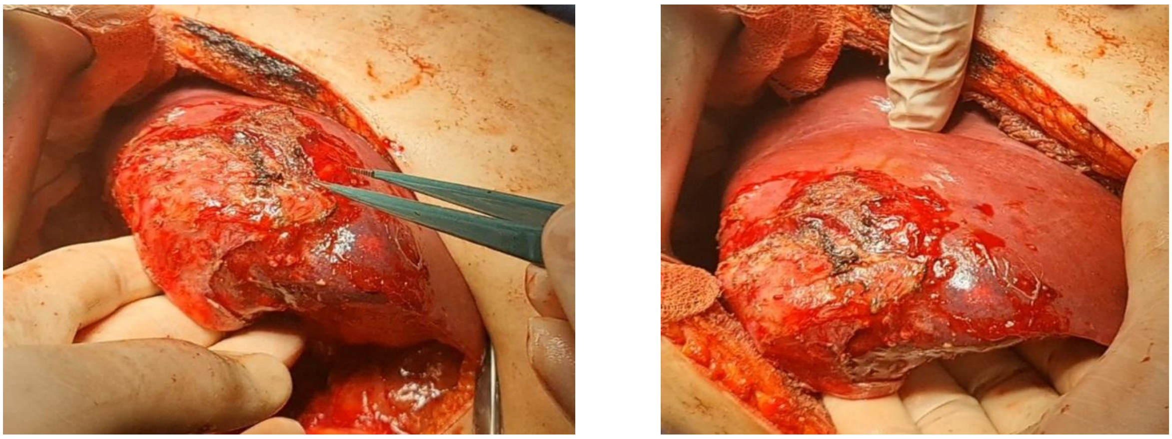

Figure 9: Hepatic cystic lesion in segments VI and VII

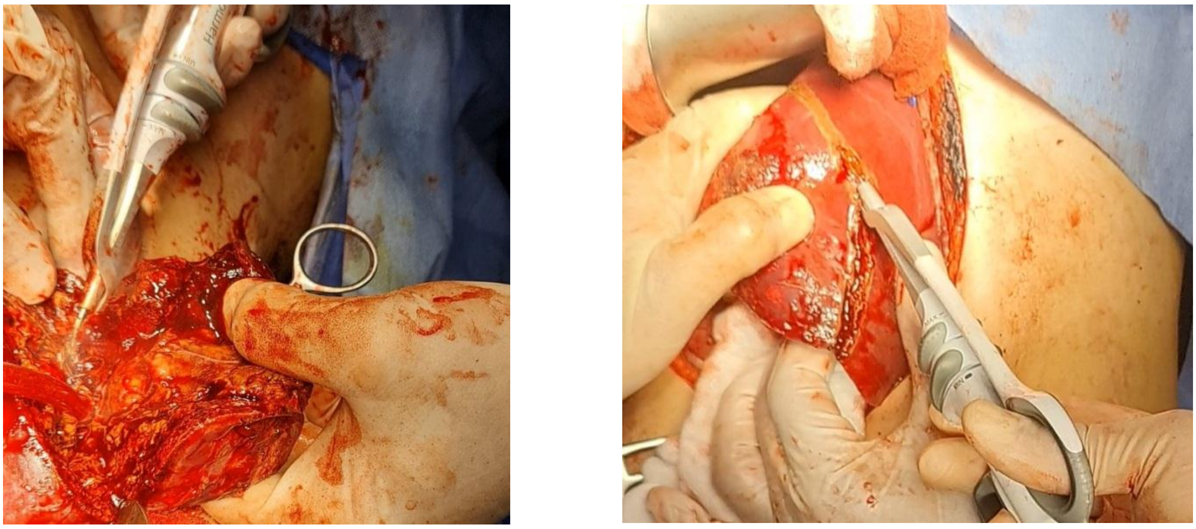

Figure 10: Transection of hepatic parenchyma by harmonic scalpel

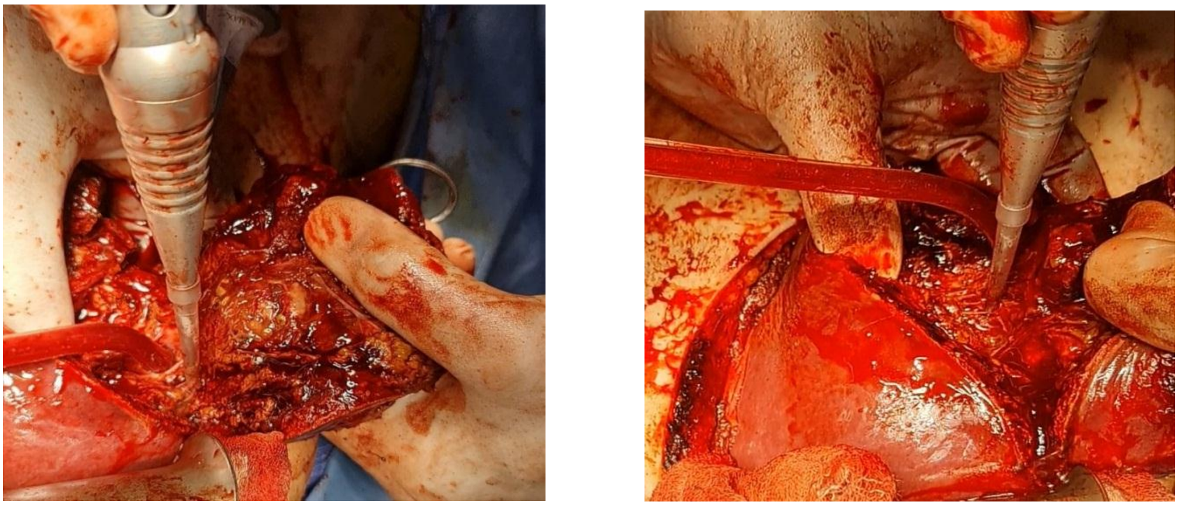

Figure 11: Transection of hepatic parenchyma by CUSA

Figure 12: Liver bed after resection

Figure 13: The specimen of case 1 and Cut section of the resected segment.

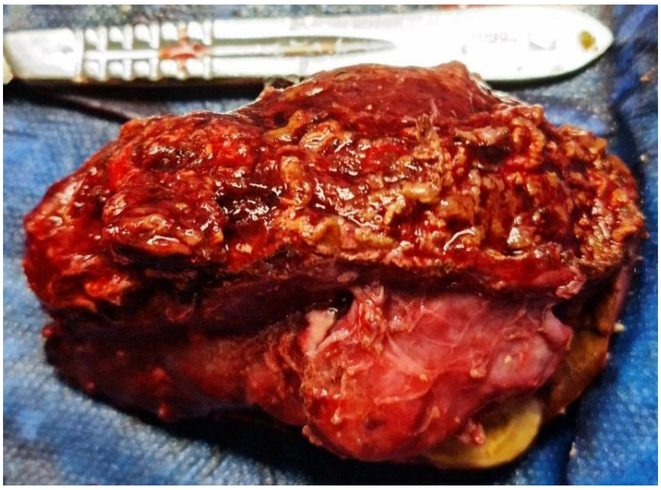

Figure 14: J-shaped incision

Discussion

Hemorrhage is one of the main factors contributing to morbidity and mortality in major liver resections. Various techniques and devices have been devised to improve accuracy and speed of parenchymal transection, minimizing blood loss and collateral tissue damage. There has been a wide variety of tissue-selective parenchymal transection devices for liver resection. However, there is inconsistent and conflicting evidence regarding superiority of one device over the other.[12]

Conversely, the Pringle maneuver represents a valuable tool for managing intraoperative bleeding but places the patient at a high risk of liver damage due to ischemic reperfusion syndrome and other complications, such as splanchnic congestion and hemodynamic alterations due to vascular occlusion.

Intermittent occlusion, hemihepatic vascular occlusion, and ischemic preconditioning of the liver have been used to minimize liver damage while simultaneously reducing intraoperative bleeding.[14]

This study demonstrates that parenchymal transection using CUSA and harmonic scalpel is a standardized procedure causing minimal blood loss thus decreasing morbidity and mortality and minimizing the dangers of hepatic inflow occlusion incurred with alternative techniques such as the Pringle maneuver.[15, 16]

CUSA selectively destroys and aspirates parenchyma leaving vessels and biliary ducts almost intact with larger vessels and large intrahepatic bile ducts to be ligated or clipped.[17]

Harmonic scalpel uses ultrasonically activated shears to seal small vessels between the vibrating blades resulting in hemostasis. Hence, harmonic scalpel is efficient in controlling the small bleeding vessels within the liver parenchyma simultaneously when ducts and vessels are exposed by CUSA. [18]

The median blood loss reported from other specialized centers ranges from 155 ml to more than 750 ml, while the perioperative blood transfusion range is from 12.6 to 65%. Our series has a low intraoperative blood loss (374.5 ml), low blood loss during parenchymal transection (132.5 ml), and a low rate of blood transfusions (5%) that are comparable or even lower than the current published data from leading liver units as mentioned above. This contributes to short time of hospital stay in our study (5.25 days) and accordingly low rates of morbidity.

The combined use of these two devices shorten the parenchymal transection time thus ensuring an efficient overall operative time (mean parenchymal transection time is 42.5 minutes and total operative time 216 minutes) and ameliorate the safety of vessel ligation achieving almost bloodless parenchymal transection with decreasing the need for hepatic inflow occlusion.

Our results are consistent with another study comparing the CUSA, harmonic scalpel, and clampcrush in 100 patients each, the CUSA with harmonic scalpel group had a lower blood loss (500 mL versus 700 mL, p-value = 0.005), number of patients transfused (22 versus 39, p-value = 0.009), tumor exposure at the transection surface (4 versus 12, p-value = 0.012), and hospital stay (7 versus 8.5 days, p-value = 0.020). A longer operative time was recorded in the CUSA with harmonic scalpel group (385 versus 330 min, p-value = 0.001). Postoperative major complications, particularly fluid collections and biliary fistula were less frequent in CUSA with harmonic scalpel group (2 versus 9, p-value = 0.030).[19]

In another study comparing The CUSA with the harmonic scalpel, the results showed that the mean operative time was 226.93min and the resection time was 117.77min in the CUSA group, while in the harmonic group, the mean operative time was 202.33 min and the resection time was 102.5min. In the CUSA group, the mean amount of blood loss was 736.67 ml; while in the harmonic group, the mean amount of blood loss was 516.67 ml. The bile leakage was significantly more in the harmonic group (26.7%) while in the CUSA group (6.7%). The postoperative hospital stay was longer in the CUSA group (mean=8.5 days) while in the harmonic it was significantly shorter (mean=6.43 days). [20]

Elimination of the Pringle maneuver allows transection of the liver without the previous limitation of clamp times. This results in the opportunity for meticulous parenchymal transection and gives surgical trainees the chance to develop their skills in this procedure without the previous time pressures.

This time comfort in combination with the use of CUSA dissection (which leaves biliary ducts intact) allows meticulous ligation or clipping of large intrahepatic biliary ducts with small biliary ducts dealt with using the heating effects of the harmonic scalpel. The above characteristics of this combined technique results in the very low rates of bile leak (5%) in this study. Leakage was due to injury of main bile duct during parenchymal transection and the patient was managed conservative.

Postoperative Liver Injury was assessed by measuring serial serum bilirubin, transaminase levels, and prothrombin time after surgery. Our study failed to show any significant differences with results shown by other Investigators. Other studies comparing the CUSA with LigaSure, CUSA with harmonic scalpel, and clamp-crush technique also failed to establish any difference between markers of liver injury. A much larger sample size might be required to show significant differences based on currently observed values.[21]

This data suggests that liver resection with the use of the combined technique of CUSA and harmonic scalpel, is a useful and efficient procedure toward bloodless liver resection without the use of vascular occlusion and ensures that liver resection becomes a comparatively safer procedure.[22]

One of the restriction of our study is low sample which is not powered enough to detect morbidity & mortality rates adequately.

Another restriction of this study is the absence of a comparative group.

Funds: No fund

Conclusion

combined technique of ultrasonic aspiration and harmonic scalpel for liver resection is a safe method for both major and minor liver resections. This method is associated with decreased blood loss, reduced postoperative morbidity, and minimal mortality rates. We believe that this combined technique is comparable to other techniques and should be considered as an alternative.

This data supports that our technique can synergize the advantages of different hepatectomy tools, improve hepatic transection efficiency, and optimize surgical procedures by reducing blood loss and decreasing operative time. We strongly recommend this emerging technique to be applied in other hepatectomy institutes.

References

1. Ahmed, A., et al., A Randomized Comparative Study of CUSA and Waterjet in Liver Resections. Indian Journal of Surgery, 2022.
2. Cloyd, J.M., et al., Comprehensive complication index validates improved outcomes over time despite increased complexity in 3,707 consecutive hepatec-tomy. Annals of surgery, 2020.271(4):p. 724.
3. El Shobary, M., et al., Spray Diathermy Versus Harmonic Scalpel Technique for Hepatic Parenchymal Transection of Living Donor. J Gastrointest Surg, 2017. 21(2): p. 321-329.
4. Famularo, S., et al., Does the Pringle maneuver affect survival and recurrence following surgical resection for hepatocellular carcinoma? A western series of 441 patients. Journal of surgical oncology, 2018. 117(2): p. 198-206.
5. Martin, A.N., et al., Blood transfusion is an independent predictor of morbidity and mortality after hepatectomy. Journal of Surgical Research, 2016.206(1):p.106-112.
6. Latchana, N., et al., Red blood cell transfusion in liver resection. Langenbeck's Archives of Surgery, 2019. 404(1): p. 1-9.
7. Figueroa, R., et al., Perihilar Glissonian approach for anatomical parenchymal sparing liver resections: technical aspects: the taping game. Annals of surgery, 2018. 267(3): p. 537-543.
8. Hu, J., et al., Types of Segment-Oriented Hepatic Resection by the Glissonean Pedicle Approach, in Atlas of Anatomic Hepatic Resection for Hepatocellular Carcinoma. 2019, Springer. p. 49-260.
9. Shin, S., et al., Is the anatomical resection necessary for single hepatocellular carcinoma smaller than 3 cm?: single-center experience of liver resection for a small HCC. Annals of hepato-biliary-pancreatic surgery, 2018. 22(4): p.326-334.
10. Karamarković, A., et al., The Importance of the Glissonean Approach and Laennec Capsule Concept in Open Anatomical Liver Resections: What we Need to Know. Surg. Gastroenterol, 2020.25(2): p. 93-100.
11. Mogahed, M., et al., The value of intra-operative ultrasonography on safety margin and outcome during liver resection and radio-frequency ablation in the management of hepatocellular carcinoma patients. Egyptian Journal of Radiology and Nuclear Medicine, 2021. 52(1): p. 1-8.
12. Kamarajah, S.K., et al., A systematic review and network meta-analysis of parenchymal transection techniques during hepatectomy: an appraisal of current randomised controlled trials. HPB, 2020. 22(2): p. 204-214.
13. Gaujoux, S. and D. Goéré, Surgical approach for hepatectomy. Journal of visceral surgery, 2011. 148(6): p. e422.
14. Ortiz Galindo, S.A., et al., Safety of intermittent Pringle maneuver during minimally invasive liver resection in patients with hepatocellular carcinoma with and without cirrhosis. Langenbeck's archives of surgery,2022.407(1):p.235-244
15. Ercolani, G., et al., Open Hepatic Transection Using Ultrasonic Dissector. 2012: p. 89-95.
16. Bodzin, A.S., et al., Liver resection using cavitron ultrasonic surgical aspirator (CUSA) versus harmonic scalpel: a retrospective cohort study. International Journal of Surgery, 2014.12(5): p.500-503.
17. Honda, G., et al., How to dissect the liver parenchyma: Excavation with cavitron ultrasonic surgical aspirator. J Hepatobiliary Pancreat Sci,2020.27(11):p.907-912.

18. Appéré, F., et al., Comparative Study With Propensity Score Matching Analysis of Two Different Methods of Transection During Hemi-Right Hepatectomy: Ultracision Harmonic Scalpel Versus Cavitron Ultrasonic Surgical Aspirator. Surgical innovation,2017.24(5): p.499-508.
19. Aldrighetti, L., et al., "Technological" approach versus clamp crushing technique for hepatic parenchymal transection: a comparative study. Journal of Gastrointestinal Surgery, 2006. 10(7): p. 974-979.
20. Naga, M.A. and H. Sayed, Randomized, comparative study between using harmonic scalpel with monopolar cautery versus cavitron ultrasonic surgical aspirator with bipolar cautery in liver resection. The Egyptian Journal of Surgery, 2019. 38(1): p. 87-94.
21. Lesurtel, M., et al., How should transection of the liver be performed?: a prospective randomized study in 100 consecutive patients: comparing four different transection strategies. Annals of surgery, 2005. 242(6): p. 814.
22. Ahmed, A., et al., A Randomized Comparative Study of CUSA and Waterjet in Liver Resections. Indian Journal of Surgery, 2022: p. 1-8.